Deutsche Physikalische Gesellschaft DPG

DPG-Frühjahrstagung 2024
(DPG Spring Meeting 2024)

of the Divisions

Environmental Physics, Extraterrestrial Physics, History of Physics, Physics Education, Plasma Physics, Short Time-scale Physics and Applied Laser Physics

as well as the Working Group
Equal Opportunities

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26 – 29 February 2024

Universität Greifswald

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Content

Dear Participants,

On behalf of the German Physical Society (DPG), as President, I would like to welcome you to the DPG-Frühjahrstagung (DPG Spring Meeting) on the campus of the University of Greifswald organised by the divisions Physics Education, Extraterrestrial Physics, History of Physics, Short Time-scale Physics and Applied Laser Physics, Plasma Physics, Environmental Physics and the working group on Equal Opportunities.

With around 55,000 members, the DPG and its conferences with up to ten thousand participants provide the largest platform for professional exchange in physics in Germany with an impact on Europe and the whole world. Science thrives on exchange and discourse! Moreover, in times of increasing tensions and fake news, scientific exchange strengthens not only physics as a science but helps to promote acceptance and awareness of the importance of basic research and scientific facts in the general public.We are very keen to make our DPG conferences even more international. I am therefore very pleased that, thanks to the support of the Wilhelm and Else Heraeus Foundation, we are now able to award around 80 scholarships to scientists from countries in Central Europe and from those being members of the SESAME synchrotron collaboration in the Near East.

The DPG is in close contact with its scientific sister societies and scientific institutions around the world. Together with 16 other physical societies (including the American, the Chinese and the European Physical Society), we published “Principles & Policies for International Scientific Collaboration” at the end of December 2023. This calls on all stakeholders, national governments, research institutions and professional societies to set clear and well-communicated standards for integrity, transparency, and reciprocity, the foundations of any value-based scientific collaboration. In addition, as part of a joint and large international effort, we are preparing for the Year of Quantum Science and Technology in 2025, one hundred years after the consistent formulation of quantum theory, shedding light on its enormous successes, its origins and its outstanding future potential in quantum sensing and metrology, quantum computing or cryptography. Quantum theory has fundamentally changed our view of the world and is having an impact on all areas of our culture, science, technology, and art!

In order to strengthen physics as a science and scientific exchange, the commitment of each individual physicist is essential. I would therefore like to thank all participants of this DPG conference for their contributions and their support to make the conference a success and would like to encourage you all to become members of the DPG, if you have not already done so.

The success of this DPG Spring Meeting is only possible with the greatest commitment of many science enthusiasts involved – thanks to you all! My special thanks go to the conference organiser, Professor André Melzer, Institute of Physics, University of Greifswald, and the programme committee with the chairs of the divisions and the participating working groups: They have put together excellent speakers and an extensive and outstanding programme. Further, I would like to express my sincere thanks to the Wilhelm and Else Heraeus-Stiftung for again providing generous financial support to our young members. Last but not least, my particular thanks go to the very motivated staff of the DPG Head Office for their support at all DPG conferences.

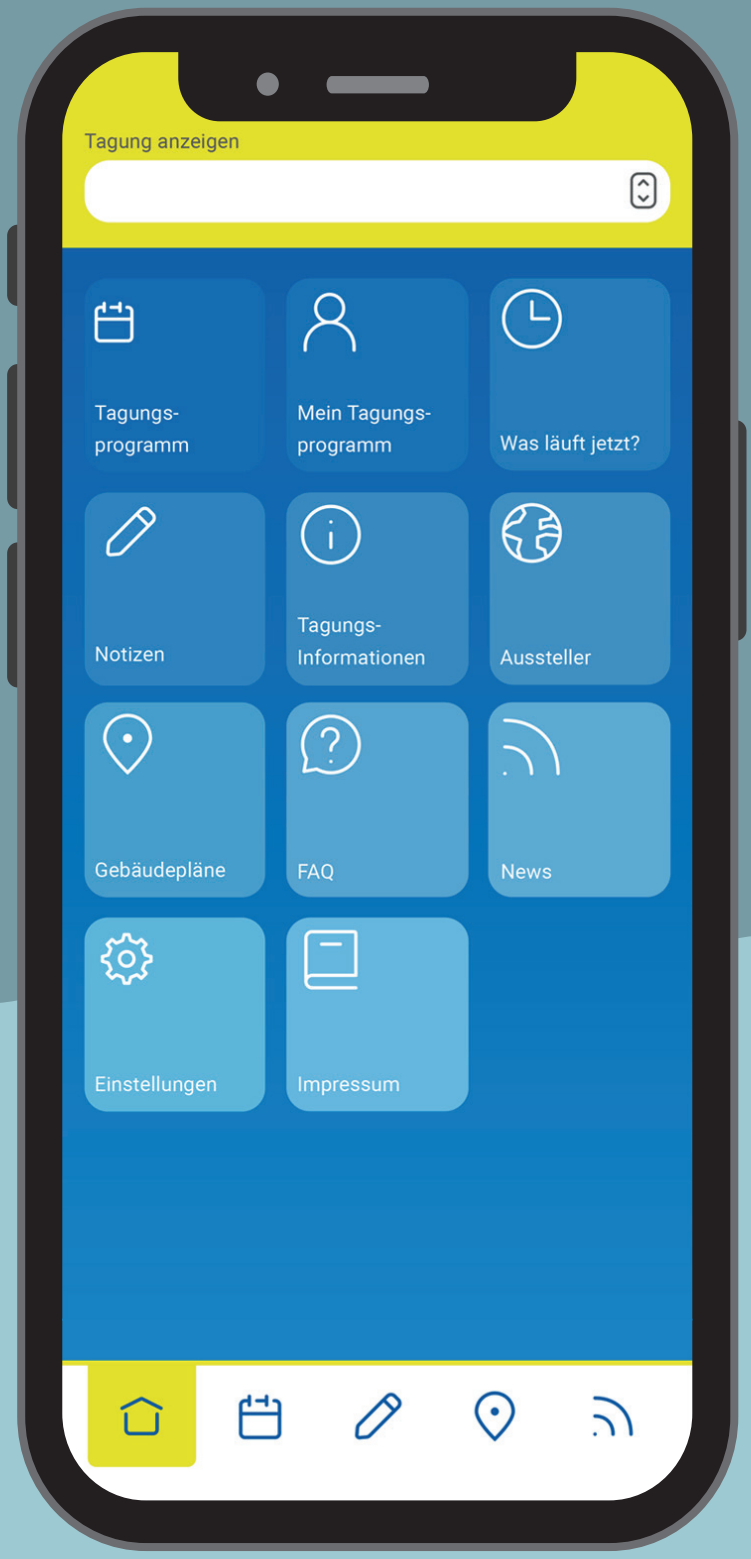
I wish you all an exciting conference, good discussions, and many new insights.

Prof. Dr. Joachim Ullrich
President
Deutsche Physikalische Gesellschaft e.V.

DOWNLOAD OUR APP

DPG-FRÜHJAHRSTAGUNGEN

Android



iOS

Organisation

Organiser
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Local Organiser
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Institut für Physik
Universität Greifswald
Felix-Hausdorff-Straße 6
Phone +49 (0) 3834 420 4790
Email melzer@physik.uni-greifswald.de

Scientific Organisation

Chairs of the Participating Divisions

(DD)	Physics Education	–	Prof. Dr. Susanne Heinicke (susanne.heinicke@uni-muenster.de)
(EP)	Extraterrestrial Physics	–	Dr. Miriam Sinnhuber (miriam.sinnhuber@kit.edu)
(GP)	History of Physics	–	Prof. Dr. Peter Heering (peter.heering@uni-flensburg.de)
(K)	Short Time-scale Physics and Applied Physics	–	Dr. Andreas Görtler (AGoertler@gmx.de)
(P)	Plasma Physics	–	Prof. Dr. Jan Benedikt (benedikt@physik.uni-kiel.de)
(UP)	Environmental Physics	–	Dr. Stefanie Falk (stefanie.falk@lmu.de)

Chair of the Participating Working Group

(AKC)	Equal Opportunities	–	OStR Agnes Sandner (akc@dpg-physik.de)

Symposia

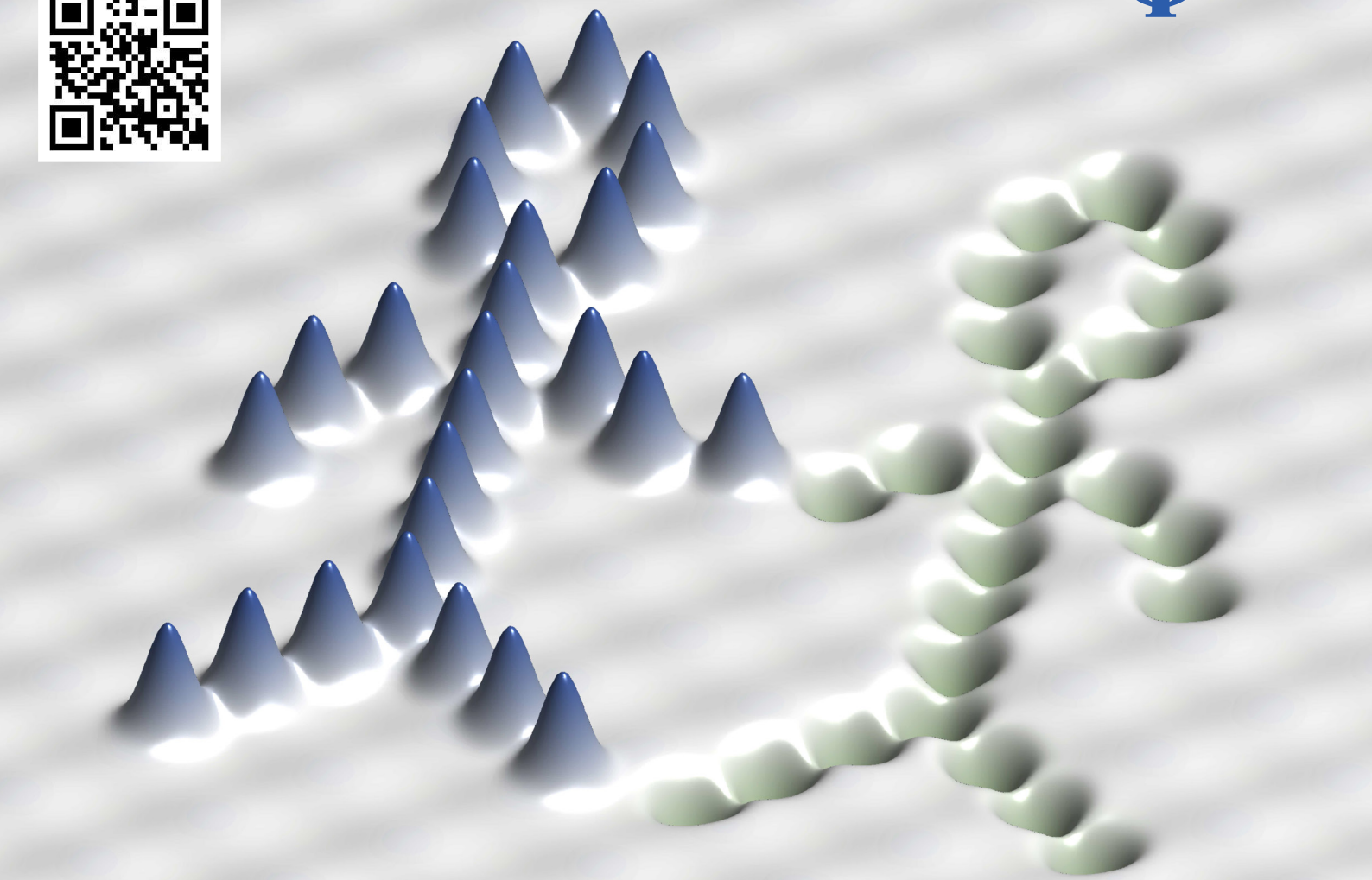
SYAN	–	How to Cope with Apocalyptic Narratives?
SYEC	–	Lasers and Photonic Technologies for Environmental Challenges
SYPS	–	Plasmas in the Solar System

Programme
The scientific programme consists of **480** contributions:

7	Plenary talks
1	Evening talk
3	Prize talks
50	Invited talks
244	Talks
174	Posters
1	Discussion

The programme stated in this document corresponds to the status of the programme publication January 18, 2024 and will not be updated!

Deutsche Physikalische Gesellschaft DPG



DPG Mentoring Programm 2024

Profitiere als **Mentee** von erfahrenen Physiker:innen im Berufsleben.

Begleiten Sie als **Mentor:in** junge Physiker:innen beim Berufseinstieg.

Jetzt anmelden unter:
mentoring.dpg-physik.de
Anmeldezeitraum: 1. - 31. Mai 2024

DPG mentoring

Information for Participants

The conference will be held February 26 – 29, 2024.

Conference Information

Conference Venue
Universität Greifswald
Campus Loefflerstraße
17489 Greifswald

The conference will take place in the buildings around Ernst-Lohmeyer-Platz (ELP) on the campus Loefflerstraße of the University of Greifswald. The plenary talks will be held in ELP 6 in lecture halls 3/4 and will also be broadcast in lecture halls 1 and 2.
For a detailed map of the campus and the buildings please see "Maps" at the end of this document.

Conference Office / Information Desk
The conference office and the information desk are located in seminar room 0.25 (ground floor) of ELP 1. The opening hours are the following:

		Registration	Information Desk
Monday	February 26	08:00 – 19:00	08:00 – 19:00
Tuesday	February 27	08:00 – 17:00	08:00 – 19:00
Wednesday	February 28	08:00 – 17:00	08:00 – 21:00
Thursday	February 29	08:00 – 17:00	08:00 – 13:00

You will receive your name tag, a receipt for your conference fee, food and drink vouchers for the welcome evening and the Login-Password for using WiFi at the registration. The name tag must be worn visibly during the entire conference.

The organisers, staff of the conference desk, and the student assistants will be identifiable by coloured name tags or Φ-T-shirts. Please contact them if you have any questions. Do not hesitate to enquire about all necessary information concerning the conference, orientation in Greifswald, accommodation, restaurants, going out, and cultural events at the information desk.

Use the DPG app for the DPG Spring Meetings!
Create your own conference programme, find out about the conference venue or the latest conference news. With the help of the building plans you can orientate yourself on site. The updated DPG app is ready release in mid february and also contains completely new features: You can now save your own notes and store your participant number in the settings in order to conveniently use the express check-in on site.

Presentation
Scientific presentations will be held either orally or by poster and will be given in English (conference language) or German.

All lecture halls will be equipped with a projector (16:9) or monitor (16:9) and a computer. Speakers are requested to upload their presentations on the conference website one day before the corresponding session. An email with the access data and the upload deadlines will be sent to the lecturers before the conference. If you require to change your uploaded contribution, you may again upload the document at latest 4 hours before the session starts (not before the talk starts). In any case you should also bring a copy your presentation on an USB drive as a backup.
The file formats accepted for all parallel sessions are pdf and Powerpoint. Own laptops cannot be used for the presentation. The presentations will be transferred to the provided PCs/laptops in the lecture hall before the session.
All lecture theatres will be opened, at the latest, 30 minutes prior to the talks. Speakers are requested to be in the lecture hall at least 20 minutes prior to the start of the session, reporting to the chairperson of the

session as well as the technical staff ensure that the presentation upload was successful and to receive a brief introduction to the equipment in the lecture hall. If you need other presentation facilities, please ask for availability at the information desk as soon as you arrive at the conference.

Usually, presentations will have the following durations:

- For contributed talks a total of 15 minutes including discussion time and speaker change (12 min talk + 3 min discussion/speaker change).
- For invited talks a total of 30 minutes including discussion time and speaker change (25 min talk + 5 min discussion/speaker change).
- For plenary talks 45 minutes without discussion time.

For further information on the language or length of the presentation, please contact the division or working group at which you will be giving the presentation.

Poster Presentation
The site for poster sessions is located at the foyer of the lecture hall building 'Ernst-Lohmeyer-Platz 6' (ELP 6). Posters must fit within a rectangle 85 cm wide and 120 cm high (DIN A0, portrait format!).
The poster boards will be marked with the number according to the scientific programme. Authors are asked to mount their poster once the poster board with the corresponding poster number is prepared. Usually this will be arranged in the morning, or one hour before the session when there are several poster sessions per day. Each poster should display the number according to the scientific programme.

For the mounting of the poster please use the prepared pins/strips at the poster frame or contact the available student staff. The presenting authors should be at hand for discussion at their poster during at least half of the poster session and should note this time at the poster. The posters have to be removed after the session. Any posters remaining on display will be removed and disposed without requesting your permission. The conference management accepts no liability for the posters.

Broadcast of Plenary Talks
All plenary talk will be broadcast in lecture halls 1 and 2 (ELP 6).

Wilhelm and Else Heraeus Communication Programme
Important notes for participants who apply for a grant of the Wilhelm and Else Heraeus Foundation:
At the beginning of the conference you will receive an identification form at the conference office. The participation in the conference must be certified by the conference desk. You have the possibility to leave this certificate with the staff members of the DPG at the conference office (preferably) or submit it to the DPG head office (DPG-Geschäftsstelle, Hauptstr. 5, 53604 Bad Honnef, Germany) by **April 5, 2024 at the latest.** For more detailed information refer to *http://greifswald24.dpg-tagungen.de*.

The Deutsche Physikalische Gesellschaft thanks the Wilhelm and Else Heraeus Foundation for the generous financial support of young academic talents. We hope that young physicists will continue to seize the offered opportunity for active scientific communication at scientific conferences. A total of about 41,900 young academics were supported by this programme so far.

Communication / Internet Access
To use the WLAN network on the campus of the University of Greifswald with your own notebooks, access data, login and password will be issued with the registration documents.
The University of Greifswald is a member of the eduroam union. If your university is also part of the eduroam union, you can also use the university WiFi in all buildings via your own eduroam access.

Catering
Coffee breaks: Coffee and tea are offered for free in the conference locations during the breaks.
Lunch: The mensa at Campus Loefflerstraße offers plenty of opportunities for lunch at moderate prices (self-payment, please check the opening hours). The capacity of the mensa is limited to about 400 seats. Only cash payments are possible in the mensa (no cards!). Please wear your badge to get staff or student prices. In the town centre (Lange Straße, Markt, Schuhhagen and adjoining streets) there is a large selection of opportunities for lunch and snacks.

Cloakroom
Participants are asked to look carefully after their wardrobe, valuables, laptops, and other belongings. The organisers decline any liability. In the basement of ELP 6 you will find a cloakroom managed by student assistants. The opening hours are as follows:

Monday	February 26	08:30 – 19:15
Tuesday	February 27	08:30 – 19:15
Wednesday	February 28	08:30 – 21:30
Thursday	February 29	08:30 – 19:15

Notice Board
All changes to the conference programme (i.e. cancellation of presentations, change of rooms, etc.) are also transferred directly to the online version of the programme which will be updated continuously and is available in different formats (sorted by publication date, filterable by conference parts and as an rss-feed). Please use the form *https://greifswald24.dpg-tagungen.de/programm/notice-board-form* to notify changes or cancellations.

Lost Property
You can hand in lost property at the information desk. You can also collect your lost property there.

Liability Exclusion
Participants are asked to look carefully after their wardrobe, valuables, laptops and other belongings. There can be no liability assumed.

SAY CHEESE!
The DPG Spring Meetings are basically public to the press. Please note: On behalf of DPG, photos and videos will be recorded during the Spring Meetings. In the context of public relations, these recordings (as the case may be) will be published on our website, in social media or within prints of the DPG for example.

CO_2 compensation for the DPG conferences
By decision of its council, the DPG will compensate for fossil CO_2 emissions resulting from mobility for DPG conferences and committee meetings.

Acknowledgement
The Deutsche Physikalische Gesellschaft (DPG) and the local organisers want to thank the following institutions for supporting the conference:

- Wilhelm and Else Heraeus Foundation, Hanau
- University of Greifswald
- and all staff, who make the success of the conference possible.

Social Events

Opening of the Conference
A short opening address will be given by the local conference organisation on Monday, February 26, from 08:45 until 09:00 in the lecture hall 3/4 in ELP 6.

Welcome Evening
The Welcome Evening will be held in the Mensa at the Berthold-Beitz-Platz on Monday, February 26, at 19:30. All registered participants are kindly invited.
You will receive your badge as well as food and drink vouchers for the Welcome Evening during conference registration. Snacks, beer and soft drinks will be served. Do not miss the opportunity to register (08:00 to 19:00) and meet people in informal atmosphere. Please wear your name badge which you have received during the registration. Access to the welcome evening is only available to registered participants.

Exhibition of Scientific Instruments and Literature
From Tuesday, February 27, to Thursday, February 29, there will be a small exhibition of scientific instruments and literature in Building ELP 6, first floor. Companies (see list of exhibitors at the end of this booklet) will present their products. Opening hours are from 10:30 to 18:00. All conference participants are welcome to attend the exhibition. The entrance is free.

Public Evening Talk
Wednesday, February 28, 19:30 – 21:00, lecture hall 3/4 in ELP 6.
Prof. Dr. Holger Kersten, University of Kiel will speak about *„Exotische Gasentladungen"*.
The Public Evening Talk is open for the interested public and all conference participants. It will be held in German. The entrance is free.

Members' Assemblies of the Divisions
During the conference, the members' assemblies of the participating divisions will take place. Please refer to the scientific programme for the time and place of the meetings.

Guided Tours
Wendelstein 7-X
Guided tours of the Wendelstein 7-X at the Max Planck Institute for Plasma Physics (IPP) are offered free of charge. Please register under the following links:

Wednesday, 28.02.2024, 16:00
https://plan.events.mpg.de/event/121/

Wednesday, 28.02.2024, 17:00
https://plan.events.mpg.de/event/122/

Thursday, 29.02.2024, 16:00
https://plan.events.mpg.de/event/124/

Thursday, 29.02.2024, 17:00
https://plan.events.mpg.de/event/123/

Institute for Plasma Science and Technology (INP)
Guided tours of the Leibniz Institute for Plasma Science and Technology (INP) are offered free of charge. Details will be announced at the conference in the Conference Office/Information Desk.

Deutsche Physikalische Gesellschaft DPG

63. Wochenendseminar „Physiker:innen im Beruf“

Der Übergang von der Hochschule in die **berufliche Karriere** fällt vielen nicht leicht: Die Möglichkeiten und Aufgabengebiete sind vielfältig - und wer kennt schon nach Studium oder Promotion die verschiedenen Anforderungen und Arbeitsabläufe?

Das Seminar bietet durch **Erfahrungsberichte** etablierter Physiker:innen sowie junger Berufsanfänger:innen Orientierung. Die 15 Vortragenden repräsentieren ganz verschiedene Arbeitsgebiete und zeigen damit das breite **Einsatzspektrum** von Physikerinnen und Physikern.

Neben den Vorträgen bietet der gemütliche Lichtenbergkeller des Physikzentrums Bad Honnef ein ideales Forum, mit den Vortragenden am Abend **in kleiner Runde offen** zu **diskutieren** und Erfahrungen zu sammeln.

Zielgruppe:
Physikstudierende ab Bachelor bis zur Promotion. Max. 80 Personen.

3. bis 5. Mai 2024

Physikzentrum Bad Honnef

Weitere Infos und Anmeldung: www.pib.dpg-physik.de

Synopsis of the Daily Programme

Monday, February 26, 2024

08:45	ELP 6: HS 3+4		**Opening of the conference**
			Plenary Talks
09:00	ELP 6: HS 3+4	PV I	The role of the North Atlantic Ocean for European Climate •Johanna Baehr
09:45	ELP 6: HS 3+4	PV II	The role of plasma conversion technology in the greening of the chemical industry •Richard van de Sanden

SYAN

			Invited Talks
14:00	ELP 6: HS 4	SYAN 1.1	The Apocalyptic Moment Is Over – And It Won't Come Back Anytime Soon •Frank Uekoetter
14:40	ELP 6: HS 4	SYAN 1.2	Shaping Cold War Futures through the Nuclear Winter Study: Narratives, Imaginaries and Legitimacy •Egle Rindzeviciute
15:20	ELP 6: HS 4	SYAN 1.3	The Role of Storytelling in Climate Communication •Denise Müller-Dum
			Session
14:00	ELP 6: HS 4	SYAN 1	How to Cope with Apocalyptic Narratives?

DD

			Invited Talks
11:00	ELP 6: HS 2	DD 1.1	Wie kann Bildung junge Menschen zur Mitgestaltung gesellschaftlicher Transformation im Kontext der Klimakrise ermächtigen? •Martin Schwichow
17:40	ELP 6: HS 2	DD 7.1	Öfter mal die Brille wechseln? Interdisziplinäres Lernen in Schulphysik und Lehramtsausbildung •Lutz Kasper
			Sessions
11:00	ELP 6: HS 2	DD 1	Hauptvortrag 1: Schwichow und Kranz
16:30	ELP 1: SR 3.21	DD 2	Lehr-Lernforschung II
16:30	ELP 1: SR 3.22	DD 3	Hochschuldidaktik – Studiengänge
16:30	ELP 1: SR 3.25	DD 4	Hochschuldidaktik – Experimente
16:30	ELP 1: SR 2.26	DD 5	Anregungen, Sonstige
16:30	ELP 1: SR 2.28	DD 6	Quantenphysik I
17:40	ELP 6: HS 2	DD 7	Hauptvortrag 2: Kasper

EP

			Invited Talk
14:30	ELP 1: HS 1.22	EP 1.1	Gravity wave vertical coupling from the troposphere to the thermosphere •Markus Rapp
			Session
14:30	ELP 1: HS 1.22	EP 1	Near-Earth Space and Space Weather

Monday, February 26, 2024

GP

Invited Talk

16:30	ELP 3: HS 2.33	GP 1.1	Competition, Cooperation, Representation. The Many Faces of the International Geophysical Year from the German Perspective •Beate Ceranski

Sessions

16:30	ELP 3: HS 2.33	GP 1	Understanding the Environment
19:00	ELP 3: HS 2.33	GP 2	Meeting of Early Career Scholars

K

Invited Talks

11:00	ELP 6: HS 1	K 1.1	Zufall, Struktur und Gesetze in physikalischer Information •Rudolf Germer
11:35	ELP 6: HS 1	K 1.2	Wellenfunktion und Realität •Alfred Eichhorn

Sessions

11:00	ELP 6: HS 1	K 1	New Methods
14:00	ELP 6: HS 1	K 2	Gas dynamics – Laser Systems and Laser Applications
15:20	ELP 6: HS 1	K 3	Members‘ Assembly
16:30	ELP 6: Foyer	K 4	Poster

P

Invited Talks

11:00	ELP 6: HS 3	P 1.1	On the observation of Trapped Electron Modes in W7-X •Andreas Krämer-Flecken
11:00	WW 1: HS	P 2.1	Interaction of reactive components of non-equilibrium atmospheric plasmas with liquids and surfaces •Kerstin Sgonina
14:00	ELP 6: HS 3	P 3.1	Influence of Nanosecond Pulsed Plasmas in Liquids on Copper Surfaces •Pia-Victoria Pottkämper
14:00	WW 1: HS	P 4.1	Ab initio calculations of conductivities under planetary interior conditions •Martin Preising

Sessions

11:00	ELP 6: HS 3	P 1	Magnetic Confinement I/HEPP I
11:00	WW 1: HS	P 2	Atmospheric Pressure Plasmas and their Applications I
14:00	ELP 6: HS 3	P 3	Plasma Wall Interaction I
14:00	WW 1: HS	P 4	Astrophysical Plasmas/Laser Plasmas
16:30	ELP 6: HS 3	P 5	Magnetic Confinement II/HEPP II
16:30	ELP 6: Foyer	P 6	Poster I

UP

Invited Talks

11:00	ELP 6: HS 4	UP 1.1	Atmospheric impact of energetic particle precipitation from the lower thermosphere to the surface •Miriam Sinnhuber
16:45	ELP 6: HS 4	UP 2.2	Increasing water limitation of global ecosystems in a changing climate •Rene Orth

Sessions

11:00	ELP 6: HS 4	UP 1	Atmospheric Trace Gases and Aerosols
16:30	ELP 6: HS 4	UP 2	Soil and Water

Monday, February 26, 2024

19:30		Mensa (Berthold-Beitz-Platz) **Welcome Evening (for registered participants)**	

Tuesday, February 27, 2024

Plenary Talks

09:00	ELP 6: HS 3+4	PV III	Physics as an environmental science: The case of climate history •Richard Staley
09:45	ELP 6: HS 3+4	PV IV	Climate Crisis Education-Physics Instruction‘s Role in Ensuring a Sustainable Future •Doug Lombardi

SYEC

Invited Talks

11:10	ELP 6: HS 1	SYEC 1.1	Nanostructured optical waveguides inside YAG crystals as a crucial step towards the development of microlasers for advanced sensing applications •Omar de Varona
11:40	ELP 6: HS 1	SYEC 1.2	Laser surface modification of graphite anodes for lithium-ion batteries with improved fast-charging capability •Max-Jonathan Kleefoot
14:00	ELP 6: HS 4	SYEC 2.1	Development of soft glass optical fibers based on 3D printed preforms •Ryszard Buczynski
14:30	ELP 6: HS 4	SYEC 2.2	Three-dimensional Ultrashort-Pulse Laser Nanolithography of Optical Materials •Omar de Varona
15:00	ELP 6: HS 4	SYEC 2.3	Fibre-based plasmonic micro reactor CO2 reduction •Devin O‘Neill
17:15	ELP 6: HS 4	SYEC 5.1	Studying atmospheric dynamics with lasers in remote places •Bernd Kaifler

Sessions

11:00	ELP 6: HS 1	SYEC 1	Laser-Based Micro-/Nanostructuring for Environmental Challenges
14:00	ELP 6: HS 4	SYEC 2	Fiber-Based Plasmonic Microreactor for Flow Chemistry
15:30	ELP 6: HS 4	SYEC 3	Photonics-Assisted Green Energy Production I
16:30	ELP 6: HS 4	SYEC 4	Photonics-Assisted Green Energy Production II
17:15	ELP 6: HS 4	SYEC 5	Photonic Measurement Technology for the Environment

DD

Invited Talk

15:10	ELP 6: HS 2	DD 19.1	Umweltkrise = Verhaltenskrise? Individuelle und systemische Katalysatoren nachhaltigen Handelns •Gerhard Reese

DPG Akademie

Mehr können. Mehr bewirken.

Zielsetzung:

- Ergänzung des Service-Angebots der DPG durch neue Formate
- Maßgeschneidertes Weiterbildungsprogramm für Physiker:innen
- Intensiver Austausch durch kleine Gruppengrößen
- Unterstützung für Physiker:innen bei der beruflichen und persönlichen Weiterentwicklung

Angebot:

- Karrierekompass für Physiker:innen Patentrecht - Erfindungen erkennen und sichern
- Umgang mit Medien
- Projektmanagement für Physiker:innen
- Systemmodellierung
- Besprechungen und Workshops souverän moderieren
- Kommunikation

Alle weiteren Informationen finden Sie unter:
www.dpg-akademie.de

Tuesday, February 27, 2024

DD

Sessions

11:00	ELP 1: SR 3.21	DD 8	Lehr-Lernforschung II
11:00	ELP 1: SR 3.22	DD 9	Hochschuldidaktik – Formate
11:00	ELP 1: SR 3.25	DD 10	Hochschuldidaktik – Kompetenzen
11:00	ELP 1: SR 2.26	DD 11	Geschichte der Physik und physikdidaktische Forschung
11:00	ELP 1: SR 2.28	DD 12	Quantenphysik II
14:00	ELP 6: Foyer	DD 13	Quantenphysik – Poster
14:00	ELP 6: Foyer	DD 14	Neue / digitale Medien – Poster
14:00	ELP 6: Foyer	DD 15	Neue Konzepte – Poster
14:00	ELP 6: Foyer	DD 16	Lehr-Lernforschung – Poster
14:00	ELP 6: Foyer	DD 17	Außerschulisches Lernen – Poster
14:00	ELP 6: Foyer	DD 18	Bildung für nachhaltige Entwicklung – Poster
15:10	ELP 6: HS 2	DD 19	Hauptvortrag 3: Reese
16:30	ELP 1: SR 3.21	DD 20	Lehr-Lernforschung III
16:30	ELP 1: SR 3.22	DD 21	Hochschuldidaktik – Mathematik
16:30	ELP 1: SR 3.25	DD 22	Neue / digitale Medien
16:30	ELP 1: SR 2.26	DD 23	Bildung für nachhaltige Entwicklung
16:30	ELP 1: SR 2.28	DD 24	Quantenphysik III
18:00	ELP 6: HS 2	DD 25	Mitgliederversammlung

EP

Invited Talks

15:00	ELP 1: HS 1.22	EP 2.3	Interdisciplinary science through space plasma physics: the example of Jupiter's radiation belts •Elias Roussos
17:00	ELP 1: HS 1.22	EP 2.8	Learning more about planets: What we expect from PLATO •Heike Rauer

Session

14:30	ELP 1: HS 1.22	EP 2	Planets in their Environment

GP

Invited Talk

16:30	ELP 3: HS 2.33	GP 4.1	Infusoria, Cress, and Tulips: Physical Experiments with Living Organisms •Caterina Schürch

Sessions

14:00	ELP 3: HS 2.33	GP 3	Dirty Physics
16:30	ELP 3: HS 2.33	GP 4	Exploring the experimental approach
18:30	ELP 3: HS 2.33	GP 5	Members' Assembly

P

Invited Talks

11:00	ELP 6: HS 3	P 7.1	Physics of Electrical Currents and Fields in the Scrape-off Layer of Tokamak Plasmas •D. Brida
11:00	WW 1: HS	P 8.1	Pulsed Complex Plasma In Microgravity •Christina A. Knapek
14:00	WW 1: HS	P 10.1	Filament interaction in dielectric barrier discharges •Hans Höft
16:30	ELP 6: HS 3	P 11.1	Collaboration on RDM in low-temperature plasma physics •Marina Prenzel

Tuesday, February 27, 2024

P

Sessions

11:00	ELP 6: HS 3	P 7	Magnetic Confinement III
11:00	WW 1: HS	P 8	Complex Plasmas and Dusty Plasmas I
14:00	ELP 6: HS 3	P 9	HEPP III
14:00	WW 1: HS	P 10	Atmospheric Pressure Plasmas and their Applications II
16:30	ELP 6: HS 3	P 11	Codes and Modeling I
16:30	ELP 6: Foyer	P 12	Poster II

UP

Sessions

11:00	ELP 6: HS 4	UP 3	Remote Sensing
12:30	ELP 6: HS 4	UP 4	Members‘ Assembly

AKC

Invited Talk

11:30	ELP 6: HS 2	AKC 1.1	The tragic destiny of Mileva Marić Einstein •Pauline Gagnon

Sessions

11:30	ELP 6: HS 2	AKC 1	AKC
12:30	ELP 6: HS 2	AKC 2	Women in Physics Lunch

Wednesday, February 28, 2024

Plenary Talk

09:45	ELP 6: HS 3+4	PV V	Nonlinear optical effects and their utilization in thin film interference coatings •Morten Steinecke

DD

Prize Talks

11:20	ELP 1: SR 3.21	DD 31.1	Satellitenfunk, MoonBounce und Atmosphärenforschung: Die modernste Technologie in der Schule •Safia Ouazi (Laureate of the DPG-Lehrerprize 2024)
11:50	ELP 1: SR 3.21	DD 31.2	Rückblick auf 40 Jahre Physikunterricht mit Sonderaktivitäten •Heinz-Werner Oberholz (Laureate of the DPG-Lehrerprize 2024)
15:10	ELP 6: HS 2	DD 40.1	Quantenphysik in der Schule: Neue Perspektiven durch Quantentechnologien •Rainer Müller (Laureate of the Georg-Kerschensteiner-Prize 2024)

Sessions

11:00	ELP 1: SR 3.21	DD 26	Anregungen
11:00	ELP 1: SR 3.22	DD 27	Hochschuldidaktik – Sachwissen
11:00	ELP 1: SR 3.25	DD 28	Experimente und Praktika
11:00	ELP 1: SR 2.26	DD 29	Workshop: Maschinelles Lernen in der naturwissenschaftsdidaktischen Forschung

Wednesday, February 28, 2024

DD

11:00	ELP 1: SR 2.28	DD 30	Astronomie
11:20	ELP 1: SR 3.21	DD 31	Vorträge Lehrerpreise
14:00	ELP 6: Foyer	DD 32	Lehreraus- und -fortbildung – Poster
14:00	ELP 6: Foyer	DD 33	Sprache und Physikunterricht – Poster
14:00	ELP 6: Foyer	DD 34	Physikdidaktik und Inklusive – Poster
14:00	ELP 6: Foyer	DD 35	Hochschuldidaktik – Poster
14:00	ELP 6: Foyer	DD 36	Praktika und neue Praktikumsversuche – Poster
14:00	ELP 6: Foyer	DD 37	Präsentation von Experimenten – Poster
14:00	ELP 6: Foyer	DD 38	Astronomie – Poster
14:00	ELP 6: Foyer	DD 39	Sonstiges – Poster
15:10	ELP 6: HS 2	DD 40	Hauptvortrag 4 (Georg-Kerschenstein-Preis): Müller
16:00	ELP 1: SR 3.21	DD 41	Workshop: Studienreformforum

EP

Invited Talks

11:00	ELP 1: HS 1.22	EP 3.1	Arne Richter, Rekonnexion und das ebenso wechselhafte Schicksal der AEF •Jörg Büchner
11:30	ELP 1: HS 1.22	EP 3.2	The Sun in Focus: Current Findings and Challenges in Solar Physics •Markus Roth
12:00	ELP 1: HS 1.22	EP 3.3	Vortical motions in the solar atmosphere: observations, physics, cause and effect •Oskar Steiner

Sessions

11:00	ELP 1: HS 1.22	EP 3	Sun and Heliosphere I with Arne-Richter Lecture
12:45	ELP 1: HS 1.22	EP 4	Members‘ Assembly / Mitgliederversammlung
14:15	ELP 1: HS 1.22	EP 5	Astrophysics
16:30	ELP 6: Foyer	EP 6	Postersession

GP

Sessions

11:00	ELP 3: HS 2.33	GP 6	Crossing Disciplinary and Institutional Boundaries
14:00	ELP 3: HS 2.33	GP 7	Instruments and Exhibitions
16:30	ELP 3: HS 2.33	GP 8	Closing Session

P

Invited Talks

11:00	WW 1: HS	P 14.1	Insights into the Non-Thermal Character of Molecular Plasmas from Optical Frequency Comb Spectroscopy •Ibrahim Sadiek
14:00	ELP 6: HS 3	P 15.1	Particle fueling, profiles and transport in neutral beam heated plasmas at Wendelstein 7-X •Sebastian Bannmann
14:00	WW 1: HS	P 16.1	CO_2 dissociation by microwave plasmas: experimental studies on interfaces in view of industrial applications •Rodrigo Antunes
16:30	ELP 6: HS 3	P 17.1	Finite Element Method to Describe Magnetic Measurements of Tearing Modes in ASDEX Upgrade •Magdalena Bauer
16:30	WW 1: HS	P 18.1	Diffusion of reactive species in aqueous solutions treated by a humid atmospheric pressure plasma jet •Steffen Schüttler

Wednesday, February 28, 2024

P

Sessions

11:00	ELP 6: HS 3	P 13	Magnetic Confinement IV/HEPP IV
11:00	WW 1: HS	P 14	Low Pressure Plasmas and their Application I
14:00	ELP 6: HS 3	P 15	HEPP V
14:00	WW 1: HS	P 16	Atmospheric Pressure Plasmas and their Applications III
16:30	ELP 6: HS 3	P 17	Magnetic Confinement V/HEPP VI
16:30	WW 1: HS	P 18	Atmospheric Pressure Plasmas and their Applications IV
18:45	ELP 6: HS 3	P 19	Members‘ Assembly

UP

Invited Talk

11:00	ELP 6: HS 4	UP 5.1	Melting from below: An abrupt transition in Antarctic sea ice-ocean system •Alexander Haumann

Sessions

11:00	ELP 6: HS 4	UP 5	Cryosphere and Arctic Oceans
14:30	ELP 6: HS 4	UP 6	Other Topics
16:30	ELP 6: Foyer	UP 7	Posters

Public Evening Talk (Entrance free)

19:30	ELP 6: HS 3+4	PV VI	Exotische Gasentladungen •Holger Kersten

Thursday, February 29, 2024

Plenary Talks

09:00	ELP 6: HS 3+4	PV VII	Progress in solar flare modeling •Rony Keppens
09:45	ELP 6: HS 3+4	PV VIII	Achieving target gain > 1 from inertial confinement fusion implosions at the National Ignition Facility* •Tilo Döppner

SYPS

Invited Talks

11:00	ELP 6: HS 4	SYPS 1.1	Energetic Particles in the Turbulent Heliosphere •Horst Fichtner
11:30	ELP 6: HS 4	SYPS 1.2	Persistent solar wind forcing of the F2-region ionosphere observed at Tromsø •Claudia Borries
12:00	ELP 6: HS 4	SYPS 1.3	In-orbit diagnostics for artificial plasmas created by electric propulsion systems: The Heinrich Hertz Satellite Mission •Thomas Trottenberg
12:30	ELP 6: HS 4	SYPS 1.4	Plasma-based space propulsion: status and scientific challenges •Kristof Holste

Session

11:00	ELP 6: HS 4	SYPS 1	Plasmas in the Solar System

EP

Session

14:00	ELP 6: HS 2	EP 7	Sun and Heliosphere II

P

Invited Talks

11:00	ELP 6: HS 3	P 20.1	Modelling of tungsten erosion and deposition in fusion devices •Andreas Kirschner
11:30	ELP 6: HS 3	P 20.2	Drift flows in the island divertor of W7-X •Carsten Killer
14:00	ELP 6: HS 3	P 21.1	The collisionally modified Bohm criterion: Insight or illusion? •Ralf Peter Brinkmann
14:00	ELP 6: HS 4	P 22.1	First Results of Laser-Induced Desorption – Quadrupole Mass Spectrometry (LID-QMS) at JET •Miroslaw Zlobinski
14:30	ELP 6: HS 4	P 22.2	Deuterium retention analysis in pre-damaged tungsten using laser-induced breakdown spectroscopy •Erik Wüst
16:30	ELP 6: HS 3	P 23.1	Characterizing electron depleted, nanodusty plasmas recent developments and future outlooks •Andreas Petersen
16:30	ELP 6: HS 4	P 24.1	Electron surface scattering kernel for plasma simulations •Franz Xaver Bronold

Sessions

11:00	ELP 6: HS 3	P 20	Magnetic Confinement VI
14:00	ELP 6: HS 3	P 21	Low Pressure Plasmas and their Application II
14:00	ELP 6: HS 4	P 22	Plasma Wall Interaction II/HEPP VII
16:30	ELP 6: HS 3	P 23	Complex Plasmas and Dusty Plasmas II
16:30	ELP 6: HS 4	P 24	Codes and Modeling II
16:30	ELP 6: Foyer	P 25	Poster III

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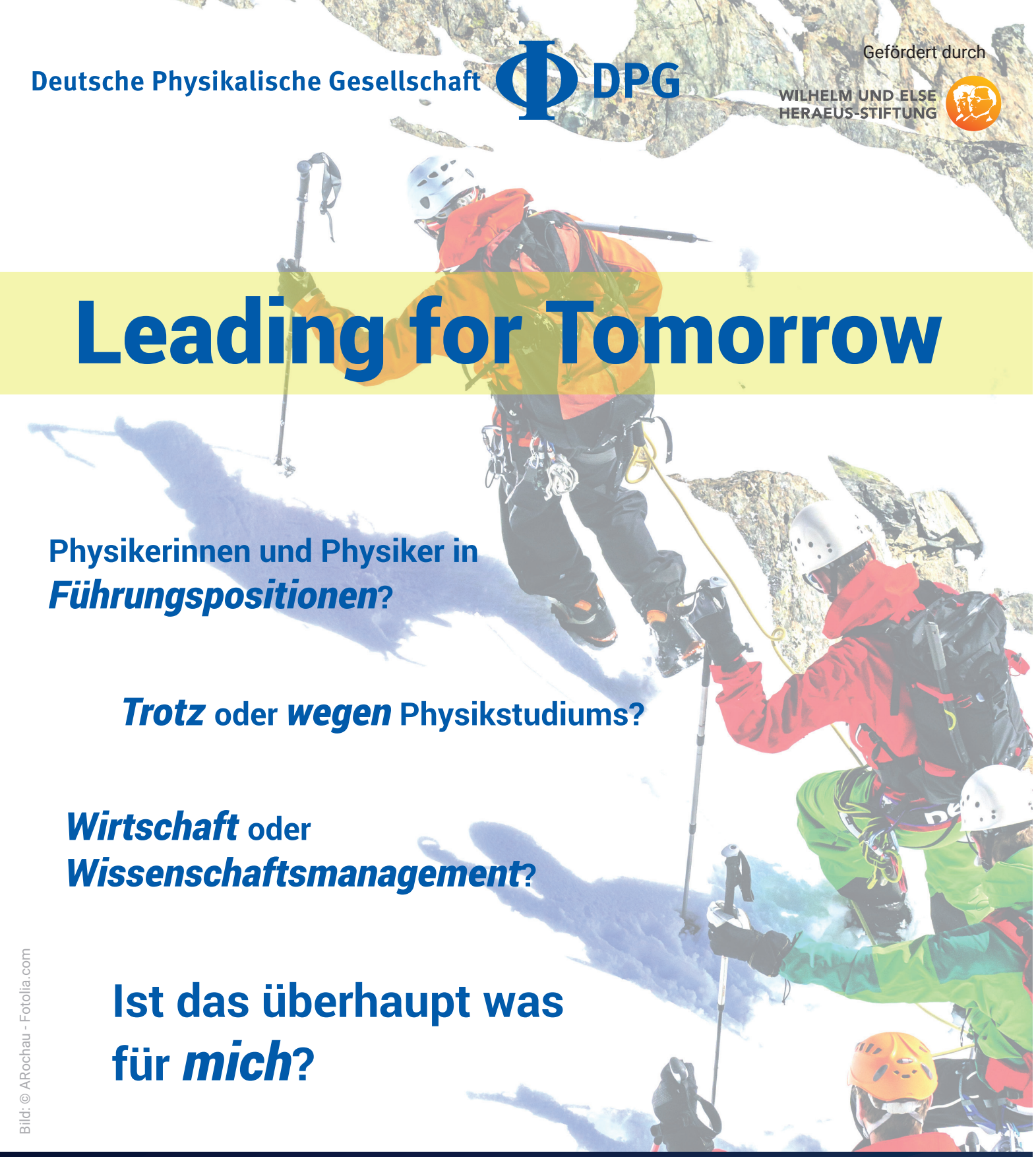

Physikerinnen und Physiker in *Führungspositionen*?

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Plenary and Evening Talks

Plenary Talk PV I Mon 9:00 ELP 6: HS 3+4

The role of the North Atlantic Ocean for European Climate — •Johanna Baehr — Uni Hamburg

The role of the North Atlantic ocean circulation in shaping European climate variations has hardly been overestimated in scientific or popular scientific discussions alike. In this contribution, I will examine the complex dynamics of the Atlantic Meridional Overturning Circulation (AMOC) and its pivotal role in the Earth's climate system for both the current and the potential future evolution of European climate. I will put these in context of our fundamental understanding as well as recent advances. I will further discuss the role of the North Atlantic circulation in the discussion of the concept of tipping points in the climate system.

Plenary Talk PV II Mon 9:45 ELP 6: HS 3+4

The role of plasma conversion technology in the greening of the chemical industry — •Richard van de Sanden — Dutch Institute for Fundamental Energy Research (DIFFER), P.O. Box 6336, 5600 HH, Eindhoven, The Netherlands — Eindhoven Institute for Renewable Energy Systems (EIRES), Eindhoven University of Technology, The Netherlands

The worldwide climate crisis has greatly driven the current deployment of sustainable energy sources, such as wind and solar to lower CO2 emissions. A next grand challenge is to develop effective and economical chemical conversion processes for green chemicals and fuels.

In this talk, after an introduction to the challenges facing the world in the next decades, I will discuss the opportunities of using plasmas, powered by renewable electricity, for scalable gas conversion of key molecules such as CO2 and N2. In particular I will address the use of microwave plasma to dissociate CO2 into CO and O2, and the formation of NOx from air and the possible, often claimed, role of nonequilibrium vibrational kinetics. A scheme to possibly exploit vibrational stimulation of chemical reactions by plasma, I will present a unique hybrid type reactor consisting of a plasma reactor and solid state water electrolysers with oxygen ion or proton conducting membranes. One aided benefit of this proposed approach is that both technologies, i.e. water electrolyser and plasma activation, utilize base molecules (N2 and H2O) and can be directly powered by renewable electricity. Such a scheme may be a stepping stone to zero carbon footprint processes.

Plenary Talk PV III Tue 9:00 ELP 6: HS 3+4

Physics as an environmental science: The case of climate history — •Richard Staley — University of Cambridge, United Kingdom — University of Copenhagen, Denmark

Environmental physics courses began to appear only from the late 1960s and largely treated their subject as the study of pollution, applying physics to the world's environmental problems, before more recently expanding to incorporate Earth System Sciences. This lecture explores instead what we can learn about physics by treating it as always an environmental science, as much grounded in understanding the earth and environment as in the search for the fundamental principles of matter. Drawing on the Leverhulme funded project "Making climate history", the emergence of the climate sciences and long history of temperature as a key climatic index will serve as my case studies. How is global knowledge achieved, practically, when the earth is the subject matter? I explore several key elements (and the relation between projection and achievement) in building the global arguments and long-term histories required to know that man has changed climate. When, why and how has the earth been treated as an instrument? How did natural philosophers first begin to think it had a temperature (and how did they try to measure that)? Why were the oceans understood to have climates, from the 1870s? How did ocean histories resolve the dilemmas of geological eras? And how have scientists constructed hemispheric or global arguments and million-year histories from foraminifera shells? This lecture aims to provide a historical orientation to physics as an environmental science.

Plenary Talk PV IV Tue 9:45 ELP 6: HS 3+4

Climate Crisis Education-Physics Instruction's Role in Ensuring a Sustainable Future — •Doug Lombardi — University of Maryland, United States

It might be as simple as one, two, three. One, the climate crisis is upon us; two, this crisis is impacting Earth's entire environment; and three, humans, who are intertwined in Earth's complex environmental system, are the culpable actors causing the climate crisis. However, addressing this crisis is no simple matter. Over many decades, the science community has characterized and forecasted climate change. Planners and policymakers now face the task of mitigating and adapting to extreme weather events, mass migrations, disease outbreaks, collapsing ecosystems, and social and economic injustice caused by the climate crisis. Despite these challenges, hope remains. Educators across many disciplines, including physics educators and physics education researchers, can help turn hopelessness into hope and despair into agency and action. Multidisciplinary collaborations involving physicists, physics education researchers, and physics instructors, along with other scientific disciplines, are needed to shape theoretical frameworks and methodologies that will facilitate innovation for a sustainable future. This presentation overviews my research team's efforts–in collaboration with a wide variety of scientists and educators–to design and rigorously test effective instructional interventions and strategies that facilitate students deep understanding of the climate crisis and how to adaptively respond.

Plenary Talk PV V Wed 9:45 ELP 6: HS 3+4

Nonlinear optical effects and their utilization in thin film interference coatings — •Morten Steinecke — Laser Zentrum Hannover e.V., Optical Components Department, Hanover, Germany

Nonlinear optical effects play a crucial role in modern optical systems. They are applied in mode-locking for the generation of ultrashort optical pulses and for unlocking measurements at new timescales. However, implementing the required nonlinear optical processes mainly relies on conventional optical systems comprising separate components and free-space constructions, which limits the possibilities for future applications and miniaturization. Contrary to this, optical coatings offer highly developed capabilities for combining optical functions into a monolithic stack of transparent materials. But, so far, the applications of optical coatings have generally been limited to the linear optical regime or for assisting the implementation of nonlinear processes, e.g., with chirped mirrors. This talk provides an overview of the combination of selected nonlinear optical effects with specially designed optical coatings aiming to create novel components as alternatives to established optical systems. Different effects are considered, e.g., the optical Kerr effect, which can be utilized to achieve all-optical switching of light, and the THG, where the concept can solve phase-matching issues and significantly increase conversion efficiency. The results for the THG, and especially the Kerr-based optical switches, show great promise for this novel field of optical components and indicate a large potential for further research into the fundamentals of nonlinear effects in different optical materials and the required manufacturing processes.

Evening Talk PV VI Wed 19:30 ELP 6: HS 3+4

Exotische Gasentladungen — •Holger Kersten — Institut für Experimentelle und Angewandte Physik, Universität Kiel

Der durch Irving Langmuir in die Physik eingeführte Begriff des Plasmas beschreibt ein elektrisch leitfähiges Gas, das aus freien Ladungsträgern (Elektronen und Ionen) sowie aus Neutralteilchen (Atome, Moleküle) besteht und das oftmals auffällige Leuchterscheinungen zeigt. Dieses manchmal auch als "vierter Aggregatzustand" bezeichnete Medium weist eine Reihe von besonderen Eigenschaften auf.

Während für den "Normalverbraucher" auf der Erde das Plasma einen recht exotischen Zustand der Materie darstellt, ist es im Universum die dominierende Daseinsform der Materie. Im Labor zeigen sich Plasmaerscheinungen z.B. in elektrischen Gasentladungen, deren Erforschung für eine Vielzahl von technologischen Anwendungen von Bedeutung ist. Denn wer weiß eigentlich schon, dass mittels Plasmaverfahren Computerchips hergestellt, Plastikflaschen beschichtet oder Brillengläser kratzfest gemacht werden. Im Automobilbau werden Bleche durch sog. Bogenplasmen verschweißt, Kunstgegenstände werden im Plasma gereinigt, Raumsonden werden durch Ionenstrahlen aus Plasmen beschleunigt - und in nicht allzu ferner Zukunft wird man hoffentlich mit Fusionsplasmen die Energieproblematik beherrschen können.

Im Rahmen des Abendvortrages, der durch einige eindrucksvolle und sehenswerte Experimente "exotischer" Gasentladungen ergänzt wird, soll auf unterhaltsame Weise eine Reise durch die faszinierende Welt der Plasmen unternommen werden.

Plenary Talk PV VII Thu 9:00 ELP 6: HS 3+4

Progress in solar flare modeling — •Rony Keppens — Centre for mathematical Plasma Astrophysics, KU Leuven, Belgium

A violent plasma process to study is the solar flare, which represents the most energetic explosion in our heliosphere. It involves a dramatic change - or reconnection - in the magnetic topology of the atmosphere, and the so-called "standard solar flare model" collects all observationally established info on flares in a cartoon. This cartoon emphasizes that macroscopic (magnetohydrodynamic) and microscopic (energetic particles) plasma physical processes dynamically interact, although most model efforts only simulate the large magnetohydrodynamic (MHD) or the small (kinetic) scales. I will present our first self-consistent model of a standard solar flare, where electron beam physics dynamically couples to a large-scale, multi-dimensional magnetohydrodynamic evolution of a flaring ar-

cade. By varying the magnetic field strength, we explore the various flare classes, and we can compare with 1D flare models to point out the multi-dimensional aspects they lack. We continued simulating the hour-long postflare behaviour, to ensure that the hot meets the cold: the first numerical demonstration of post-flare coronal rain due to thermal instability! I will also show recent results on full 3D standard flare modeling, where we obtained Kelvin-Helmholtz induced turbulent looptops consistent with observed non-thermal broadenings, and where we find clear multi-phase behaviour in the gradual phase. All simulations use our open-source MPI-AMRVAC toolkit [amrvac.org], where grid-adaptivity is essential to zoom in on details that can be resolved by future observing facilities.

Plenary Talk PV VIII Thu 9:45 ELP 6: HS 3+4

Achieving target gain > 1 from inertial confinement fusion implosions at the National Ignition Facility* — •Tilo Döppner — Lawrence Livermore National Laboratory, Livermore, USA — Indirect Drive Inertial Confinement Fusion Collaboration

Creating a controlled fusion reaction that produces more energy than supplied to initiate it (i.e. target gain >1) is a grand scientific challenge with broad societal implications. Predominantly, current approaches use the fusion of deuterium and tritium nuclei, which generates 17.6 MeV of energy released in a neutron and an alpha particle. The latter, carrying 1/5 of the energy, can further heat the fusion plasma. A plasma in which the alpha self-heating is greater than external heating is termed a burning plasma, and one in which the self-heating dominates over all loss mechanisms, leading to a run-away increase in temperature, is termed ignited. Inertial Confinement Fusion has pursued these scientific milestones using large laser drivers, notably the National Ignition Facility at LLNL. It provides laser energy up to 2.2 MJ to generate a hot x ray bath, which creates ablation pressures of hundreds of Mbar at the outer surface of a fuel-containing capsule. The ablation pressure implodes the capsule, with fuel pressures of several hundred Gbar generated as the fuel stagnates at the center to initiate fusion burn. In recent years several improvements in the scientific design and requisite technologies have enabled increasing performance of NIF experiments through the burning plasma and ignition regimes.

*Work performed under the auspices of the U.S. Department of Energy by LLNS, LLC, under contract DE-AC52- 07NA27344.

Symposium How to Cope with Apocalyptic Narratives?

jointly organized by
the Physics Education Division (DD),
the History of Physics Division (GP), and
the Environmental Physics Division (UP)

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Scientific results require communication, especially when they call for social action and have political consequences. In the past decades, there have been many challenges and crises concerning the treatment of our natural environment. To communicate these scientific results, different narratives have been used to convey our message to both policymakers and the general public. In this symposium, we want to explore exemplary the kind of stories and narratives that have been told over the past decades each time scientists observed, analyzed, and modeled environmental pollution and destruction. From the different perspectives of environmental, historical, educational, and journalistic positions, we will discuss narratives ranging from empowerment to apocalyptical scenarios, their impact on our communication and action, and what we can learn from these examples about the correlation between narratives and our readiness to act.

Overview of Invited Talks and Sessions

(Lecture hall ELP 6: HS 4)

Invited Talks

SYAN 1.1	Mon	14:00–14:40	ELP 6: HS 4	**The Apocalyptic Moment Is Over - And It Won't Come Back Anytime Soon** — •Frank Uekoetter
SYAN 1.2	Mon	14:40–15:20	ELP 6: HS 4	**Shaping Cold War Futures through the Nuclear Winter Study: Narratives, Imaginaries and Legitimacy** — •Egle Rindzeviciute
SYAN 1.3	Mon	15:20–16:00	ELP 6: HS 4	**The Role of Storytelling in Climate Communication** — •Denise Müller-Dum

Sessions

SYAN 1.1–1.3	Mon	14:00–16:00	ELP 6: HS 4	**How to Cope with Apocalyptic Narratives?**

Sessions

– Invited Talks –

SYAN 1: How to Cope with Apocalyptic Narratives?

Time: Monday 14:00–16:00 Location: ELP 6: HS 4

Invited Talk SYAN 1.1 Mon 14:00 ELP 6: HS 4

The Apocalyptic Moment Is Over - And It Won't Come Back Anytime Soon — •Frank Uekoetter — Lehrstuhl für Technik- und Umweltgeschichte, Ruhr-Universität Bochum, 44780 Bochum, Germany

The presentation offers an overview of apocalyptic tropes in Western environmental rhetoric since the 1950s. Taking a transnational big-picture approach, it reviews the proliferation of horror scenarios, the driving forces (no, it was not the environmentalists), the political potential, and the gradual decline in the political potency of horror scenarios since the 1980s. In recent decades, apocalyptic rhetoric became something of a default language of environmental discourse. But maybe that was only for lack of something better?

Invited Talk SYAN 1.2 Mon 14:40 ELP 6: HS 4

Shaping Cold War Futures through the Nuclear Winter Study: Narratives, Imaginaries and Legitimacy — •Egle Rindzeviciute — Kingston University, London, United Kingdom

This talk explores the narratives and imaginaries that were produced by the East and West scientists engaged in the computer simulation of the environmental effects of nuclear war (1982-1990s). It reflects on the spatialities, temporalities and agencies that were attributed to human and non-human actors. Whereas this modelling exercise was heuristic, it was deployed as part of political argumentation calling for nuclear disarmament and arms control. This raises important questions of the public perception of computer modelling, scientific prediction and performativity of scientific knowledge.

Invited Talk SYAN 1.3 Mon 15:20 ELP 6: HS 4

The Role of Storytelling in Climate Communication — •Denise Müller-Dum — Agentur für Wissenschaftskommunikation Dr. Jens Kube (awk/jk), Obernstraße 76, 28195 Bremen

Climate change has already begun to impact our daily lives, and yet it is perceived as abstract and too complex. Reducing its complexity to tangible bits and pieces is vital to achieving a cognitive and emotional understanding of what*s happening to our planet. In this context, storytelling can serve as an instrument to enable understanding, allow different perspectives, evoke empathy and inspire action * for children and adults. I will discuss its merits and challenges and show examples from my own work as an author as well as from others.

Lasers and Photonic Technologies for Environmental Challenges (SYEC)

jointly organized by
the Short Time-scale Physics and Applied Laser Physics Division (K) and
the Environmental Physics Division (UP)

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As one of the major issues facing the world, the ongoing climate crisis substantially threatens today's society. To mitigate this threat we need to increase the overall energy usage efficiency (greener industrial designs) and reduce CO_2, methane, black carbon and CFC emissions (avoid environmental pollution, safeguard human health and weaken greenhouse warming) by establishing low-carbon "clean" energy sources (renewables, nuclear fusion and others). At the same time, the current century is known as the age of the photon spawned through the invention of the laser and its continuous development. At this special symposium, current solutions to environmental challenges based on lasers and photonic technologies will be presented and discussed. These solutions will be as diverse as the environmental challenge they aim to solve and cover, e.g., optical fibre and waveguide technology, photonic sensing, photocatalysis, nanophotonics, (ultrashort pulsed) lasers, or photonic quantum technologies.

Overview of Invited Talks and Sessions

(Lecture hall ELP 6: HS 1 and ELP 6: HS 4)

Invited Talks

SYEC 1.1	Tue	11:10–11:40	ELP 6: HS 1	**Nanostructured optical waveguides inside YAG crystals as a crucial step towards the development of microlasers for advanced sensing applications** — •Omar de Varona, Franzette Paz-Buclatin, Paul Santos, Pablo Molina, Leopoldo Martín, Airán Ródenas
SYEC 1.2	Tue	11:40–12:10	ELP 6: HS 1	**Laser surface modification of graphite anodes for lithium-ion batteries with improved fast-charging capability** — •Max-Jonathan Kleefoot, Jens Sandherr, Jiri Martan, Volker Knoblauch, Harald Riegel
SYEC 2.1	Tue	14:00–14:30	ELP 6: HS 4	**Development of soft glass optical fibers based on 3D printed preforms** — •Ryszard Buczynski, Pawel Wiencław, Przemyslaw Golebiewski, Dariusz Pysz, Adam Filipkowski, Grzegorz Stepniewski, Olga Czerwinska, Andrzej Burgs
SYEC 2.2	Tue	14:30–15:00	ELP 6: HS 4	**Three-dimensional Ultrashort-Pulse Laser Nanolithography of Optical Materials** — •Airán Ródenas, Omar de Varona, Franzette Paz-Buclatin
SYEC 2.3	Tue	15:00–15:30	ELP 6: HS 4	**Fibre-based plasmonic micro reactor CO2 reduction** — •Devin O'Neill, Patrick Spath, Wiebke Albrecht
SYEC 5.1	Tue	17:15–17:45	ELP 6: HS 4	**Studying atmospheric dynamics with lasers in remote places** — •Bernd Kaifler

Sessions

SYEC 1.1–1.3	Tue	11:00–12:25	ELP 6: HS 1	**Laser-Based Micro-/Nanostructuring for Environmental Challenges**
SYEC 2.1–2.3	Tue	14:00–15:30	ELP 6: HS 4	**Fiber-Based Plasmonic Microreactor for Flow Chemistry**
SYEC 3.1–3.2	Tue	15:30–16:00	ELP 6: HS 4	**Photonics-Assisted Green Energy Production I**
SYEC 4.1–4.3	Tue	16:30–17:15	ELP 6: HS 4	**Photonics-Assisted Green Energy Production II**
SYEC 5.1–5.4	Tue	17:15–18:30	ELP 6: HS 4	**Photonic Measurement Technology for the Environment**

Sessions

– Invited and Contributed Talks –

SYEC 1: Laser-Based Micro-/Nanostructuring for Environmental Challenges

Time: Tuesday 11:00–12:25 Location: ELP 6: HS 1

Introduction to 'Lasers and Photonic Technologies for Environmental Challenges'

Invited Talk SYEC 1.1 Tue 11:10 ELP 6: HS 1

Nanostructured optical waveguides inside YAG crystals as a crucial step towards the development of microlasers for advanced sensing applications — •Omar de Varona[1,2], Franzette Paz-Buclatin[1], Paul Santos[1], Pablo Molina[3], Leopoldo Martín[1,2], and Airán Ródenas[1,2] — [1]Department of Physics, University of La Laguna, 38200 Santa Cruz de Tenerife, Spain — [2]Instituto Universitario de Estudios Avanzados en Física Atómica, Molecular y Fotónica (IUDEA), University of La Laguna, 38200 Santa Cruz de Tenerife, Spain — [3]Departamento de Física de Materiales, Instituto de Materiales Nicolás Cabrera and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, 28049 Madrid, Spain

Nanophotonics stands as a pivotal technology to fight climate change, offering diverse solutions across multiple disciplines. Recent advancements in fabrication processes have enabled spectrum engineering, plasmonic nanoparticles techniques and miniaturization of light-trapping and guiding structures. These innovations equip researchers with novel tools for applications spanning from CO2 capture and enhancement of solar energy harvesting efficiency, to precise detection of pollutants for air and water monitoring. This presentation delves into the fabrication process of 3D nanostructures within crystalline materials tailored for photonic applications by means of femtosecond laser lithography. We report our latest results on the production of waveguides embedded in YAG crystals as a crucial step towards the development of microlasers for advanced sensing applications.

Invited Talk SYEC 1.2 Tue 11:40 ELP 6: HS 1

Laser surface modification of graphite anodes for lithium-ion batteries with improved fast-charging capability — •Max-Jonathan Kleefoot[1,3], Jens Sandherr[1], Jiri Martan[2], Volker Knoblauch[1], and Harald Riegel[1] — [1]LaserApplicationCenter (LAZ), Aalen University, Beethovenstraße 1, 73430 Aalen, Germany — [2]New Technologies Research Centre (NTC), University of West Bohemia, Plzen, Czech Republic — [3]Department of Machining Technology, Faculty of Mechanical Engineering (FST), University of West Bohemia, Pilsen, Czech Republic

In order to fulfil the high energy density requirements of lithium-ion batteries used in battery electric vehicles, electrodes with high active mass loading and low porosity or high compaction are required. However, such high-energy electrodes have a significantly lower rate capability, which is mainly a consequence of the limited lithium-ion diffusion. Laser-based microstructure adaptations can help to partially overcome the conflict of objectives between energy and power density. Various approaches such as the selective removal of binder components on the surface or the perforation of the electrode layer as deep structuring were investigated for this purpose. The aim of the work was to gain a better understanding of the machining processes but also to investigate the resulting performance of the electrode. It could be shown that the investigated processes lead to an significantly improved electrode performance in the fields of fast charging capability, wetting and lifetime compared to unprocessed electrodes.

SYEC 1.3 Tue 12:10 ELP 6: HS 1

Ultrashort pulse laser surface nanostructuring and its application — •Pierre Lorenz, Joachim Zajadacz, Martin Ehrhardt, and Klaus Zimmer — Leibniz-Institut für Oberflächenmodifizierung, Leipzig, Deutschland

Ultrashort pulse laser radiation can be used to irradiate metal surfaces and create self-organized micrometer and nanostructured surfaces. The surface morphologies depend on various laser parameters, including laser power, scan speed, wavelength, and repetition rate. In addition, the nanostructures can be transferred to an arylate surface using UV nanoimprint lithography (UV-NIL). The directly lasered or molded surfaces exhibit interesting optical, electrical, and fluidic properties. For example, laser-assisted nanostructuring of copper surfaces allows the fabrication of Cu surfaces with adjustable secondary electron yield. Similarly, laser-assisted nanostructuring of stainless steel surfaces allows the water contact angle to be adjusted from superhydrophobic to superhydrophilic. In addition, the forming of nanostructured surfaces allows the production of surfaces with adjustable optical reflectance. This presentation provides an overview of laser-assisted nanostructuring of surfaces and its applications.

SYEC 2: Fiber-Based Plasmonic Microreactor for Flow Chemistry

Time: Tuesday 14:00–15:30 Location: ELP 6: HS 4

Invited Talk SYEC 2.1 Tue 14:00 ELP 6: HS 4

Development of soft glass optical fibers based on 3D printed preforms — •Ryszard Buczynski[1,2], Pawel Wiencław[2,3], Przemyslaw Golebiewski[1,2], Dariusz Pysz[1], Adam Filipkowski[1], Grzegorz Stepniewski[1], Olga Czerwinska[3], and Andrzej Burgs[3] — [1]Lukasiewicz Research Network, Institute of Microelectronics and Photonics, Al. Lotnikow 32/46, 02-668 Warsaw, Poland — [2]Faculty of Physics, University of Warsaw, Pasteura 5, 02-093 Warsaw, Poland — [3]Sygnis S.A., Al. Grunwaldzka 472, 80-309 Gdansk, Poland

We report on the development of a 3D printing system dedicated to the development of soft glass optical fiber preforms. In contrast to previous studies on 3D printing of optical fiber preforms, the proposed process is based on the deposition of straight, horizontally oriented lines to replace the manual stack-and-draw fiber assembly process. The printer consists of a miniaturized crucible for melting glass blocks and a pneumatic extrusion head. Developed in-house heavy metal oxide glass was used to print the preform. The proposed 3D glass printing system is recognized as green technology, as it significantly reduces glass waste compared to standard stack-and-draw methods, and does not use difficult-to-recycle polishing powders in the fabrication process. As a proof-of-concept, a microstructured fiber preform with a solid core and 3 rings of air holes was printed. The fiber preform was composed of 2500 microrods. The total dimensions of the preform were 60x25x25 mm. Next, the final fibers are drawn at the fiber drawing tower and further characterized. The optical quality of the glass is maintained during the process and no crystallization is observed. The proposed 3D printing method is very promising for automating development process of microstructured fibres and free-form optical components. Since there are no restrictions related to the symmetry or circular shape of the printed fiber preform, this method can be applied to develop new types of fiber optic sensors and flow-through micro-optofluidic systems.

Invited Talk SYEC 2.2 Tue 14:30 ELP 6: HS 4

Three-dimensional Ultrashort-Pulse Laser Nanolithography of Optical Materials — •Airán Ródenas[1,2], Omar de Varona[1,2], and Franzette Paz-Buclatin[1,2] — [1]Department of Physics, University of La Laguna, 38200 Santa Cruz de Tenerife, Spain — [2]Instituto Universitario de Estudios Avanzados en Física Atómica, Molecular y Fotónica (IUDEA), University of La Laguna, 38200 Santa Cruz de Tenerife, Spain

In this talk we will discuss our recent results on 3D ultrashort pulse laser nanolithography of optical materials towards novel optical instrumentation for harsh-environments. We will present recent results on the understanding of the photomodification processes in optical crystals on different irradiation dose accumulation regimes. We will also discuss the microstructuring of hollow optical fibers towards novel optofluidic micro-reactor systems.

Invited Talk SYEC 2.3 Tue 15:00 ELP 6: HS 4

Fibre-based plasmonic micro reactor CO2 reduction — •Devin O'Neill, Patrick Spath, and Wiebke Albrecht — AMOLF, Amsterdam, The Netherlands

As part of a bid to achieve carbon neutrality or even atmospheric remediation of CO2 levels new, sustainable, and efficient technologies are needed. The EU "reaCtor" project aims to combine the chemical selectivity of a flow microreactor with plasmon-induced photocatalysis in a highly efficient light guiding system - a hollow core optical fibre with annular light propagation; capitalizing on

short lived (0.1-1 ps)[1] hot-electrons generated with plasmon relaxation to drive CO2 reduction to useful products[2]. We strive to unify disparate literature in a highly photon-efficient photocatalytic system. Here, we show work on surface enhanced Raman scattering from a single nanoparticle for CO2 reduction where the hot electron is extracted by imidazolium[2] binding CO2 and driving the chemical reaction[3] with the restrictions of the optofluidic environment.

[1] Nature Nanotech (2015), 25-34, 10(1), [2] Nature Comm (2019), 1-7, 10(1), [3] J. Phys Chem. C (2021), 17734-17741, 125(32)

This project has received funding from the EIC program under grant agreement No 101099405.

SYEC 3: Photonics-Assisted Green Energy Production I

Time: Tuesday 15:30–16:00 Location: ELP 6: HS 4

SYEC 3.1 Tue 15:30 ELP 6: HS 4

Upconversion Nanoparticles Towards Sensing in Hydrogen Electrolysis Cells — •Rajesh Komban[1], Simon Spelthann[2], Lea Kötters[2], Michael Steinke[2,3], and Christoph Gimmler[1] — [1]Fraunhofer Center for Applied Nanotechnology CAN, D-20146 Hamburg, Germany — [2]Institute of Quantum Optics, Leibniz University Hannover, D-30167 Hannover, Germany — [3]QUEST-Leibniz-Research School, Leibniz University Hannover, D-30167 Hannover, Germany

With its potential to address environmental concerns and energy security, hydrogen is gaining prominence in various energy sectors. In this scenario, the proton exchange membrane (PEM) electrolysis cell emerges as a significant tool for generating green hydrogen from water. The temperature inside these cells is crucial, as it directly correlates with their efficiency. To monitor the temperature in situ, a specialized technique needs to be developed.

The utilization of luminescent intensity ratio-based thermometry coupled with a fiber sensor would be an optimal choice for such an application. As lanthanide ions excited energy levels enable such correlation, we develop lanthanide doped green emitting upconversion nanoparticles (UCNP) for this purpose. Highly efficient submicron range $NaYF_4$:Er^{3+},Yb^{3+} UCNP core particles are developed and further modified their surface with silicon dioxide shell to enable them to stick on surface of the fiber. We assume that these functionalized UCNP can be used in different fiber based temperature sensors not only in PEM cells, but also in battery technology.

SYEC 3.2 Tue 15:45 ELP 6: HS 4

Nanothermometers on Fiber Tip for Temperature Measurements in Water Electrolysis Cells — •Lea Koetters[1], Simon Spelthann[1], Lena Bühre[2], Mareike Benecke[2], Rajesh Komban[3], Patrick Späth[4], Wiebke Albrecht[4], Boris Bensmann[2], Christoph Gimmler[3], Richard Hanke-Rauschenbach[2], and Michael Steinke[1] — [1]Leibniz University Hannover, Institute of Quantum Optics, Hannover, Germany — [2]Leibniz University Hannover, Institute for Electric Power Systems, Hannover, Germany — [3]Fraunhofer-Institut für Angewandte Polymerforschung IAP, Hamburg, Germany — [4]AMOLF, Amsterdam, Netherlands

Hydrogen from Proton Exchange Membrane Water Electrolysis (PEMWE) cells enables the storage of sustainably generated energy. The efficiency and longevity of these cells depend on operating conditions such as the temperature of the membrane. We set up a fiber sensor using lanthanide-doped nanoparticles as nanothermometers and employed it to measure the temperature at the cell's membrane for different operational conditions. The results will help us to optimize the cell's operational parameters. The sensor is also applicable in strong electromagnetic fields, for example in battery technology or magnetic resonance tomography.

SYEC 4: Photonics-Assisted Green Energy Production II

Time: Tuesday 16:30–17:15 Location: ELP 6: HS 4

SYEC 4.1 Tue 16:30 ELP 6: HS 4

Laser-based diagnostics in nuclear fusion research at Wendelstein 7-X — •Jannik Wagner[1], Golo Fuchert[1], Ekkehard Pasch[1], Jens Knauer[1], Kai Jakob Brunner[1], Marcus Beurskens[1], Sergey A. Bozhenkov[1], Matthias Hirsch[1], Petra Kornejew[1], Maciej Krychowiak[1], Miklos Porkolab[2], Adrian v. Stechow[1], Thomas Wegner[1], Robert C. Wolf[1], and W7-X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [2]Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge, MA, USA

Thermonuclear fusion offers the potential of unlimited, carbon-free and safe energy production with little or no long living radioactive waste, compared to nuclear fission. At Wendelstein 7-X (W7-X), one of the world's largest fusion experiments, several laser-based diagnostic methods are employed. Using various wavelengths, they obtain information on plasma parameters, which are important to determine the performance of the W7-X plasma. These diagnostics evaluate for example the light scattered by plasma electrons (Thomson scattering), phase shifts of the laser beam due to plasma density fluctuations (phase contrast imaging), changes in the refractive index (interferometry) or the light emitted by laser-induced electronic transitions in spectroscopic measurements. Lasers are also used for targeted material injection into the plasma edge in order to investigate the transport of impurities (laser blow-off).

In this talk, we will give a short introduction to nuclear fusion and an overview of the laser-based diagnostics at W7-X as an example of diagnostics commonly used in fusion research.

SYEC 4.2 Tue 16:45 ELP 6: HS 4

Making ultra-thin silicon solar cells competitive through hyperuniform disordered light trapping. — •Alexander Lambertz[1,2], Esther Alarcon-Llado[1], and Jorik van de Groep[2] — [1]NWO-i AMOLF, Amsterdam, Netherlands — [2]University of Amsterdam, Amsterdam, Netherlands

Current industrys crystalline silicon solar cells rely on fossil fuels for wafer production and require too much high-quality silicon per watt-peak and are thus unsuitable to meet climate goals. Substantially reducing the absorber thicknesses will not only allow to save silicon, but also to avoid the wasteful Czoralski process, use lower quality poly-silicon, expand the application of c-Si cells to light-weight, semi-transparent, flexible, and wearable photovoltaics.

In order to overcome the shortcoming of poor absorption in thin silicon layers, we present light-trapping patterns based on hyperspectral uniformity to achieve unprecedented absorptance values. We experimentally demonstrated beyond 65% sunlight absorption in one micron thick free-standing silicon membranes and developed an analytical model based on temporal coupled-mode theory to find optimum Fourier-space profiles.

We recently fabricated ultra-thin silicon solar cells of less than five micron thickness by molecular beam epitaxy that have shown over 15 % power conversion efficiencies when our patterns were applied, where flat silicon-nitride-coated references only achieved about 10%. We furthermore give reasonable indication that efficiencies beyond 20 % are achievable already below 10 micron silicon thicknesses.

SYEC 4.3 Tue 17:00 ELP 6: HS 4

Search for ferromagnetism in Mn-doped lead halide perovskites — •Maryam Sajedi[1], Chen Luo[1], Konrad Siemensmeyer[1], Maxim Krivenkov[1], Kai Chen[1,2], James M. Taylor[1,3], Marion A. Flatken[1], Florin Radu[1], and Oliver Rader[1] — [1]Helmholz-Zentrum Berlin für Materialien und Energie — [2]National Synchrotron Radiation Laboratory, university of Science and Technology of China, — [3]Fakultät für Physik, Technische Universität München,

Lead halide perovskites are new key materials in various application areas such as high efficiency photovoltaics, lighting, and photodetectors. Doping with Mn, which is known to enhance the stability, has recently been reported to lead to ferromagnetism below 25 K in methylammonium lead iodide (MAPbI3) mediated by superexchange. Two most recent reports confirm ferromagnetism up to room temperature but mediated by double exchange between Mn2+ and Mn3+ ions. Here we investigate a wide concentration range of MAMnxPb1*xI3 and Mn-doped triple-cation thin films by soft X-ray absorption, X-ray magnetic circular dichroism, and quantum interference device magnetometry. The X-ray absorption lineshape shows clearly an almost pure Mn2+ configuration, confirmed by a sum-rule analysis of the dichroism spectra. A remanent magnetization is not observed down to 2 K. Curie-Weiss fits to the magnetization yield negative Curie temperatures. All data show consistently that significant double exchange and ferromagnetism do not occur. Our results show that Mn is not suitable for creating ferromagnetism in lead halide perovskites.

SYEC 5: Photonic Measurement Technology for the Environment

Time: Tuesday 17:15–18:30 Location: ELP 6: HS 4

Invited Talk SYEC 5.1 Tue 17:15 ELP 6: HS 4

Studying atmospheric dynamics with lasers in remote places — •Bernd Kaifler — Deutsches Zentrum für Luft- und Raumfahrt, Oberpfaffenhofen, Germany

Light detection and Ranging (LiDAR) is so far the only active remote sensing technology which allows almost continuous profiling of the atmosphere from ground to space. LiDAR systems provide measurements of key variables related to atmospheric dynamics such as air density, temperature and wind speed. As numerical weather prediction and climate models are extended to higher altitudes, observations in the middle atmosphere (approximately 15-90 km altitude) have become increasingly important for process studies and the validation of these models, and in the last decade a new generation of automatic LiDAR systems has been developed and the instruments deployed to locations around the world. Driven by the desire to probe regions of particular scientific interest, such as hotspots of atmospheric gravity waves, the instruments are often set up in remote places that could be described as "the world's end": from a small town above the Arctic Circle in Finland, the southern tip of the Andes Mountains in South America, to South Pole Station high on the Antarctic Plateau. This presentation highlights these places and the scientific results that were obtained by observing atmospheric gravity waves using LiDAR instruments operated on the ground, on aircrafts and on long duration stratospheric balloons.

SYEC 5.2 Tue 17:45 ELP 6: HS 4

A portable OCT system to investigate the influence of environmental factors on plants under field conditions — •Miroslav Zabic[1,2], Mohamad Bsata[1], Akshay Solleti[1], Timm Landes[1,2,3], Hans Bethge[1,2], and Dag Heinemann[1,2,3] — [1]Hannover Centre for Optical Technologies (HOT), Leibniz University Hannover, Germany — [2]Institute of Horticultural Production Systems, Leibniz University Hannover, Germany — [3]PhoenixD Cluster of Excellence, Leibniz University Hannover, Germany

Optical coherence tomography (OCT), a non-destructive imaging technique, is increasingly recognized in the field of plant biology for its potential in addressing environmental challenges in agriculture. The conventional stationary setup of OCT systems limits their application for on-site use, often necessitating plant dissection for laboratory analysis. Here we present a portable OCT system, enabling direct observation of plants in their natural environments. A possible application of this system is the monitoring of russeting in apple skin. Russeting in apples, which manifests as brown, rough patches on the skin, is promoted by several environmental factors and leads to significant economic losses, as affected apples often fail to meet market standards for sale. This not only affects profitability but also raises concerns about sustainability, as it results in increased food waste and resource inefficiency. By enabling OCT imaging on apples still on the tree, our system could offer new insights in russeting development and its dynamic interplay with environmental factors such as humidity. We detail technical aspects of our system and present preliminary results.

SYEC 5.3 Tue 18:00 ELP 6: HS 4

Characterization of PFAS transport in groundwater via laser-based ^{85}Kr and ^{39}Ar age dating — •Florian Meienburg[1,2,3,4], David Wachs[1,2], Axel Suckow[3], Christoph Gerber[3], Alec Deslandes[3], Punjehl Craine[3], Rohan Glover[4], Thomas Chambers[4], Ivan Herrera[4], Hue T. Nguyen[5], Jochen Müller[5], Markus Oberthaler[1], and Werner Aeschbach[2] — [1]Kirchhoff Institute for Physics, Heidelberg, Germany — [2]Institute of Environmental Physics, Heidelberg, Germany — [3]CSIRO, Adelaide, Australia — [4]University of Adelaide, Adelaide Australia — [5]University of Queensland, Brisbane, Australia

Radioisotopes are a widely used and important tool for dating environmental systems. Due to their chemical inertness and their well-understood input functions, the radioisotopes of argon and krypton are especially valuable tracers. Furthermore, their half-lives of 10.8 years (^{85}Kr), 269 years (^{39}Ar) and 229,000 years (^{81}Kr) cover a wide range of timescales and are therefore of interest for various tracer-based water studies. However, a very small abundance as small as 10^{-16}, requires an ultra-sensitive and highly isotopically selective detection method which is achieved by the quantum technology Atom Trap Trace Analysis (ATTA).

The presented study makes use of this unique measurement technique to investigate a per- and polyfluoroalkyl substance (PFAS) plume in groundwater at a site in Queensland, Australia. Age dating tracers combined with PFAS concentration measurements give insights into the transport characteristics of these forever chemicals.

SYEC 5.4 Tue 18:15 ELP 6: HS 4

ArTTA - Dating of environmental samples with ^{39}Ar — •David Wachs[1,2], Joshua Marks[1], Pascal Bohleber[3,4], Andrea Fischer[3], Yannis Arck[1], Martin Stocker-Waldhuber[3], Julian Robertz[2], Markus Oberthaler[2], and Werner Aeschbach[1] — [1]Institute of Environmental Physics, Heidelberg — [2]Kirchhoff-Institute for Physics, Heidelberg — [3]Institute for Interdisciplinary Mountain Research, Innsbruck, Austria — [4]Ca* Foscari University of Venice, Venice, Italy

Argon Trap Trace Analysis (ArTTA) for measuring ^{39}Ar concentrations represents an applied quantum technology to perform age dating of environmental samples. The isotope ^{39}Ar with its half life of 268 years uniquely enables dating in the age range between 50 and 1000 years. The very low isotopic abundance of about 10^{-15} however sets high demands on the measurement method. ArTTA has reduced the required sample sizes to routinely applicable amounts and thus enables ^{39}Ar age measurements in various settings from oceans over groundwater to glaciers. This work aims at presenting the technical concept of the ArTTA analytical method, from the initial excitation of the atoms by plasma discharge to the trapping by laser cooling methods and the current challenges and upgrades of the system. Furthermore, environmental applications will be discussed with a focus on the dating of Alpine glaciers. In this environmental archive, the age itself can provide information about environmental changes and processes.

Symposium Plasmas in the Solar System (SYPS)

jointly organized by
the Plasma Physics Division (P) and
the Extraterrestial Physics Division (EP)

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There are many different types of plasma in our solar system. The natural ones range from the hot, dense thermal plasma in the Sun, with fusion plasma in the Sun's core being the main source of energy, to low-density corona and solar wind, to auroras, partially ionized plasma of the ionosphere and lightnings in the Earth's atmosphere, and in general in the atmospheres of other planets as well. The human-generated plasmas in research and industry are mainly found on the Earth's surface, but there has been more than half a century of research into plasma-based electric propulsion systems for our satellites, thousands of which can now be found in Earth orbit. This symposium "Plasmas in the Solar System" will illustrate this broad spectrum of plasmas with selected examples introducing experimental and theoretical methods for their analysis.

Overview of Invited Talks and Sessions

(Lecture hall ELP 6: HS 4)

Invited Talks

SYPS 1.1	Thu	11:00–11:30	ELP 6: HS 4	**Energetic Particles in the Turbulent Heliosphere** — •Horst Fichtner
SYPS 1.2	Thu	11:30–12:00	ELP 6: HS 4	**Persistent solar wind forcing of the F2-region ionosphere observed at Tromsø** — •Claudia Borries, Pelin Iochem
SYPS 1.3	Thu	12:00–12:30	ELP 6: HS 4	**In-orbit diagnostics for artificial plasmas created by electric propulsion systems: The Heinrich Hertz Satellite Mission** — •Thomas Trottenberg
SYPS 1.4	Thu	12:30–13:00	ELP 6: HS 4	**Plasma-based space propulsion: status and scientific challenges** — •Kristof Holste

Sessions

SYPS 1.1–1.4	Thu	11:00–13:00	ELP 6: HS 4	**Plasmas in the Solar System**

Sessions

– Invited Talks –

SYPS 1: Plasmas in the Solar System

Time: Thursday 11:00–13:00 Location: ELP 6: HS 4

Invited Talk SYPS 1.1 Thu 11:00 ELP 6: HS 4

Energetic Particles in the Turbulent Heliosphere — •Horst Fichtner — Ruhr-Universitaet Bochum, Institut fuer Theoretische Physik IV

Observations of numerous energetic particle populations in the heliosphere, e.g. solar energetic particles, Jovian electrons, pickup ions, anomalous and Galactic cosmic rays, have - in connection with theoretical and modelling advances - provided tremendous insight into their transport and acceleration in turbulent plasma environments. At the same time the understanding of turbulence and its interaction with thermal and nonthermal plasma populations has progressed. In the talk an overview will be given that reaches from the simulation of (possibly intermittent) turbulence via (possibly anomalous) transport of energetic particles to heliospheric applications. The latter demonstrate the continuously increasing significance of heliospheric physics as a vital link between basic plasma physics and astrophysics.

Invited Talk SYPS 1.2 Thu 11:30 ELP 6: HS 4

Persistent solar wind forcing of the F2-region ionosphere observed at Tromsø — •Claudia Borries and Pelin Iochem — DLR, Institut für Solar-Terrestrische Physik

The state of the high-latitude thermosphere-ionosphere system gets modified by the solar wind passing Earth. The modifications are best visible during storm conditions. During these conditions, large amounts of solar wind energy are ingested into the thermosphere-ionosphere system which cause global changes in thermosphere and ionospheric electron density. This study investigates 22 years of Total Electron Content (TEC) and 15 years of ionosonde data (critical frequency foF2 and height of maximum electron density hmF2) at Tromsø (70°N, 19°E) with a correlation analysis. The ionosphere parameters are correlated with different solar wind parameters observed at the Lagrangean Point L1. The results show that the ionospheric parameters systematically respond with an increase or decrease depending on local time, season and solar cycle. During winter night conditions TEC and foF2 increase with solar wind energy and during summer daytime they decrease with increasing solar wind energy. The summer negative ionospheric response is more intense during solar maximum conditions, while the winter positive ionospheric response is stronger during solar minimum. Cross polar cap plasma convection, particle precipitation and Joule heating are considered to be the main drivers of the electron density changes at Tromsø. Local time, season and solar cycle changes in the background ionosphere-thermosphere conditions lead to different effects of theses driving processes.

Invited Talk SYPS 1.3 Thu 12:00 ELP 6: HS 4

In-orbit diagnostics for artificial plasmas created by electric propulsion systems: The Heinrich Hertz Satellite Mission — •Thomas Trottenberg — Christian-Albrechts-Universität zu Kiel, Kiel, Germany

The Heinrich Hertz Satellite (H2Sat) was launched in July 2023 and is now positioned in a geostationary orbit around the Earth. H2Sat is primarily a technology mission for the exploration of telecommunication techniques, but it is also equipped with a new electric propulsion system, the 'Highly Efficient Multistage Plasma Thruster' (HEMPT), developed in Germany. Propulsion systems, whether chemical or electric, may imply unwanted effects on the spacecraft. In case of plasma-based electric propulsion systems, a secondary plasma is created during the operation of the thruster that surrounds the satellite. To assess its effects on the spacecraft's surface, an Electric Propulsion Plasma Diagnostic Package (EPDP) was developed by a consortium of Kiel University, von Hoerner & Sulger GmbH, and OHB System AG [1]. This presentation will describe the diagnostics and show data from on-ground tests as well as first data from the satellite.

[1] Trottenberg et al., EPJ Techn. Instrum. 8, 16 (2021). https://doi.org/10.1140/epjti/s40485-021-00073-8

Invited Talk SYPS 1.4 Thu 12:30 ELP 6: HS 4

Plasma-based space propulsion: status and scientific challenges — •Kristof Holste — I. Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

Ion thrusters have been researched for more than 60 years and have reached a high level of maturity. They are routinely used for a range of orbital manoeuvres, e.g. for station keeping and, for the last ten years, for electric orbit raising (EOR). The latter has led to a new boom in the field of ion propulsion, as EOR has significantly reduced launch costs.

Nevertheless, there are a number of challenges. The amount of available xenon, currently the most important propellant, is limited. The increasing demand can hardly be met with existing resources, so that alternatives must be found.

The talk is dedicated to the search for alternative propellants and discusses some interesting approaches, such as the use of stable hydrocarbons (e.g. diamondoids) or iodine and the concept of air-breathing thruster, which has been under investigation for several years due to the great interest in low-flying satellites.

In addition, the current topic of the standardisation or comparability of measurements will be addressed, i.e. the transfer of measurements during tests on earth to performance in space, which is becoming increasingly important in view of the boom in these thrusters.

Physics Education Division
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Übersicht über Hauptvorträge, Fachsitzungen und Workshops

Hörsaal ELP 6: HS 2
Seminarräume ELP 1: SR 3.21, SR 3.22, SR 3.25, SR 2.26, SR 2.28
Poster ELP 6: Foyer

Plenarvortrag der Didaktik

PV IV	Tue	9:45–10:30	ELP 6: HS 3+4	**Climate Crisis Education-Physics Instruction's Role in Ensuring a Sustainable Future** — •Doug Lombardi

Hauptvorträge

DD 1.1	Mon	11:00–12:30	ELP 6: HS 2	**Wie kann Bildung junge Menschen zur Mitgestaltung gesellschaftlicher Transformation im Kontext der Klimakrise ermächtigen?** — •Martin Schwichow, Johanna Kranz
DD 7.1	Mon	17:40–18:30	ELP 6: HS 2	**Öfter mal die Brille wechseln? Interdisziplinäres Lernen in Schulphysik und Lehramtsausbildung** — •Lutz Kasper
DD 19.1	Tue	15:10–16:00	ELP 6: HS 2	**Umweltkrise = Verhaltenskrise? Individuelle und systemische Katalysatoren nachhaltigen Handelns** — •Gerhard Reese

Preisvorträge der Didaktik

DD 31.1	Wed	11:20–11:50	ELP 1: SR 3.21	**Satellitenfunk, MoonBounce und Atmosphärenforschung: Die modernste Technologie in der Schule** — •Safia Ouazi
DD 31.2	Wed	11:50–12:20	ELP 1: SR 3.21	**Rückblick auf 40 Jahre Physikunterricht mit Sonderaktivitäten** — •Heinz-Werner Oberholz
DD 40.1	Wed	15:10–16:00	ELP 6: HS 2	**Quantenphysik in der Schule: Neue Perspektiven durch Quantentechnologien** — •Rainer Müller

Invited Talks of the joint Symposium How to Cope with Apocalyptic Narratives? (SYAN)

See SYAN for the full program of the symposium.

SYAN 1.1	Mon	14:00–14:40	ELP 6: HS 4	**The Apocalyptic Moment Is Over - And It Won't Come Back Anytime Soon** — •Frank Uekoetter
SYAN 1.2	Mon	14:40–15:20	ELP 6: HS 4	**Shaping Cold War Futures through the Nuclear Winter Study: Narratives, Imaginaries and Legitimacy** — •Egle Rindzeviciute
SYAN 1.3	Mon	15:20–16:00	ELP 6: HS 4	**The Role of Storytelling in Climate Communication** — •Denise Müller-Dum

Fachsitzungen

DD 1.1–1.1	Mon	11:00–12:30	ELP 6: HS 2	**Hauptvortrag 1: Schwichow und Kranz**
DD 2.1–2.3	Mon	16:30–17:30	ELP 1: SR 3.21	**Lehr-Lernforschung II**
DD 3.1–3.3	Mon	16:30–17:30	ELP 1: SR 3.22	**Hochschuldidaktik – Studiengänge**
DD 4.1–4.3	Mon	16:30–17:30	ELP 1: SR 3.25	**Hochschuldidaktik – Experimente**
DD 5.1–5.3	Mon	16:30–17:30	ELP 1: SR 2.26	**Anregungen, Sonstige**
DD 6.1–6.3	Mon	16:30–17:30	ELP 1: SR 2.28	**Quantenphysik I**
DD 7.1–7.1	Mon	17:40–18:30	ELP 6: HS 2	**Hauptvortrag 2: Kasper**
DD 8.1–8.4	Tue	11:00–12:20	ELP 1: SR 3.21	**Lehr-Lernforschung II**
DD 9.1–9.4	Tue	11:00–12:20	ELP 1: SR 3.22	**Hochschuldidaktik – Formate**
DD 10.1–10.4	Tue	11:00–12:20	ELP 1: SR 3.25	**Hochschuldidaktik – Kompetenzen**
DD 11.1–11.4	Tue	11:00–12:20	ELP 1: SR 2.26	**Geschichte der Physik und physikdidaktische Forschung**
DD 12.1–12.4	Tue	11:00–12:20	ELP 1: SR 2.28	**Quantenphysik II**
DD 13.1–13.5	Tue	14:00–15:00	ELP 6: Foyer	**Quantenphysik – Poster**
DD 14.1–14.10	Tue	14:00–15:00	ELP 6: Foyer	**Neue / digitale Medien – Poster**
DD 15.1–15.2	Tue	14:00–15:00	ELP 6: Foyer	**Neue Konzepte – Poster**
DD 16.1–16.7	Tue	14:00–15:00	ELP 6: Foyer	**Lehr-Lernforschung – Poster**
DD 17.1–17.4	Tue	14:00–15:00	ELP 6: Foyer	**Außerschulisches Lernen – Poster**
DD 18.1–18.1	Tue	14:00–15:00	ELP 6: Foyer	**Bildung für nachhaltige Entwicklung – Poster**
DD 19.1–19.1	Tue	15:10–16:00	ELP 6: HS 2	**Hauptvortrag 3: Reese**
DD 20.1–20.4	Tue	16:30–17:50	ELP 1: SR 3.21	**Lehr-Lernforschung III**
DD 21.1–21.4	Tue	16:30–17:50	ELP 1: SR 3.22	**Hochschuldidaktik – Mathematik**
DD 22.1–22.4	Tue	16:30–17:50	ELP 1: SR 3.25	**Neue / digitale Medien**
DD 23.1–23.4	Tue	16:30–17:50	ELP 1: SR 2.26	**Bildung für nachhaltige Entwicklung**
DD 24.1–24.4	Tue	16:30–17:50	ELP 1: SR 2.28	**Quantenphysik III**
DD 25	Tue	18:00–20:00	ELP 6: HS 2	**Mitgliederversammlung**
DD 26.1–26.1	Wed	11:00–11:20	ELP 1: SR 3.21	**Anregungen**
DD 27.1–27.4	Wed	11:00–12:20	ELP 1: SR 3.22	**Hochschuldidaktik – Sachwissen**
DD 28.1–28.3	Wed	11:00–12:00	ELP 1: SR 3.25	**Experimente und Praktika**
DD 29.1–29.1	Wed	11:00–12:30	ELP 1: SR 2.26	**Workshop: Maschinelles Lernen in der naturwissenschaftsdidaktischen Forschung**
DD 30.1–30.4	Wed	11:00–12:20	ELP 1: SR 2.28	**Astronomie**
DD 31.1–31.2	Wed	11:20–12:20	ELP 1: SR 3.21	**Vorträge Lehrerpreise**
DD 32.1–32.6	Wed	14:00–15:00	ELP 6: Foyer	**Lehreraus- und -fortbildung – Poster**
DD 33.1–33.1	Wed	14:00–15:00	ELP 6: Foyer	**Sprache und Physikunterricht – Poster**
DD 34.1–34.1	Wed	14:00–15:00	ELP 6: Foyer	**Physikdidaktik und Inklusive – Poster**
DD 35.1–35.6	Wed	14:00–15:00	ELP 6: Foyer	**Hochschuldidaktik – Poster**
DD 36.1–36.4	Wed	14:00–15:00	ELP 6: Foyer	**Praktika und neue Praktikumsversuche – Poster**
DD 37.1–37.3	Wed	14:00–15:00	ELP 6: Foyer	**Präsentation von Experimenten – Poster**
DD 38.1–38.9	Wed	14:00–15:00	ELP 6: Foyer	**Astronomie – Poster**
DD 39.1–39.4	Wed	14:00–15:00	ELP 6: Foyer	**Sonstiges – Poster**
DD 40.1–40.1	Wed	15:10–16:00	ELP 6: HS 2	**Hauptvortrag 4 (Georg-Kerschenstein-Preis): Müller**
DD 41.1–41.1	Wed	16:00–17:30	ELP 1: SR 3.21	**Workshop: Studienreformforum**

Mitgliederversammlung des Fachverbands Didaktik der Physik

Dienstag 27.02.2024 18:00–20:00 ELP 6: HS 2

- Genehmigung der Tagesordnung
- Genehmigung des Protokolls der MV vom 07.03.2023
- Berichte aus den Arbeitsgruppen
- Wahl des Vorstands
- Termine
- Verschiedenes

Sessions

– Invited Talks, Prize Talks, Contributed Talks, and Posters –

DD 1: Hauptvortrag 1: Schwichow und Kranz

Time: Monday 11:00–12:30 Location: ELP 6: HS 2

Invited Talk DD 1.1 Mon 11:00 ELP 6: HS 2

Wie kann Bildung junge Menschen zur Mitgestaltung gesellschaftlicher Transformation im Kontext der Klimakrise ermächtigen? — •Martin Schwichow[1] und Johanna Kranz[2] — [1]PH Freiburg, Kunzenweg 21, 79117 Freiburg — [2]Rheinland-Pfalz Kompetenzzentrum für Klimawandelfolgen, Hauptstraße 16, 67705 Trippstadt

Bildung soll junge Menschen befähigen, die zur Eindämmung des Klimawandels notwendige gesellschaftliche Transformation nachzuvollziehen und mitzugestalten. Bisherige Klimabildungsansätze fokussieren jedoch auf eine Veränderung des individuellen Konsumverhaltens und schreiben damit die Verantwortung für einen ganzheitlichen Systemwandel den einzelnen Menschen zu. Individuelle Änderungen im Konsumverhalten reichen jedoch nicht aus, um eine bedeutsame Reduktion von Treibhausgasemissionen zu erreichen. Stattdessen bedarf es politischer Regulation. Klimabildung muss daher auch politische Steuerungsmöglichkeiten thematisieren, um junge Menschen zur aktiven Mitgestaltung der anstehenden Transformation zu ermächtigten. Der Vortrag zeigt auf, dass bisher im Unterricht überwiegend Handlungen im privaten und nicht im politischen Raum adressiert werden. Anhand eines theoretischen Handlungsmodells werden unterschiedliche Arten des umweltbewussten Engagements vorgestellt, um Wissen, Einstellungen und Kompetenzen abzuleiten, welche Lernenden zu privaten und öffentlichen Handlungen befähigen. Abschließend wird diskutiert, welchen Beitrag der Physikunterricht zu einer Klimabildung leisten kann, welche auch die politische Dimension der Klimakrise adressiert.

DD 2: Lehr-Lernforschung II

Time: Monday 16:30–17:30 Location: ELP 1: SR 3.21

DD 2.1 Mon 16:30 ELP 1: SR 3.21

Eye-Tracking-Studie zur Untersuchung von Strategien im Umgang mit Schaltplänen — •Stefanie Peter und Olaf Krey — Universität Augsburg

Beim Lernen, Anwenden und Kommunizieren physikalischer Konzepte spielen externe Repräsentationen eine zentrale Rolle. In der Elektrizitätslehre werden Schaltpläne genutzt, um elektrische Stromkreise auf einheitliche und übersichtliche Weise darzustellen. Der Umgang mit Schaltplänen stellt für Lernende jedoch eine Herausforderung dar, was beispielsweise bei Schwierigkeiten im Erkennen von Reihen- und Parallelschaltungen oder dem Misslingen von Translationen zwischen Schaltplan und Realschaltung deutlich wird. Auf welche Weise Lernende Informationen aus Schaltplänen entnehmen und diese mit physikalischen Konzepten verknüpfen ist bisher jedoch nicht bekannt. In einer Eye-Tracking-Studie untersuchen wir, inwiefern aus der visuellen Aufmerksamkeit von Lernenden beim Lösen von Aufgaben zu elektrischen Stromkreisen Strategien im Umgang mit Schaltplänen rekonstruiert werden können. Erste Ergebnisse zeigen Unterschiede im visuellen Verhalten der Lernenden, die im Zusammenhang mit verschiedenen Argumentationsweisen stehen.

DD 2.2 Mon 16:50 ELP 1: SR 3.21

Zum Einfluss der Nutzung von Modellanalogien auf das Konzeptwissen - Bericht zum Leistungsstand gymnasialer Mittelstufenschüler*innen in der Elektrizitätslehre — •Florian Frank und Thomas Trefzger — Julius-Maximilians-Universität Würzburg, Lehrstuhl für Physik und ihre Didaktik

Zur Vermittlung der grundlegenden Konzepte der Elektrizität werden häufig Modelle zum elektrischen Stromkreis verwendet. Diese Modelle basieren meist auf Analogien zu den Schülerinnen und Schülern (SuS) bekannten Objekten oder Konzepten, wie einer Fahrradkette oder dem Luftdruck. Durch die Nutzung der Modellvorstellungen wird versucht, zwischen den bekannten Objekten (z.B. den Gliedern einer Fahrradkette) und den Fachinhalten (z.B. den sich in einem Stromkreis bewegenden Elektronen) Verknüpfungen herzustellen. Diese Verknüpfungen sollen den SuS dabei helfen, ein Grundverständnis von den Konzepten der Elektrizität zu entwickeln. In einem Forschungsprojekt zu digitalen Unterstützungsmöglichkeiten der Vermittlung in der E-Lehre wurden in den Schuljahren 2022/23 und 2023/24 unter anderem Daten zum Konzeptwissen zur Elektrizität von Mittelstufen-Schülerinnen und -Schülern bayerischer Gymnasien erhoben. Diese Daten wurden gemeinsam mit den erhobenen Rahmeninformationen zum von den SuS besuchten Unterricht dazu genutzt, den Einfluss der im Unterricht genutzten Modellanalogien auf das Konzeptwissen der SuS zu untersuchen. Im Vortrag wird über den Leistungsstand der SuS berichtet, Lernschwierigkeiten und -hürden in der Elektrizitätslehre beleuchtet und ausgewählte Analogiemodelle vorgestellt.

DD 2.3 Mon 17:10 ELP 1: SR 3.21

Konzeptionelles Verständnis von Studierenden der Ingenieurwissenschaften zum elektrischen Stromkreis — •Bernadette Schorn[1] und Alexander Voigt[2] — [1]Europa-Universität Flensburg — [2]Hochschule Flensburg

Sowohl national als auch international zeigen sich in den Studien zu Lernendenvorstellungen zum elektrischen Stromkreis bei Studierenden typische Lernendenvorstellungen und Lernschwierigkeiten wie z. B. die Stromverbrauchsvorstellung (Burde et al. 2022, Chang & Shieh 2018, Fromme 2018, Goris & Dyrenfurth 2013). Zur Untersuchung des Verständnisses von Studierenden der Ingenieurwissenschaften zu grundlegenden Konzepten des elektrischen Stromkreises und möglichen Veränderungen des konzeptionellen Verständnisses durch Lehrveranstaltungen wurden an der Hochschule Flensburg in einem Zwei-Gruppen-Pretest-Posttest-Design Befragungen durchgeführt. Es werden erste Ergebnisse zum konzeptionellen Verständnis der Proband:innen im Allgemeinen sowie erste Ergebnisse der Interventionsstudie vorgestellt.

DD 3: Hochschuldidaktik – Studiengänge

Time: Monday 16:30–17:30 Location: ELP 1: SR 3.22

DD 3.1 Mon 16:30 ELP 1: SR 3.22

Das Q-Masterstudium als wissenschaftsbasierter Quereinstieg in das Lehramt. Ergebnisse der Begleitforschung zum Fach Physik an der FU Berlin — •Novid Ghassemi und Volkhard Nordmeier — Freie Universität Berlin

Mit dem bestehenden und für die kommenden Jahre erwarteten Mangel an grundständig qualifizierten Lehrpersonen werden weiterhin alternative Wege in das Lehramt benötigt. Ein diesbezüglich oftmals positiv hervorgehobenes Modell sind die sogenannten Quereinstiegs-Masterstudiengänge (kurz: Q-Master). Dabei wird zwar kein grundständiges Lehramtsstudium absolviert; im Gegensatz zum Quereinstieg ist dem Vorbereitungsdienst hier allerdings ein spezielles Lehramtsmasterstudium vorangestellt. Empirische Studien zu diesem alternativen Weg in den Lehrer*innenberuf deuten bislang auf günstige motivationale und kognitive Eingangsbedingungen sowie eine vergleichbare Ausprägung und Entwicklung der berufsrelevanten, professionellen Kompetenzen der Studierenden hin. Der Vortrag stellt die Ergebnisse der Begleitstudie zum Q-Masterstudiengang im Fach Physik an der FU Berlin vor und diskutiert diese hinsichtlich ihrer Implikationen für alternative Wegen in den Beruf sowie die Lehrer*innenbildung in Deutschland allgemein.

DD 3.2 Mon 16:50 ELP 1: SR 3.22

Fachwissenschaft fürs Lehramt: 2 Beispiele und was sich daraus lernen lässt — •Andreas Schulz[1], Stefan Brackertz[1] und Thomas Jockweg[2] — [1]Universität zu Köln, Mathematisch-Naturwissenschaftliche Fakultät — [2]Gesamtschule Köln-Holweide

Seit Langem, zuletzt in diesem Jahr [1,2] fordert die DPG ein Lehramtsstudium sui generis inklusive eigener, auf das Lehramt zugeschnittener fachwissenschaft-

licher Veranstaltungen. Allein: Trotz angeregter Debatten und pointierter Stellungnahmen, wie etwa in den Leserbriefen im Physik Journal ist allerdings kaum klar, was diese Veranstaltungen eigentlich ausmacht außer weniger Details, weniger Mathe und Auslassen von Inhalten [2].

In diesem Vortrag werden exemplarisch zwei fachwissenschaftliche Veranstaltungen fürs Lehramt zur modernen Physik vorgestellt: Kern- und Elementarteilchen-Physik und Astrophysik.

An Hand der Konzeption dieser Veranstaltungen werden einige Leitideen für die Gestaltung von Lehramts-bezogenen fachwissenschaftlichen Physikveranstaltungen heraus gearbeitet. Zuletzt soll die mit Sicherheit kontroverse Frage diskutiert werden, ob Veranstaltungen, die diesen Leitideen folgen, nicht für alle Studierenden die besseren sind.

[1] Woitzik et al.: Physik Journal 7/23, S. 35ff
[2] Heinicke et al.: Physik Journal 12/23, S. 43ff

DD 3.3 Mon 17:10 ELP 1: SR 3.22

Vom Karzer zum Bachelor: Eine kurze Geschichte der Prüfungsversuchsbeschränkungen — •Stefan Brackertz[1], Annemarie Sich[1], Barbara Obwaller[4], Lisa Lehmann[2], Amr El Miniawy[3], Robert Bartz[1], Philipp Bönninghaus[1] und Jonathan Moeller[2] — [1]Universität zu Köln, Fachschaft Physik — [2]TU Dresden, Fachschaft Physik — [3]HU Berlin, Fachschaftsinitiative Physik — [4]Universität Innsbruck, Studienvertretung Physik

Die erschreckenden Ergebnisse jüngster Studien zur mentalen Gesundheit [1] von Studierenden geben der Debatte über Prüfungsversuchsrestriktionen eine neue Aktualität. Die Argumente dieser Diskussion und die Erfahrungen in Physikstudiengängen an verschiedenen Universitäten sind inzwischen weitgehend systematisiert und dokumentiert [2], einige Vorreiter-Universitäten haben bereits mehr als ein Jahrzehnt an Erfahrung mit der Abschaffung dieser Restriktionen und an einigen Orten gibt es vorsichtige Schritte zur Lockerung.

Hauptbedenken bei diesen Schritten ist in der Regel, dass Studierende ohne Restriktionen die Prüfungsvorbereitung weniger ernst nähmen. Interessant ist, dass solche Überlegungen in der Entstehungsgeschichte dieser Restriktionen kaum eine Rolle gespielt haben. Als Beitrag zur Debatte sollen daher Ursprung der Prüfungsversuchsbeschränkungen und die Debatte um diese Regelung seit dem 19. Jh. skizzenhaft rekonstruiert werden.

[1] TK-Gesundheitsreport 2023, https://ogy.de/2kr6
[2] Themenseite des Studienreformforums, https://studienreform-forum.de/de/themen/prufungsversuchsbeschrankungen/

DD 4: Hochschuldidaktik – Experimente

Time: Monday 16:30–17:30 Location: ELP 1: SR 3.25

DD 4.1 Mon 16:30 ELP 1: SR 3.25

Zentrales Datenmanagement im Praktikumslabor mit elektronischen Laborbüchern — •Cedric Kessler, Johannes Marczinkowski, Stefan Mohn, Rebekka Murati, Valentina Alberini, Antonia Pérez-Cerezo, Andrea Merli, Christian Hennig, Ralph Ernstorfer und Nina Owschimikow — Institut für Optik und Atomare Physik, Technische Universität Berlin

Die erfolgreiche Digitalisierung an Hochschulen erfordert neben moderner Hardware, auch die Schulung der Studierenden auf die neuen Technologien. Es muss auf den Laboralltag mit hochmodernen Computercluster, vollautomatisierten Elektronenmikroskopen und Kollaboration mit internationalen Kolleg*Innen über digitale Plattformen vorbereitet werden. Das seit Langem genutzte händische Laborbuch kann mit diesem Fortschritt nicht mithalten und immer strengere Forschungsrichtlinien erfordern einen umfangreichen Datenmanagementplan. Im modernen Labor unterstützt das frei verfügbare elektronische Laborbuch openBIS [1] die digitale Protokollierung vom Laborgeschehen, zentrale Datensammlung, Verwaltung von Laborinventar und flexiblen Zugriff hierauf über eine Vielzahl von Plattformen. Die Studierenden können durch vorgegebene oder Freitext-Felder in die Laborbuchführung eingeführt werden. Die zentrale Datenverwaltung erleichtert Evaluationen und ermöglicht den Datenaustausch unter Studierenden.

[1] Barillari, C., Et al. (2016). openBIS ELN-LIMS: an open-source database for academic laboratories. Bioinformatics (Oxford, England), 32(4), 638 - 640.

DD 4.2 Mon 16:50 ELP 1: SR 3.25

Digitalisierung im physikalischen Anfänger*innenpraktikum als Zweck oder Mittel?: — •Johannes Marczinkowski, Cedric Kessler, Rebekka Murati, Stefan Mohn, Valentina Aberini, Antonia Pérez-Cerezo, Christian Henning, Andrea Merli, Ralph Ernstorfer und Nina Owschimikow — Institut für Optik und Atomare Physik, Technische Universität Berlin

"Digitalisierung" zählt zu den Schlüsselbegriffen in der Debatte um die Modernisierung der Bildung auf allen Ebenen. Traditionelle Ausbildungsinhalte werden zunehmend durch digitale Hilfsmittel ergänzt. Darüber hinaus hat die Digitalisierung zu grundlegenden Veränderungen im Arbeitsalltag von Physiker*innen geführt, insbesondere im Hinblick auf den Umfang und die Geschwindigkeit der Datenerfassung, die Ansteuerung von Experimenten und die Datenanalyse. Diese Entwicklungen müssen nun in das Physikstudium integriert werden. Das Erlernen von grundlegenden Kompetenzen im Umgang mit Daten, wie Datendokumentation und -management, ist ein unverzichtbarer Bestandteil der modernen Physiker*innenausbildung. An der TU Berlin ersetzen in den physikalischen Anfängerpraktika elektronische Laborbücher die herkömmlichen Papierlaborbücher. Diese bieten Zugang zu weiterführenden Inhalten, wie der professionellen Dokumentation nach FAIR-Kriterien [1], dem Umgang mit Labor-Informations-Management-Systemen (LIMS) und einer Datenbankfunktion.

[1] M. D. Wilkinson et al., Sci. Data 3, 160018 (2016)

DD 4.3 Mon 17:10 ELP 1: SR 3.25

Physik.SMART: Mit Smartphone-Experimenten die Grenzen zwischen Vorlesung, Übung und Praktikum überwinden — •Heidrun Heinke[1], Dominik Dorsel[1], Sebastian Staacks[1], Mosab Abumezied[1], Marina Hruska[2], Christoph Stampfer[1] und Christian Effertz[2] — [1]RWTH Aachen University — [2]FH Aachen

Im Projekt Physik.SMART der Stiftung Innovation in der Hochschullehre wird exemplarisch für verschiedene Adressatengruppen demonstriert, wie Smartphone-basierte eigenständig durchgeführte Studierenden-Experimente die tradierte Physiklehre an Hochschulen grundlegend verändern können. Hierfür wird die App phyphox weiterentwickelt und es werden einfache Zusatzmaterialien für Experimente mit Smartphone-internen Sensoren, v.a. aber externe Sensorboxen für eine breite Vielfalt von kostengünstigen, digital gestützten Experimenten in allen Teilgebieten der Physik bereitgestellt. Dies ermöglicht Experimente im gesamten Kanon typischer Veranstaltungen zur Experimentalphysik und schafft die Voraussetzung für eine grundlegende Umgestaltung der Physiklehre an Hochschulen durch die Überwindung der aktuellen Trennung zwischen den Vorlesungen und dem Experimentieren der Studierenden (bisher in Praktika). Die Studierenden können damit zeitlich passend zum Vorlesungsstoff instruktive Experimente durchführen und dabei mit einfachen (Alltags-)Mitteln unter Nutzung ihrer fachlichen Neugier und Kreativität individuelle Versuchsaufbauten und Messszenarien entwickeln. Im Beitrag wird das Konzept vorgestellt und es werden erste Erfahrungen mit der Umsetzung präsentiert.

DD 5: Anregungen, Sonstige

Time: Monday 16:30–17:30 Location: ELP 1: SR 2.26

DD 5.1 Mon 16:30 ELP 1: SR 2.26

Klimabildung - schulisch und außerschulisch vernetzt — •Jonas Tischer[1], Elena Vetter[2], Ina de Buhr[2] und Michael Komorek[1] — [1]Universität Oldenburg — [2]Neues Gymnasium Wilhelmshaven

Komplexe gesellschaftliche Herausforderungen wie der Klimawandel zu verstehen und anzugehen, erfordert das Zusammenspiel vieler disziplinärer Zugänge. Schule ist hierbei oft überfordert, weil separierte Fächer in ihren Angeboten unterkomplex bleiben. Im Projekt ReBiS (Regionales MINT-Bildungsökosystem) werden daher außerschulische Lernangebote, die meist multidisziplinär strukturiert sind, in mehreren Schulfächer eingebettet. Dadurch entsteht zum komplexen Thema Klimawandel ein neues Lernangebot, an dem mehrere Fächer und außerschulische Lernorte beteiligt sind. Es weist eine dem Thema angemessene Komplexität auf, ohne Lehrkräfte und Schüler:innen zu überfordern. ReBiS wird von der Deutschen Telekom Stiftung gefördert; im Raum Wilhelmshaven/Friesland/Oldenburg wirken sechs außerschulische Lernorte und vier Schulen mit vielfältigen Fächerkombinationen mit. Die Schulklassen wählen einen

Problemkontext, den sie vielfältig und über mindestens ein Schuljahr lang angehen. Im Vortrag stellen wir das Konzept 'Herausforderung Leben im Klimawandel' des Neuen Gymnasiums in Wilhelmshaven vor.

DD 5.2 Mon 16:50 ELP 1: SR 2.26

Kooperative Datenerfassung am Beispiel des Hertzsprung-Russell-Diagramms — •Sven Levetzow und Lukas Maczewsky — Universität Rostock

Die digitale Messwerterfassung ist in den Rahmenplänen für das Fach Physik in Mecklenburg-Vorpommern fest verankert. Neben der Nutzung von Smartphones und Sensoren zur Messwerterfassung oder Videoanalysesoftware ist die kooperative Datenerfassung eine Möglichkeit, der digitalen Messwerterfassung gerecht zu werden. Dieser Vortrag stellt die kooperative Methode mit einem Ersatzversuch zur Einführung des Hertzsprung-Russell-Diagramms vor. Schülerinnen und Schüler werten Aufnahmen von Sternen in verschiedenen Himmelsauschnitten hinsichtlich ihrer Farbe und ihrer Helligkeit bezüglich der HSL-Farbskala aus. Durch das Zusammentragen vieler Messwerte kann das Hertzsprung-Russell-Diagramm erarbeitet und der wissenschaftliche Erkenntnisprozess nachvollzogen werden.

Es wird eine mögliche Unterrichtsstunde vorgestellt, die die Entwicklung der experimentellen Teilkompetenz *Fragestellung entwickeln* fokussiert. Weiterhin wird diese Unterrichtsstunde anhand verschiedener didaktischer Modelle und Theorien in den Erkenntnisprozess von Schülerinnen und Schülern eingeordnet.

DD 5.3 Mon 17:10 ELP 1: SR 2.26

Prozess- und Sequenzanalyse von schriftlichen Problemlöseansätzen — •Paul Tschisgale[1], Stefan Petersen[1], Peter Wulff[2] und Knut Neumann[1] — [1]IPN, Kiel, Germany — [2]Heidelberg University of Education, Heidelberg, Germany

Problemlösen ist eine zentrale Arbeitsweise für PhysikerInnen und spielt im Physikunterricht und -studium eine wichtige Rolle. Individualisiertes Feedback zum Problemlösen ist dabei für den Erwerb von Problemlösefähigkeiten unabdingbar, jedoch zeitaufwändig und erfolgt daher eher selten. Methoden des maschinellen Lernens bieten Potential für skalierbare, automatisierte und personalisierte Rückmeldungen. Solche Rückmeldungen überprüfen in der Regel primär, ob bestimmte Elemente in einer Problemlösung vorhanden sind. Die Reihenfolge, in der bestimmte Elemente in einer Problemlösung auftreten, spielt hierbei keine Rolle. Wir gehen der Frage nach, wie sich schriftliche Problemlösungen von SchülerInnen auf dieser Prozessebene charakterisieren und welche Problemlösestrategien sich identifizieren lassen. Hierfür wurden Problemlösungen auf Satzebene betrachtet und jedem Satz eines der Themen Annahmen, Konzepte, quantitative Aspekte, Hypothesen, Metabeschreibungen zugeordnet. Basierend darauf wurde untersucht, 1) inwieweit bestimmte Sequenzen von Themen prädiktiv für erfolgreiches Problemlösen sind und 2) inwieweit sich die Struktur der Problemlösungen zwischen SchülerInnen unterscheidet. Der Vortrag präsentiert erste Ergebnisse dieser Untersuchung und beschreibt Implikationen für die Verbesserung automatisierter Rückmeldesysteme durch Einbeziehung der Prozessebene von Problemlösungen.

DD 6: Quantenphysik I

Time: Monday 16:30–17:30 Location: ELP 1: SR 2.28

DD 6.1 Mon 16:30 ELP 1: SR 2.28

Quantentechnologien in der Industrie: Herausforderungen, Bedarfe und Empfehlungen für die Gestaltung von Bildungsangeboten — •Franziska Greinert, Rainer Müller, Ismet N. Dogan und Malte S. Ubben — Technische Universität Braunschweig, IFdN, Physik und Physikdidaktik

Quantentechnologien wie Quantensensoren, Quantencomputer und Quantenkommunikationssysteme gewinnen rasant an industrieller Bedeutung. Damit steigt auch der Bedarf an Fachkräften in der Industrie. Doch was braucht die Industrie? Vor welchen Herausforderungen steht sie, welche Rollen sind zu besetzen und welche Personengruppen benötigen welche Bildungsmaßnahmen? Und wie sollten die Bildungsangebote aussehen?

Diese Bildungsbedarfe der Industrie in Europa wurden in 34 Interviews und einem Follow-up-Fragebogen mit über 50 Antworten erhoben. Im Vortrag werden die zentralen Bedarfe thematisiert und Empfehlungen für die Gestaltung von Bildungsangeboten gegeben.

DD 6.2 Mon 16:50 ELP 1: SR 2.28

Quantentechnologien für die Industrie: Entwicklung und Evaluation von Bildungsangeboten — •Ismet N. Dogan, Franziska Greinert, Malte S. Ubben und Rainer Müller — Technische Universität Braunschweig, Institut für Fachdidaktik der Naturwissenschaften, Abteilung Physik und Physikdidaktik

Mit der steigenden Bedeutung der Quantentechnologien zweiter Generation wird auch ein deutlicher Anstieg des Bedarfs an Fachkräften prognostiziert. An den bereits bestehenden und kontinuierlich ausgebauten Angeboten an Studiengängen anknüpfend, zielt das QTIndu- Projekt auf die Entwicklung und die Evaluation von Bildungsangeboten für die Industrie ab. Im Vortrag werden das QTIndu-Projekt, die bisherigen Ergebnisse sowie zukünftige Vorhaben präsentiert. Hierzu erfolgt ein Einblick in das allgemeine Evaluationssystem des Projektes und die in 2023 gestartete Konzipierung und Entwicklung von Lernmaterialien.

DD 6.3 Mon 17:10 ELP 1: SR 2.28

Quanteninformatik in der Lehrerbildung mit Transfer in den berufsorientierenden Unterricht — Moritz Förster, •Gesche Pospiech und Julia Unger — TU Dresden, Professur für Didaktik der Physik

Quantentechnologien bilden ein fest etabliertes und weiterhin stark wachsendes Forschungsfeld mit großem Anwendungspotenzial für die Industrie. Eine der aktuellen Herausforderungen für Deutschland und Europa besteht darin, den erwartbar wachsenden Bedarf an spezifisch ausgebildeten Fachkräften mittel- und langfristig zu decken.

Das Projekt QUILT (Quanteninformatik in der Lehrerbildung mit Transfer in den berufsorientierenden Unterricht) zielt langfristig auf die Gewinnung von Fachkräften durch einen berufsorientierenden Ansatz im Physikunterricht ab. Unter aktiver Beteiligung industrieller Partner wird eine universitäre Lehrveranstaltungen konzipiert, in der Lehramtsstudierende die Grundlagen der Quanteninformatik in einem allgemeinbildenden Sinne erlernen, einen konkreten Einblick in die Berufswelt erhalten und die Kompetenzen erwerben, ihren eigenen Unterricht berufsorientierend zu gestalten. Auf diese Weise soll der Unterricht dazu beitragen, dass die Schüler:innen zum einen berufliche Perspektiven erfahren und zum anderen ein Verständnis für das Zusammenspiel von Wissenschaft, Technik und Wirtschaft entwickeln.

Im Vortrag wird ein Überblick über die konzipierte Lehrveranstaltung sowie über erste Ergebnisse der Evaluation gegeben.

DD 7: Hauptvortrag 2: Kasper

Time: Monday 17:40–18:30 Location: ELP 6: HS 2

Invited Talk DD 7.1 Mon 17:40 ELP 6: HS 2

Öfter mal die Brille wechseln? Interdisziplinäres Lernen in Schulphysik und Lehramtsausbildung — •Lutz Kasper — PH Schwäbisch Gmünd, Abteilung Physik

Die gegenwärtige Situation des Physikunterrichts wie auch der Ausbildung von Physiklehrkräften zwingt alle Beteiligten zu einer kritischen Reflexion. Während ersterer seit langem an Motivationsdefiziten bei Lernenden krankt, trübt der Lehrkräftemangel bei gleichzeitig immer öfter unbesetzt bleibenden Studienplätzen des Physik-Lehramtes das Gesamtbild weiter ein. Lösungen für diese Probleme müssen auf verschiedenen Ebenen, z.B. der inhaltlich-curricularen, der bildungspolitischen und der gesellschaftlichen, gesucht werden. Indem die Begriffe des authentischen Alltagskontextes und der Interdisziplinarität miteinander in Zusammenhang gebracht werden, soll hier ein Faktor der inhaltlichen Ebene zur Diskussion gestellt werden. Authentizität und Kontextorientierung sind in fachdidaktischer Forschung und Lehre längst keine Unbekannten. Lehrende, die diese in standardisierte Curricula (Bildungsstandards) integrieren, sehen sich oft in der Lage, die Grenzen der Physik überschreiten zu müssen. Wie gut werden sie in ihrem Studium darauf vorbereitet? Welchen Stellenwert hat Interdisziplinarität in einem Studiengang, der mit zwei Fächern und den bildungswissenschaftlichen Anteilen ohnehin multiperspektivisch angelegt ist? Wie können inhaltlich und methodisch integrative Ansätze bereits in der Schule, vor allem aber in der Lehrkräftebildung gefördert werden? Neben begrifflichen Klärungen und beispielhaften Einblicken greift der Vortrag die oben genannten Fragen auf.

DD 8: Lehr-Lernforschung II

Time: Tuesday 11:00–12:20 Location: ELP 1: SR 3.21

DD 8.1 Tue 11:00 ELP 1: SR 3.21

Kontexte empathisierend oder systematisierend gestalten? Einflüsse auf das Interesse an Physik — •Julia Welberg, Daniel Laumann und Susanne Heinicke — Universität Münster

Das Interesse von Lernenden beeinflusst deren Engagement und Leistung. Es besteht daher ein besonderer Bedarf an einem umfassenden Verständnis des Interesses an naturwissenschaftlichen Fächern, insbesondere an einem unbeliebten Fach wie Physik. Während sich frühere Forschungen auf genderspezifische Unterschiede konzentrierten, deuten neuere Studien darauf hin, dass es sinnvoll sein könnte den Fokus zu erweitern. In dieser Studie wird die Empathizing-Systemizing Theorie (EST) zur Analyse des Interesses von Lernenden an Physik herangezogen. Es wird untersucht, wie sich das Interesse von Schülerinnen und Schülern bei einer eher empathisierenden oder systematisierenden Kontextformulierung verändert. Die Ergebnisse deuten auf einen Zusammenhang zwischen der EST und dem Interesse an Kontexten für den Physikunterricht in Bezug auf die Formulierung der Kontexte hin, was für die Gestaltung von Physikunterricht von Bedeutung sein kann.

DD 8.2 Tue 11:20 ELP 1: SR 3.21

Wirksamkeit aktivierender Lehrmethoden in einführenden Physikmodulen - Ein exemplarischer Vergleich zwischen der Schweiz und Deutschland — •Andreas Johannes Modler — Berliner Hochschule für Technik, Luxemburger Straße 10, 1353 Berlin

In einführenden Physikmodulen zur Mechanik wurden als aktivierende Lehrmethoden Peer Instruction (PI), Just-in-Time-Teaching (JiTT) und Tutorials der Physik eingesetzt. Die Wirksamkeit der Lehrmethoden wurde mittels des Force Concept Inventories (FCI) gemessen, der als Vor-und Nachtest zu Beginn und Ende der Lehrveranstaltungen durchgeführt wurde. Als Maß für den Lernzuwachs und damit für die Wirksamkeit der Lehrmethoden wurde der normierte Zuwachs nach Hake, die normierte Änderung und die Effektstärke nach Cohen (Cohens d) bestimmt. Es werden die in den Studiengängen Maschinen-, Verfahrens- und Systemtechnik an der der Züricher Hochschule für Angewandte Wissenschaften (ZHAW) aus den Jahren 2012-2015 erhobenen Daten mit jenen an der Berliner Hochschule für Technik (BHT) im Studiengang Physikalische Technik und Medizinphysik aus den Zeitraum 2016-2022 verglichen. Bei signifikant unterschiedlichen Ergebnissen im Vor- und Nachttest der Schweizer Kohorte zur deutschen Kohorte der Studierenden ergeben sich miteinander verträgliche Lernzuwächse. Diese sind charakteristisch für aktivierende Lehrmethoden, wobei der zeitliche Umfang der eingesetzten aktivierenden Lehremethoden zwischen den beiden Kohorten grob um den Faktor zwei variierte. Spezifische Unterschiede zwischen den beiden Kohorten werden als mögliche Einflussfaktoren diskutiert.

DD 8.3 Tue 11:40 ELP 1: SR 3.21

Forscherboxen und Unterrichtsmaterial zum Thema „Farben" im inklusiven NaWi-Unterricht — •Giulia Pantiri[1], Lea Mareike Burkhardt[2], Thomas Wilhelm[1], Volker Wenzel[2], Arnim Lühken[3] und Dieter Katzenbach[4] — [1]Institut für Didaktik der Physik, Uni Frankfurt — [2]Abteilung Didaktik der Biowissenschaften, Uni Frankfurt — [3]Institut für Didaktik der Chemie, Uni Frankfurt — [4]Institut für Sonderpädagogik, Uni Frankfurt

Im Rahmen des Design-Based Research Projekt E^{2}piMINT wird ein inklusives und interdisziplinäres Unterrichtskonzept für die Sekundarstufe I entwickelt, getestet und evaluiert. Dafür wurde ein Projekttag zum Thema „Farben" konzipiert und in den Schülerlaboren der Goethe-Universität Frankfurt durchgeführt, an dem insgesamt 48 Schulklassen teilnahmen. Bei diesem Konzept arbeiten die Schüler*innen während des Projekttages an Stationen, die in Form von Forscherboxen erstellt wurden, und führen Experimente zu verschiedenen Themen aus den drei Naturwissenschaften durch. An dieser Erprobung in kontrollierten Laborbedingungen schließt sich eine zweite Phase in der Schule an, um die praktische Wirksamkeit des entwickelten Konzeptes in schulischen Lernumgebungen zu erforschen. In dem Vortrag werden das Konzept und das erstellte Material zum Thema „Farben" präsentiert. Das Material umfasst sowohl das Experimentiermaterial der Boxen als auch helfende Unterrichtsmaterialien wie Anleitungen in verschiedenen Formen und Hilfekarten. Das entwickelte Unterrichtsmaterial enthält besondere inklusive Merkmale, deren praktische Wirksamkeit erprobt wurde und die im Vortrag beschrieben werden.

DD 8.4 Tue 12:00 ELP 1: SR 3.21

Identität von Schüler*innen und naturwissenschaftlicher Anfangsunterricht: Ergebnisse einer Fragebogen-Studie — •Lisa-Marie Christ[1], Frederik Bub[2], Olaf Krey[1] und Thorid Rabe[2] — [1]Universität Augsburg — [2]Martin-Luther-Universität Halle-Wittenberg

Im BMBF-geförderten Forschungsprojekt IdentMINT werden während des naturwissenschaftlichen Anfangsunterrichts in Bayern und Sachsen-Anhalt Zugänge und Positionierungen von Schüler*innen aus den Jahrgangsstufen sechs bis neun zu Naturwissenschaften und Physik- und Chemieunterricht erhoben. Über zwei Schuljahre hinweg werden die Schüler*innen in der quantitativen Teilstudie des Projekts in drei Fragebogenerhebungen beispielsweise zu ihren naturwissenschaftlichen Selbstwirksamkeitserwartungen und Interessen sowie ihren Einstellungen und Wahrnehmungen zu und von Naturwissenschaften und naturwissenschaftlichem Unterricht (mit einem Fokus auf Physik und Chemie) befragt. Durch das längsschnittlich angelegte Studiendesign kann herausgearbeitet werden, wie sich einzelne dieser Konstrukte, die als Indikatoren zu MINT-Identitäten angesehen werden, während des naturwissenschaftlichen Fachunterrichts verändern.

Im Vortrag wird die naturwissenschaftliche Identitätsarbeit von Schülerinnen und Schülern auf Grundlage dieser quantitativen Daten betrachtet, wobei ausgewählte Befunde aus den bisherigen Fragebogenerhebungen vorgestellt werden.

DD 9: Hochschuldidaktik – Formate

Time: Tuesday 11:00–12:20 Location: ELP 1: SR 3.22

DD 9.1 Tue 11:00 ELP 1: SR 3.22

Flipped Classroom in der Lehramtsausbildung — •Tim Ruhe — Technische Universität Dortmund

Die Vorlesung "Basiskonzepte Physik" an der TU Dortmund richtet sich an angehende Lehrkräfte aus dem Primarbereich und wird in der Regel von 100 bis 150 Studierenden aktiv besucht. Die Veranstaltung wurde bislang als klassische Vorlesung mit freiwilligen Tutorien abgehalten und im Wintersemester 23/24 auf ein Format mit deutlich mehr interaktiven Inhalten umgestellt, die darauf abzielen im Rahmen der Vorlesung konkrete physikalische Problemstellungen - möglichst aus dem Alltag von Kindern im Grundschulalter - zu bearbeiten. Um innerhalb der Veranstaltung die notwendigen Freiräume für diese intensivere Art der Themenbearbeitung zu schaffen, wurde die Vermittlung reiner Wissensinhalte und Konzepte in die Vorbereitung der Vorlesung verlegt. Die Vorbereitung bestand seitens der Studierenden aus der Bearbeitung von Texten bzw. dem Anschauen von Lernvideos und einem dazugehörigen kurzen Quiz. Über alle Vorlesungstermine hinweg, wurden sowohl die Vorbereitung, als auch die Vorlesungstermine selbst durch kurze Umfragen evaluiert. Dieser Beitrag gibt einen kurzen Überblick über das Veranstaltungsformat, präsentiert einen ersten Einblick in die Ergebnisse der Umfragen unter den Studierenden und misst den Lernerfolg der Studierenden anhand beispielhafter Klausuraufgaben.

DD 9.2 Tue 11:20 ELP 1: SR 3.22

Physik lernen in hybrider Gruppenarbeit - ein innovativer Lehrraum als didaktisches Labor — •Michael Griesbeck und Claudia Schäfle — Technische Hochschule Rosenheim, Hochschulstr. 1, 83024 Rosenheim

Um Studierenden mehr Flexibilität zu bieten, gewinnt die Online-Übertragung von Lehrveranstaltungen (LVs) an Bedeutung. Für studierendenzentrierte und aktivierende Lehrformate ergeben sich hierbei besondere Anforderungen, insbesondere im Fall hybrider Gruppenarbeiten, bei denen Studierende synchron in Präsenz und Online in kleinen Gruppen interaktiv zusammenarbeiten. Angestrebt wird, dass der Kompetenzzuwachs der Studierenden unabhängig von der Art der Teilnahme ist und das hohe Niveau einer rein in Präsenz durchgeführten LV mit Gruppenarbeit wie beim SCALE-UP Raum- und Lehrkonzept erreicht wird. Solche hybriden Gruppenarbeiten finden in einem neuen, innovativen Lehrraum an der TH Rosenheim im Rahmen des regulären seminaristischen Unterrichts statt. Der Raum enthält sechs Gruppentische mit zugehörigen Smartboards, Tischmikrophonen und Kameras sowie hybride Technik. Die einzelnen Teams mit je etwa 4 Präsenz- und 2-3 Online-Teilnehmenden erhalten anspruchsvolle Aufgaben, um sich das jeweilige Themengebiet interaktiv zu erarbeiten. Dabei erzielen die Teams erfolgreiche Ergebnisse. In diesem Beitrag wird über Erfahrungen mit Gestaltung und Durchführung, sowie Untersuchung der Wirkungen mittels studentischer Befragungen und Lehrveranstaltungsbeobachtungen u.a. hinsichtlich des ICAP-Frameworks vorgestellt und Vergleiche zum reinen Präsenzformat gezogen.

DD 9.3 Tue 11:40 ELP 1: SR 3.22

Dem gemeinsamen Lernen Raum geben - das SCALE-UP Raum- und Lehrkonzept — •Claudia Schäfle, Silke Stanzel und Christine Lux — Technische Hochschule Rosenheim, Hochschulstr. 1, 83024 Rosenheim 1,

Studierendenzentrierte und aktivierende Physiklehre an Hochschulen kann durch eine spezielle Raumgestaltung besonders unterstützt werden. In den SCALE-UP-Lehrräumen der TH Rosenheim (SCALE-UP ist das Akronym für student-centered active learning environment for upside-down pedagogies, Beichner et al., 2007) arbeiten Studierende an runden Gruppentischen in 2-3er Teams an anspruchsvollen Aufgaben, die an fachdidaktischer Forschung, insbesondere der Physics Education Research, orientiert sind. Dabei werden u.a. Lernaktivitäten wie Peer Instruction, Whiteboards, Tutorial-Arbeitsblätter (McDermott & Shaffer, 2002) und kleinere Experimente eingesetzt. Während so die reine Vorlesungszeit auf ein Minimum reduziert wird, findet die Hinführung zum Inhalt in der studentischen Vorbereitungszeit gemäß dem Just-in-Time Teaching Lehrformat statt.

Im Beitrag wird das umgesetzte SCALE-UP Raum- und Lehrkonzept vorgestellt und Ergebnisse aus Lehrveranstaltungsbeobachtungen im Hinblick auf das kognitive Engagement im Rahmen des ICAP-Modells (Chi & Wylie, 2014) präsentiert. Es zeigt sich, dass die Studierenden mehr als zwei Drittel der Präsenzzeit in den hohen modes interactive und constructive arbeiten. Schließlich werden Daten zum Lernzuwachs der Studierenden mittels Konzepttests gezeigt.

DD 9.4 Tue 12:00 ELP 1: SR 3.22

Making Makers: Ein Seminarkonzept zum Educational Making in der Lehramtsausbildung im Fach Physik — •Fabian Bernstein und Thomas Wilhelm — Goethe-Universität Frankfurt

Educational Making erfährt seit geraumer Zeit neue Aufmerksamkeit, was sich in Initiativen wie dem "School FabLab-Netzwerk" oder "Make your school" und einer zunehmenden Zahl von Makerspaces an Schulen widerspiegelt. Die Gründe für diese Popularität sind mannigfaltig: Im Bereich der naturwissenschaftlichen Bildung werden Chancen insbesondere im Zusammenhang mit forschend-entdeckendem Lernen gesehen, verbunden mit der Hoffnung, mehr Schüler*innen für Naturwissenschaften zu begeistern. Makerspaces als innovative und projektzentrierte Lernumgebungen scheinen in besonderer Weise geeignet, diese Hoffnungen einzulösen.

Ob und bis zu welchem Grad diese "Chance Makerspace" ergriffen werden kann, hängt allerdings auch von der Verfügbarkeit entsprechend qualifizierter Lehrkräfte ab. Da Educational Making in der Lehramtsausbildung bisher noch wenig verwurzelt ist, wurde an der Goethe-Universität Frankfurt ein von der Joachim Herz Stiftung gefördertes Seminar für Lehramtsstudierende entwickelt, das sowohl technische Fähigkeiten der Studierenden schulen als auch konzeptionelle Grundlagen des Making für die Arbeit mit Schüler*innen vermitteln sollte. Diese Lehrveranstaltung wurde über drei Semester angeboten.

Im Rahmen des Vortrags wird das Seminarkonzept erläutert, Erfahrungen mit der Lehrveranstaltung reflektiert und verschiedene Projekt- und Arbeitsergebnisse zur Diskussion gestellt.

DD 10: Hochschuldidaktik – Kompetenzen

Time: Tuesday 11:00–12:20 Location: ELP 1: SR 3.25

DD 10.1 Tue 11:00 ELP 1: SR 3.25

Unterstützung zum Selbststudium: Versprachlichung von Formeln und Inhalte rekonstruieren — •Philipp Scheiger — Physik und ihre Didaktik, Universität Stuttgart, 70569 Stuttgart — Fachdidaktik der Physik und Astronomie, Friedrich-Schiller-Universität Jena, 07743 Jena

Ein wichtiger Aspekt in jedem Physikstudium ist das Selbststudium. Neben der Bearbeitung von Übungsaufgaben ist das Nacharbeiten von Lehrveranstaltungen von großer Bedeutung. Jedoch hat sich in Gesprächen mit Studierenden gezeigt, dass häufig die gesamte Zeit des Selbststudiums in die Bewältigung von Übungsaufgaben investiert wird. Einige Studierende begründen dieses Verhalten mit Zeitmangel, während andere noch nie Vorlesungsinhalte nachgearbeitet haben, auch weil sie nicht wissen, wie sie das effektiv angehen sollen. Um den Studierenden dafür Werkzeuge an die Hand zu geben, wurde Material entwickelt, das sie dazu anregt, sich qualitativ mit den Inhalten auseinanderzusetzen. Ziel ist es, dass Studierende die wesentlichen Inhalte identifizieren, das Wissen rekonstruieren und in das eigene Vorwissen integrieren. Die Materialien stützen sich dabei auf bewährte fachdidaktische Methoden, wie die didaktische Rekonstruktion und die Versprachlichung von Formeln. In diesem Beitrag werden solche Materialien vorstellt, die begleitend zu Vorlesungen der Theoretischen Physik getestet wurden und somit sowohl in Übungsserien als auch in Tutorien integriert werden können. Diese Materialien sollten besonders im Lehramtsstudium einen Mehrwert bieten, jedoch für Fachstudierende gleichermaßen nützlich sein.

DD 10.2 Tue 11:20 ELP 1: SR 3.25

Förderung digitaler Kompetenzen von Physik-Lehrkräften im ComeNet Physik — •David Weiler[1], Jan-Philipp Burde[1], Kasim Costan[2], Rike Grosse-Heilmann[3], Christoph Kulgemeyer[2], Josef Riese[3] und Thomas Schubatzky[4] — [1]Universität Tübingen, Tübingen, Deutschland — [2]Universität Bremen, Bremen, Deutschland — [3]Universität Paderborn, Paderborn, Deutschland — [4]Universität Innsbruck, Innsbruck, Österreich

Der Kompetenzverbund lernen:digital wurde gegründet, um Lehrkräfte bei der Digitalisierung von Schule zu unterstützen. Ein Teil dieses Kompetenzverbundes ist das Verbundprojekt ComeMINT, dessen Teilprojekt ComeNet Physik ein Fortbildungskonzept zum fachdidaktisch begründeten Einsatz digitaler Medien im Physikunterricht erstellt. Die Implementation des Fortbildungskonzepts erfolgt auf Basis einer ersten Erhebung von Bedarfen und Bedürfnissen von praktizierenden Lehrkräften. Aufgrund der Heterogenität der digitalen Kompetenzen von Lehrkräften wird dabei ein Ansatz gewählt, bei dem Vorerfahrungen und Eingangskompetenzen diagnostiziert und die unterschiedlichen Module des Förderkonzepts adaptiv zugeordnet werden. Eine Beforschung des Fortbildungskonzepts in Hinblick auf Lernwirksamkeit, Praktikabilität und Akzeptanz ist geplant. In dem Vortrag werden erste Ergebnisse der Bedarfserhebung, die abgeleiteten Grundzüge des Konzepts sowie Aspekte der Begleitforschung vorgestellt.

DD 10.3 Tue 11:40 ELP 1: SR 3.25

KI-basierte Analyse kontextspezifischen Professionswissens in schriftlichen Selbstreflexionen — •Lukas Mientus und Andreas Borowski — Universität Potsdam, Potsdam, Deutschland

Reflexionskompetenz wird in Praxisphasen oft als Schlüssel professioneller Entwicklung angesehen. Schriftliche Selbstreflexion sind hierbei eine häufig angewandte Praxis. Für die Vorbereitung von Unterricht wiederum scheint die Methode der Content Representations (CoRes) gewinnbringend zu sein, welche eine nützliche Technik darstellt kontextspezifisches Wissen in dessen Ausprägung und Vernetzung aufzuzeigen. Eine Kluft zwischen dem Wissen vor und dem Handeln in einer Unterrichtssituation wird seit langem als träges Wissen diskutiert. Konkret bleibt jedoch offen, inwieweit kontextspezifisches, träges Wissen im Rahmen der Reflexion von Unterricht abgerufen werden kann. Ein unsupervised Machine-Learning Algorithmus kann diese kontextspezifischen Wissensfacetten aus CoRes in schriftlichen Reflexionen identifizieren. Unterschiede und Gemeinsamkeiten vor und nach einer Unterrichtssituation können auf diese Weise handlungsnah analysiert werden. Hierzu werden die Studierenden gebeten, vor Unterrichtssituationen CoRes in einer eigens entwickelten online-Infrastruktur zu erstellen. Weiter werden schriftliche Selbstreflexionen von Studierenden nach den Unterrichtssituationen erhoben. Der Vortrag ermöglicht einen Einblick in die Methodik und präsentiert erste Befunde identifizierter Zusammenhänge.

DD 10.4 Tue 12:00 ELP 1: SR 3.25

Integrating data analysis in Python into an introductory physics laboratory course — Eugenio Tufino[1], Stefano Oss[1], and •Micol Alemani[2] — [1]Department of Physics, University of Trento, 38123 Trento, Italy — [2]Institute for Physics and Astronomy, University of Potsdam, 14476 Potsdam, Germany

In all fields of experimental science and in industry, the rate at which data is being generated is accelerating, and the use of robust tools for data analysis and interpretation has become a necessity. There is thus a growing need to teach computational skills in the physics laboratory courses (PLC), a step away from the conventional use of spreadsheets and integrated mathematical computing packages typically found in those settings. In this presentation, we describe how we introduced data analysis in Python in the first year PLC for physics major students at the University of Potsdam using an active learning type of approach. We carefully developed Jupyter notebooks with exercises and applied physics examples to guide students through the fundamentals of data handling and analysis in Python. Students engage in data analysis actively in the course and use the teaching materials independently and collaboratively, applying the learned techniques and skills in subsequent experiments. The effectiveness of the intervention was evaluated on the basis of qualitative empirical studies. They provide information on students' initial preparation, expectations, and learning.

DD 11: Geschichte der Physik und physikdidaktische Forschung

Time: Tuesday 11:00–12:20 Location: ELP 1: SR 2.26

DD 11.1 Tue 11:00 ELP 1: SR 2.26

Einsatz eines historischen Modells im modernen Astronomieunterricht — •Olaf Kretzer — 98527 Suhl, Schul- und Volkssternwarte, Friedrich-König Gymnasium Haus 3, Hoheloh 1

Im Zeitalter der Digitalisierung werden die verschiedensten Programme, Apps, virtuelle 3D Modelle etc. für die Veranschaulichung und Erarbeitung von Schulstoff entwickelt und angeboten. Bei der Suche nach neuen Modellen sollte man aber nicht der Erfahrungsschatz der vorangegangenen Generationen außer Acht lassen. Bei der Recherche nach solchen Modellen wurde, neben verschiedenen anderen auch im aktuellen Unterricht einsetzbaren Modellen, der wahrscheinlich erste Planetenwanderweg zur Veranschaulichung der Größen und Abständen im Sonnensystem wiederentdeckt. Dieses Modell, welches wir inzwischen auch im Unterricht verwenden, bietet darüber hinaus noch verschiedene Ergänzungen und Weiterentwicklungen welche zum einen die Schüler noch stärker mit einbeziehen und zum anderen die Möglichkeit auf Erweiterungen offen lässt. Dieses Modell wird stellvertretend erläutert und vorgeführt.

DD 11.2 Tue 11:20 ELP 1: SR 2.26

Das Mondrätsel und die Erfindung der modernen Optik — •Thomas Quick und Johannes Grebe-Ellis — Bergische Universität Wuppertal

In der europäischen Astronomie des 16. Jahrhunderts war es üblich, die Größen von Sonne und Mond mithilfe einer Lochkamera zu bestimmen. Die Erschließung des Monddurchmessers aus dem konkaven Randstück der teilverdeckten Sonne führte jedoch zu Werten, die rätselhaft blieben, solange keine Theorie der Lochkamera existierte, die den Einfluss der Lochblende korrekt berücksichtigte. Auf diese Unstimmigkeiten aufmerksam geworden führte der junge Johannes Kepler am 10. Juli 1600 Messungen während einer Sonnenfinsternis in Graz durch. Nur wenige Tage später präsentierte er in seinen Aufzeichnungen eine vollständig ausgearbeitete Theorie der Lochkamera, die bis heute gültig ist. In unserem Beitrag zeichnen wir den historischen Weg zur Formulierung dieser Theorie anhand ausgewählter Originalarbeiten von Kepler und Brahe nach und stellen eine Reihe veranschaulichender Experimente vor, die sich auch für den schulischen Einsatz eignen. Die damit präsentierte Episode aus der Geschichte der Optik dient zugleich auch als exemplarische Fallstudie, mit der NOS-Aspekte im Physikunterricht reflektiert werden können.

DD 11.3 Tue 11:40 ELP 1: SR 2.26

Geschichte der Quantentheorie und die Nature of Science — •Oliver Passon — Bergische Universität Wuppertal

Die Forderung, dass Physikunterricht nicht nur Begriffe, Gesetze, Theorien und experimentelle Praxen vermittelt, sondern auch von der Genese und Geltung der Wissensform Physik handelt, ist alt aber (bzw. und) berechtigt. Der Lernbereich Nature of Science (NoS) soll genau dies leisten und eine populäre Methode zur Erreichung dieses Ziels ist die historische Perspektivierung der Physik. In diesem Vortrag wird skizziert, welches Potential einzelne historische Fallstudien der Quantentheorie dabei besitzen könnten. Es fallen dabei auch einige Schlaglichter auf allgemeine Aspekte der NoS.

DD 11.4 Tue 12:00 ELP 1: SR 2.26

Entwicklung eines Kodierleitfadens zur Analyse physikdidaktischer Dissertationen — •Daniel Laumann[1], Johannes Grebe-Ellis[2], Susanne Heinicke[1], Horst Schecker[3], Heike Theyssen[4] und Thomas Wilhelm[5] — [1]Universität Münster — [2]Universität Wuppertal — [3]Universität Bremen — [4]Universität Duisburg-Essen — [5]Goethe-Universität Frankfurt

Die Fachdidaktik Physik als Forschungsdisziplin im deutschsprachigen Raum vollzieht seit der Besetzung erster Lehrstühle in den 1960er Jahren eine dynamische Entwicklung. Wesentliche Impulse kamen aus der internationalen Forschung (Science Education), aber auch durch wissenschaftspolitische Maßnahmen, wie Programmen zur Forschungsförderung. Um die Genese der Physikdidaktik mit Blick auf Forschungsinhalte und -methoden zu charakterisieren, liefern abgeschlossene Promotionen eine sinnvolle Datengrundlage. Zur Analyse der Dissertationen wurde im Rahmen der Initiative "Quo vadis Physikdidaktik" in einem mehrstufigen Verfahren ein zehn Kategorien umfassender Kodierleitfaden entwickelt und hinsichtlich empirischer Gütekriterien geprüft. Der Kodierleitfaden ermöglicht es u.a. den Bezug zu physikalischen Fachinhalten oder die wesentlichen Datengrundlagen einer Dissertation zu erfassen. Für die Anwendung des Leitfadens wurde eine aktuell etwa 660 physikdidaktische Dissertationen umfassende Datenbank erstellt. Die Initiative zur Analyse physikdidaktischer Dissertationen in beschriebener Art und Weise wurde durch die Tagung "Physikdidaktik - Quo vadis?" angeregt.

DD 12: Quantenphysik II

Time: Tuesday 11:00–12:20 Location: ELP 1: SR 2.28

DD 12.1 Tue 11:00 ELP 1: SR 2.28

Multiperspektivischer Ansatz zur Erarbeitung der Wesenszüge der Quantenphysik — •Stefan Aehle und Holger Cartarius — AG Fachdidaktik der Physik und Astronomie, Friedrich-Schiller-Universität Jena, 07743 Jena

Wie kann der Einstieg in die Quantenphysik gelingen und welche Veranschaulichungen helfen dabei, die Natur quantenphysikalischer Phänomene zu erklären? Im Rahmen der hier vorgestellten Arbeit wurde als Antwort auf diese Fragen eine multiperspektivische Herangehensweise an den Quantenphysikunterricht entwickelt, die sich einerseits auf etablierte Lehrkonzepte stützt und diese andererseits durch moderne Verfahren erweitert. Multiperspektivität bezieht sich hierbei auf das inhaltliche Vorgehen und auch auf die experimentelle Ergänzung der Theorie. Es entsteht ein Unterrichtsverlauf, der Versuche der klassischen Optik quantenphysikalischen Realexperimenten gegenüberstellt und die dazwischenliegende Kluft mit Hilfe von Analogiemodellen zu überwinden versucht. Sowohl für außerschulische Lernorte als auch für den alltäglichen Physikunterricht geeignet, ist es Ziel dieses Projekts, bereits bestehende Materialen zu ergänzen und durch seine Vielseitigkeit ein breites Spektrum an Lernenden anzusprechen. Gleichzeitig wird versucht Lehrende durch Variabilität des Materials anzuregen, ohne sie in ihrer Handlungsautonomie einzuschränken. Das Konzept bietet dazu eine enge Verknüpfung von Versuchen und Modellen, die in den Physikunterricht eingebracht werden können, mit quantenoptischen Aufbauten im Quantenphysik-Schülerlabor.

DD 12.2 Tue 11:20 ELP 1: SR 2.28

Zur Rolle mathematischer Repräsentationen für das Verständnis quantenphysikalischer Prinzipien — •Moritz Förster und Gesche Pospiech — TU Dresden, Professur für Didaktik der Physik

Die Vermittlung der Quantenphysik über Zwei-Zustands-Systeme ist seit einiger Zeit Kern zahlreicher didaktischer Untersuchungen. Im Forschungsprojekt wird die Rolle mathematischer Repräsentationen für das Verständnis grundlegender quantenphysikalischer Prinzipien in Bezug auf solche Zugänge mittels Zwei-Zustands-Systemen untersucht. Der Fokus liegt dabei auf der Verbindung algebraischer Repräsentationen (Dirac-Notation) mit einer graphischen Repräsentation (Bloch-Kugel).

Zielgruppe der Forschung sind zunächst Lehramtsstudierende und Lehrkräfte. Es werden die Akzeptanz gegenüber einem reduzierten Dirac-Formalismus sowie die Frage untersucht, welchen Beitrag die Mathematik zum Verständnis von Quantenphysik beitragen kann. Um qualitativ Einblick in Lernprozesse und Einstellungen zu gewinnen, werden leitfaden- und materialgestützte Einzelinterviews (sog. Teaching Experiments) durchgeführt. Im zweiten Teil der Studie werden diese Erhebungsinstrumente für Lernende der Sekundarstufe II angepasst und analoge Fragestellungen bearbeitet.

Seit Sommer 2023 erfolgt die Durchführung der Hauptstudie mit Studierenden sowie Lehrkräften. Im Vortrag werden erste Ergebnisse diskutiert.

DD 12.3 Tue 11:40 ELP 1: SR 2.28

Entwicklung von Testinstrumenten zu deklarativem Wissen und Vorstellungen zur Quantenphysik in der Mittelstufe — •Carsten Albert[1,2] und Gesche Pospiech[2] — [1]IFW Dresden — [2]TU Dresden

Quantenphysik ist ohne Zweifel eine fundamentale physikalische Theorie mit enormem Potential für künftige Anwendungen und gesamtgesellschaftlicher Relevanz.

Mit dem Ziel, den allgemeinbildenden Charakter der Quantenphysik zu stärken und einer breiten Zielgruppe zugänglich zu machen, wurde im Rahmen eines Promotionsprojektes ein phänomenorientiertes Unterrichtskonzept zur Quantenphysik mit umfangreichen Materialien für die gymnasiale Mittelstufe (Zielgruppe Klasse 9) entwickelt. Für die aktuell laufende Hauptstudie zur summativen Evaluierung des Konzeptes wurden u. a. zwei geschlossene Fragebögen entwickelt, mit deren Hilfe das erworbene deklarative Wissen sowie der Ausprägungsgrad quantenphysikalischer Vorstellungen zum Gegenstandsbereich bei den teilnehmenden Schülerinnen und Schülern erhoben werden.

Der Vortrag gibt eine kurze Einführung in das Unterrichtskonzept und die Forschungsmethodik und beleuchtet danach die Entwicklung der beiden Testinstrumente zur Evaluierung des kognitiven Lernerfolgs durch das Lehrkonzept.

DD 12.4 Tue 12:00 ELP 1: SR 2.28

Entwicklung und Erprobung eines Fragebogens zum quantenphysikalischen Messprozess — •Philipp Bitzenbauer[2], Gesche Pospiech[1], Kristof Toth[3], Marisa Michelini[4], Sergej Faletic[5], Lorenzo Santi[4], Alberto Stefanel[4], Antonella Archidiacono[6], Luca Mogno[6] und Stefano Montagnani[6] — [1]TU Dresden, Fakultät Physik, Professur Didaktik der Physik — [2]FAU Erlangen-Nürnberg, Arbeitsgruppe Physikdidaktik — [3]Eötvös University Budapest, Institute of Physics, — [4]Universität Udine, URDF, DMIF — [5]Universität Ljubljana, Fakultät Mathematik und Physik, Slowenien — [6]Scientific Liceum L da Vinci, Treviso,

Im Zuge der Entwicklung der Quantentechnologien gewinn die Vermittlung der Quantenphysik auf unterschiedlichen Niveaus an Bedeutung, Dabei stehen moderne Zugänge zur Quantenphysik über Zweizustandssysteme im fokus. Für solche modernen Zugänge fehlen aber bislang Instrumente, die das Verständnis Lernender über die quantenphysikalischen Konzepte erheben und einblick in Lernschwierigkeiten geben können. Im Zuge des Pilotprojekts DQC-2stap im Rahmen des Quantum Flagship wurde begonnen, ein entsprechendes Instrument zu entwickeln. Wegen der Bedeutung des Messprozesses fokussiert es auf die Sichtweise und Argumentation der Schüler über den Messprozess als Schlüsselkonzept der Quantenphysik mit deutlichen Unterschieden zur klassischen Physik. Der so entstandene Fragebogen wurde nach einer Pilotphase und Überarbeitung mit Lehramtsstudierenden aus Deutschland und Oberstufenschülern aus Ungarn erprobt. In diesem Beitrag werden erste Ergebnisse der Auswertung des Fragebogens beschrieben.

DD 13: Quantenphysik – Poster

Time: Tuesday 14:00–15:00 Location: ELP 6: Foyer

DD 13.1 Tue 14:00 ELP 6: Foyer

Vom quantenoptischen Experiment zur Beschreibung mit Hilfe der Dirac-Notation im Physikunterricht - Ergebnisse einer Akzeptanzbefragung — •Fabian Hennig[1], Kristóf Tóth[2], Moritz Förster[3] und Philipp Bitzenbauer[1] — [1]FAU Erlangen-Nürnberg — [2]Eötvös Loránd University — [3]TU Dresden

Aktuelle Forschungsergebnisse legen nahe, dass die Einführung einer formal-mathematischen Beschreibung quantenphysikalischer Phänomene die Abkehr von naiv-realistischen Vorstellungen Lernender fördern könnte. Eine systematische Untersuchung dieses Zusammenhangs steht jedoch noch aus. In diesem Projekt wurde daher eine Unterrichtskonzept für die Sek. II entwickelt, in dem Lernende von quantenoptischen Effekten (Antikorrelation, Einzelphotoneninterferenz) zu einer formal-mathematischen Beschreibung derselben geführt werden. Zu diesem Zweck wird ein reduzierter Formalismus vorgeschlagen, der die Dirac-Notation verwendet, aber keine fortgeschrittene Mathematik erfordert. Dieser Formalismus ermöglicht Lernenden eine quantitative Beschreibung der oben genannten Quantenphänomene im Einklang mit dem Experiment und soll helfen, die Aspekte Zustand, Präparation und Messung in den Vordergrund zu rücken. Im Rahmen einer Akzeptanzbefragung wurden leitfadengestützte Einzelinterviews mit 14 Schüler:innen durchgeführt. Das Zusammenspiel von Instruktion, Akzeptanzbefragung und Anwendungsaufgabe, ermöglicht (i) die Identifikation möglicher Lernhürden sowie (ii) die Weiterentwicklung der Lehr-Lernsequenz. Auf dem Poster werden das Unterrichtskonzept und Ergebnisse der Akzeptanzbefragung vorgestellt.

DD 13.2 Tue 14:00 ELP 6: Foyer

Spukhafte Fernwirkung? Exploration der Vorstellungen Physikstudierender zur Quantenverschränkung — •Michael Brang[1], Fabian Hennig[2], Helena Franke[1], Malte Ubben[3], Franziska Greinert[3] und Philipp Bitzenbauer[2] — [1]Universität Leipzig — [2]FAU Erlangen-Nürnberg — [3]TU Braunschweig

Die Quantenverschränkung ist eines der zentralen Konzepte der Quantenphysik, auf dem moderne Quantentechnologien maßgeblich beruhen. Gleichzeitig stellt das Lehren und Lernen über Verschränkung sowohl Lehrende als auch Lernende vor Schwierigkeiten - nicht zuletzt aufgrund falscher oder ungenauer Vorstellungen, die durch zahlreiche populärwissenschaftliche Darstellungen zu diesem Thema vermittelt werden. Im Rahmen einer explorativen Studie wurden die Vorstellungen angehender Physiklehrkräfte zur Verschränkung untersucht: Dazu wurden in einem ersten Schritt Freitextfragen verwendet, um die Vorstellungen von N = 31 angehenden Physiklehrkräften zur Quantenverschränkung mittels qualitativer Inhaltsanalyse zu erschließen. Auf Basis des Kategoriensystems wurde anschließend ein zweiter Fragebogen entwickelt. Dieser enthielt Aussagen zur Quantenverschränkung, zu denen N = 73 Physikstudierende ihre Zustimmung oder Ablehnung auf einer fünfstufigen Ratingskala äußerten. Es zeigt sich, dass die in populärwissenschaftlichen Darstellungen weit verbreiteten Assoziationen der Quantenverschränkung zum Beispiel mit (i) perfekten Korrelationen oder (ii) Informationsaustausch mit Überlichtgeschwindigkeit auch unter Physikstudierenden weit verbreitet sind. Das Poster stellt Methodik und Ergebnisse der Studie vor.

DD 13.3 Tue 14:00 ELP 6: Foyer

3D-gedrucktes Analogieexperiment zum Quantenschlüsselaustausch mithilfe des BB84-Protokolls — •Kim Kappl und Ronny Nawrodt — Universität Stuttgart, 5. Physikalisches Institut, Abteilung Physik und ihre Didaktik

Die Bedrohung unserer bisherigen Verschlüsselungstechnik basierend auf dem RSA-Verfahren könnte durch die immer weiter fortschreitende Entwicklung der Quantencomputer in den nächsten Jahrzehnten rapide zunehmen. Das im Jahr 1984 von den Wissenschaftlern Charles H. Bennett und Gilles Brassard entwickelte BB84-Protokoll liefert eine neue Art der Verschlüsselungstechnik basierend auf quantenmechanischen Grundprinzipien und gilt bis heute als eines der wohl bekanntesten Protokolle zum sicheren Austausch eines Quantenschlüssels.

Im Rahmen dieser Arbeit wurde ein 3D-gedrucker Aufbau entwickelt, mithilfe dessen das BB84-Protokoll mit möglichst geringem Kostenaufwand nachgestellt werden kann. Bei der Zielgruppe dieses Projekts handelt es sich dabei um Schulen und Lehrkräfte, welche ihren Quantenphysikunterricht durch Anwendungsbeispiele aus der aktuellen Forschung bereichern möchten. Aufgrund der geringen Kosten eines einzelnen Aufbaus werden die Lehrkräfte insbesondere dazu ermutigt, das Analogieexperiment als Schülerexperiment umzusetzen.

DD 13.4 Tue 14:00 ELP 6: Foyer

Experimental and Theoretical Analysis of Quantum Computing — •Philipp Schöneberg[1], Hans-Otto Carmesin[1,2,3], Phil Immanuel Gustke[1], and Jannes Ruder[1] — [1]Athenaeum, Stade — [2]Studienseminar Stade — [3]Universität Bremen

In a student research club, we explain elemental concepts of quantum computing with theory and experiments. For it, we demonstrate multiple fundamental quantum gates. These quantum gates result in a valuable universal set. By using this set, we derive two known algorithms showing quantum supremacy. Moreover, we present and discuss an opportunity to multiply the calculation speed of quantum computing.

DD 13.5 Tue 14:00 ELP 6: Foyer

Physical and robust forecast of the climate — •Jannes von Bargen[1,4] and Hans-Otto Carmesin[1,2,3] — [1]Athenaeum, Stade — [2]Studienseminar Stade — [3]Universität Bremen — [4]Brecht Schule Hamburg

Our climate is an issue for everybody. So, everyone should be able to understand and verify climate change. For this purpose, we develop a progressive set of models for the time evolution of the climate. In this manner, these models can be understood in a progressive way with a smooth learning process. Moreover, we organize the models in such a manner that a robust and verifiable forecast is possible. We carry out precise analyses by carefully comparing our calculated data with measured values. Thus, everyone can check personal CO2 emissions and take concrete action.

DD 14: Neue / digitale Medien – Poster

Time: Tuesday 14:00–15:00 Location: ELP 6: Foyer

DD 14.1 Tue 14:00 ELP 6: Foyer

Lernen mit (interaktiven) Experimentiervideos — •Mathias Ziegler und Lisa Stinken-Rösner — Universität Bielefeld

Videos stellen im Physikunterricht ein etabliertes Lernmedium dar. Neben Erklärvideos werden dabei u.a. (interaktive) Experimentiervideos zur Erkenntnisgewinnung eingesetzt. Durch ihren Einsatz können individuelle, selbstregulierende und kognitiv aktivierende Lernprozesse ausgelöst werden (Chi & Wylie, 2014). Obwohl die Einstellung der Lehrkräfte gegenüber (interaktiven) Experimentiervideos grundlegend positiv ist, werden sie im Wesentlichen als Ersatz für Realexperimente gesehen (Meier et al., 2023), die keinen weiteren Mehrwert bieten (Puentedura, 2006). Woraus diese Einstellung resultiert, stellt ein Forschungsdesiderat dar. Im Schülerlabor teutolab-physik wird das Ziel verfolgt, Implementationsbarrieren zu identifizieren, die Gelingensbedingungen für einen Unterrichtseinsatz zu ermitteln sowie die Auswirkungen des Einsatzes auf

die Einstellung der Lehrkräfte zu untersuchen. Dazu besuchen die Lehrkräfte eine Fortbildung, in der sie selbst Videos produzieren, den Einsatz mit einer Schulklasse im Schülerlabor erproben und den möglichen Transfer in die Schulpraxis reflektieren. Wissenschaftlich begleitet wird die Fortbildung durch eine Mixed-Methods-Studie. Dabei werden die Selbstwirksamkeitserwartungen, die Akzeptanz und das professionelle Wissen (TPACK) der Lehrkräfte bezüglich digitaler Medien und (interaktiven) Experimentiervideos mit einem Fragebogen im Prä-Post-Design abgefragt. Außerdem werden Implementationsbarrieren und Gelingensbedingungen qualitativ über teilnehmende Beobachtungen und Gruppeninterviews ermittelt.

DD 14.2 Tue 14:00 ELP 6: Foyer

Ein Online-Selbstlernkurs zur Teilchenphysik — •Laureen Dänzer, Tobias Reinsch und Ronny Nawrodt — Universität Stuttgart, Physik und ihre Didaktik

Das Verständnis vom Aufbau der Materie ist für viele Schülerinnen und Schüler von großem Interesse. Im Unterricht wird dieses Thema oftmals gar nicht oder nur als eine Wahlmöglichkeit abgebildet. Mithilfe des neu entwickelten Online-Selbstlernkurses und des in 3D gedruckten Quark-Puzzles können die grundlegenden Verfahren, Konzepte und Ideen der Teilchenphysik auch für Schülerinnen und Schüler (be-)greifbar gemacht werden. Der digitale Moodle-Kurs kann ebenfalls zur Einarbeitung bzw. Auffrischung des Themengebiets für Lehrkräfte und Studierende genutzt werden. Mit Hilfe eines digitalen Endgeräts kann am Poster der Selbstlernkurs direkt erprobt werden. Dazu gehört nicht nur der Onlinekurs, sondern auch das Zusammensetzen der 3D-Quark-Puzzleteile zu Hadronen.

DD 14.3 Tue 14:00 ELP 6: Foyer

Erfassung von großräumigen zweidimensionalen Bewegungen mit GPS — •Thomas Wilhelm, Patrick Zeder und Lukas Schauer — Institut für Didaktik der Physik, Goethe-Universität Frankfurt

Zunehmend mehr Lehrpläne schreiben vor, dass die Einführung in die Mechanik in der Sekundarstufe I anhand zweidimensionaler Bewegungen erfolgen soll. Die Videoanalyse von Bewegungen hat sich hier als Messwerterfassungsmöglichkeit bewährt. Es kann aber durchaus attraktiv sein, auch einmal großräumigere Bewegungen zu erfassen. Dazu eignet sich das GPS-System.

Im ersten Teil des Posters werden sechs verschiedene Apps für Smartphones aufgezeigt, die als GPS-Tracker verwendet werden können, sowie drei Möglichkeiten der Datenauswertung und Darstellung. Außerdem werden Beispiele aufgenommener Bewegungen gezeigt.

Im zweiten Teil des Posters wird aufgezeigt, dass Onlinedienste die GPS-Position von Flugzeugen in Echtzeit darstellen können, wie zum Beispiel Flightradar24.com. Wird hier von einem Flugzeug ein Bildschirmvideo aufgenommen, kann dieses mit Hilfe eines Videoanalyseprogrammes analysiert werden. Beispiele aufgenommener Bewegungen werden gezeigt.

DD 14.4 Tue 14:00 ELP 6: Foyer

Interferometrie in einer Virtual Reality Umgebung — •Gunnar Friege und Dirk Brockmann-Behnsen — Leibniz Universität Hannover, IDMP-AG Physikdidaktik

Im Rahmen des EU-Projekts STEM Digitalis zu digitalen Werkzeugen wurde u. a. eine Virtual-Reality (VR) - Umgebung zu Experimenten mit einem Michelson-Interferometer entwickelt. Lernende können darin eigenständig experimentieren. Die VR-Umgebung wurde bereits in mehreren Physikkursen der gymnasialen Oberstufe und mit Physik-Lehrkräften erprobt. Vorgestellt werden diese Experimente und Erweiterungen der VR-Umgebung, die im Rahmen von Qualifikationsarbeiten vorgenommen wurden und werden: Mach-Zehnder-Interferometer und Detektion von Gravitationswellen mit Interferometern im Weltall.

DD 14.5 Tue 14:00 ELP 6: Foyer

Videoanalyse in die Praxis bringen — •Julie Kyas, Christian Hengel, Jakub Knebloch, Andreas Hansch und Thomas Wilhelm — Institut für Didaktik der Physik, Universität Frankfurt

Neue Technologien wie Smartphones und Tablets bieten viele neue Möglichkeiten im Physikunterricht. So ist es mit der mobilen Videoanalyse von Bewegungen möglich, dass Bewegungen aus der Alltagswelt untersucht werden, Schüler*innen selbst Bewegungen analysieren und sogar Bewegungen der Schüler*innen selbst untersucht werden. Die Implementation neuer Lehr- und Lernkonzepte im Unterricht ist jedoch erfahrungsgemäß schwierig.

In einem Kooperationsprojekt mit dem hessischen Kultusministerium geht es darum, für Physiklehrkräfte Unterrichtsmaterialien zur Mechanik zu entwickeln, die es ihnen erleichtern, selbst entsprechende Geräte im Physikunterricht einzusetzen, damit Schüler*innen Interesse an der Analyse mechanischer Bewegungen finden. Dabei werden kognitiv aktivierende Aufgaben zum Aufbau von Grundvorstellungen und zur Überprüfung der Anwendbarkeit kinematischer Modelle für den Einsatz im Unterricht bereitgestellt.

Im Vorfeld werden Lehrkräfte befragt, welche Materialien sie genau benötigen. Die Unterrichtsmaterialien sollen im Schülerlabor und im Schulunterricht erprobt werden und schließlich auf einer Webseite frei zur Verfügung gestellt werden. Zusätzlich wird eine Lehrkräftefortbildung angeboten.

DD 14.6 Tue 14:00 ELP 6: Foyer

Videos von Bewegungen für den Unterricht vorbereiten — •Christian Hengel, Julie Kyas, Jakub Knebloch, Andreas Hansch und Thomas Wilhelm — Institut für Didaktik der Physik, Universität Frankfurt

Gerade am Anfang des Konzeptaufbaus ist der schnelle Weg zu fertigen Diagrammen, den Videoanalyse-Apps bieten, für das Verständnis eher hinderlich. Eine Videoanalyse zu Fuß, bei der die Schüler*innen einem Video in regelmäßigen Zeitabständen die Position eines Objekts entnehmen und die gewonnen Daten auswerten, ist eher für einen ersten Zugang zur quantitativen Betrachtung kinematischer Größen geeignet. Dafür ist es erforderlich, im Video die Zeit und die Position eines Objekts bestimmen zu können.

Im Rahmen eines Kooperationsprojekts mit dem Hessischen Kultusministerium haben wir hierfür vier Apps für Windows und MacOS entwickelt, mit denen man Videos mit einem zweidimensionalen Koordinatensystem oder einer eindimensionalen Positionsskala versehen und einen Zeitstempel zu jedem Frame hinzuzufügen kann. Wenn also in einem Video der Maßstab oder die Uhr im Bild fehlt, kann man sie auf diese Weise nachträglich hinzufügen. Damit erleichtern die Apps es auch, in einem Videoanalyseprogramm Stroboskopbilder oder Serienbilder für Aufgaben zu erzeugen, in denen die Positionen des Objekts gut abzulesen sind.

Auf dem Poster wird der Funktionsumfang der Apps vorgestellt und es werden Testversionen zum Download bereitgestellt.

DD 14.7 Tue 14:00 ELP 6: Foyer

phyphox: Eine Sensorkette als DIY-Projekt - ortsaufgelöste Messung von Beschleunigung und Temperatur — •Johannes Schlaf[1], Sebastian Staacks[2], Dominik Dorsel[2] und Heidrun Heinke[1] — [1]I. Physikalisches Institut A, RWTH Aachen — [2]II. Physikalisches Institut A, RWTH Aachen

Mithilfe der Smartphone-App phyphox wird das eigene Smartphone über die internen Sensoren zum mobilen Messinstrument. Zudem können über Bluetooth Low Energy externe Sensoren vebunden und in Echtzeit ausgelesen werden. Um auch eine ortsaufgelöste Messung physikalischer Größen zu ermöglichen, wurde eine an phyphox koppelbare Sensorkette entworfen und erfolgreich getestet. Für jede mit der Kette messbare Größe existiert ein designiertes, hinsichtlich der Darstellung der Messdaten optimiertes phyphox-Experiment. Aktuell sind Messung von Beschleunigung und Temperatur möglich, wofür erste Anwendungsbeispiele (Schwingung einer Slackline, Temperaturgradient) präsentiert werden. Die Einbindung weiterer Sensoren ist geplant.

Die Kette ist als DIY-Projekt mit 3D-druckbaren Gehäusen konzipiert, wobei die zugehörige Bauanleitung so ausgelegt ist, dass sie auch für Anfänger im 3D-Druck und im Programmieren leicht zugänglich ist.

DD 14.8 Tue 14:00 ELP 6: Foyer

Visualisierung von Elektronen in Stromkreisen mithilfe der App PUMA : Spannungslabor — •Lisa Nebel, Christoph Stolzenberger, Florian Frank und Thomas Trefzger — Lehrstuhl für Physik und ihre Didaktik, Universität Würzburg

Elektronen werden meistens als Kugeln visualisiert. Inwiefern diese Visualisierung der Natur dieses Elementarteilchens gerecht wird, bleibt dabei unklar. Dabei sollten unterschiedliche Elektronendarstellungen das Konzeptverständnis der SuS positiv beeinflussen können. Da es keine eindeutige Empfehlung auf wissenschaftlicher Grundlage zur Nutzung von Elektronendarstellungen gibt, findet man in gängigen Schulbüchern recht uneinheitlich verschiedene Visualisierungen. Diese beschränken sich in niedrigeren Klassen v.a. auf Teilchendarstellungen, welche zur Oberstufe hin langsam in Richtung einer Wellen- oder Wahrscheinlichkeitsvorstellung erweitert werden. Die Applikation PUMA : Spannungslabor erlaubt die Darstellung von Analogie-Modellvorstellungen zu elektrischen Stromkreisen und visualisiert dabei auch die sich im Stromkreis bewegenden Elektronen. Mithilfe einer Literaturrecherche wurden die gängigsten Elektronendarstellungen identifiziert und in die App implementiert. Im Rahmen einer Akzeptanzbefragung erhielten Physik-Lehrkräfte die Möglichkeit, die verschiedenen Darstellungen hinsichtlich des Einsatzes im Physikunterricht zu bewerten. In diesem Beitrag werden die Literaturrecherche, die praktische Umsetzung in der Applikation sowie die Ergebnisse der Befragung der Lehrkräfte vorgestellt.

DD 14.9 Tue 14:00 ELP 6: Foyer

Konzipierung und Erprobung einer Einführung in das Experimentieren mit der App phyphox — •Marija Herdt, Maria Hinkelmann und Heidrun Heinke — I. Physikalisches Institut A, RWTH Aachen

Die App phyphox dient als mobiles Messinstrument und wird vermehrt in der Lehre eingesetzt. Im Rahmen einer Masterarbeit wurde ein vierwöchiger Kurs für eine MINT-AG im außerschulischen Bereich konzipiert, welcher in insgesamt 6 Stunden einen Einstieg in das Experimentieren mit phyphox bietet. Dieser Kurs soll möglichst motivierend und niederschwellig gestaltet sein und richtet sich an Schüler:innen der Jahrgangsstufen 7-10. Jeder der Bausteine fokussiert ein anderes Thema, das mit phyphox-Experimenten untersucht wird. Der erste Baustein besteht aus einem modularen Lernzirkel mit sechs Stationen und liefert Einblicke in die verschiedenen Sensoren des Smartphones und deren Nutzbar-

keit in physikalischen Experimenten. In weiteren Bausteinen wird das Inhaltsfeld Akustik am Beispiel eines Flaschen-Xylophons behandelt und das Fadenpendel untersucht. Bei der Erprobung mit ca. 250 Schüler:innen hat sich gezeigt, dass insbesondere die 90-minütige einführende Lerneinheit auch im regulären Physikunterricht breite Einsatzmöglichkeiten finden kann. Die Konzeption der Kurs-Bausteine, ihre Erprobung und Weiterentwicklung im Rahmen des Design-Based-Research Ansatzes werden im Poster vorgestellt.

DD 14.10 Tue 14:00 ELP 6: Foyer

Integration digitaler Messwerterfassungssysteme im Studium: Förderung und Entwicklung von Technologieakzeptanz bei angehenden Physiklehrkräften — •Lena Lenz und Tobias Ludwig — Pädagogische Hochschule Karlsruhe; Institut für Physik und Technische Bildung

Im Physikunterricht erfolgt die Datenaufnahme bei Experimenten oft analog (Rosenberg et al., 2022).Demgegenüber steht ein Einsatz von digitalen Messwerterfassungssystemen (dMS), der es ermöglicht, schneller, länger und umfangreicher zu messen und so ein hohes didaktisches Potential birgt (Benz et al., 2022). Um zukünftige Physiklehrkräfte zur Integration dieser Systeme in ihren Unterricht zu befähigen ist es entscheidend, dass sie fachspezifische dMS-Kompetenzen im Studium erwerben. Frühere Studien untersuchten TPACK-Kompetenzen und Selbstwirksamkeitseinschätzungen zu dMS (Benz & Ludwig, 2023). Empirische Befunde deuten darauf hin, dass neben diesen Kompetenzen und der Selbstwirksamkeit auch die Technologieakzeptanz, die sich aus den beiden wahrnehmbaren Komponenten Bedienfreundlichkeit und Nützlichkeit zusammensetzt (Davis, 1985), hoch ausgeprägt sein muss, damit digitale Medien Eingang in Schule finden (Gorovoj, 2019). Vor diesem Hintergrund untersucht die vorliegende Studie die Wirkung kurzer spezifischer Interventionen zum Potential von dMS auf die Technologieakzeptanz. Es wurde insgesamt 67 ProbandInnen zu mehreren Messzeitpunkten befragt. Das Poster stellt die Implementation von dMS in unsere Studiengänge vor sowie berichtet Ergebnisse zur Entwicklung der Technologieakzeptanz der Lehramtsstudierenden.

DD 15: Neue Konzepte – Poster

Time: Tuesday 14:00–15:00 Location: ELP 6: Foyer

DD 15.1 Tue 14:00 ELP 6: Foyer

"Project Find & Link" - ein Gesellschaftsspiel zum Vertiefen und Vernetzen physikalischer Fachbegriffe — •Ramona Schauer-Bollig, Maria Hinkelmann und Heidrun Heinke — RWTH Aachen University, I. Physikalisches Institut IA

Die Fachsprache und insbesondere der Fachwortschatz sind von hoher Relevanz im naturwissenschaftlichen Unterricht und damit auch im Physikunterricht. Den natürlichen Drang des Spielens ausnutzend sowie der langen Tradition von Lernspielen folgend, wurde im Sinne der Gamification ein kooperatives und kommunikatives Gesellschaftsspiel entwickelt und evaluiert, um mit dessen Hilfe Fachbegriffe im Physikunterricht der Sekundarstufe I zu vertiefen und zu vernetzen. Dabei wurden Erkenntnisse aus Fachdidaktik, Lernpsychologie und die Bildungsstandards zur Ableitung der Ziele und zur Konzipierung des Spiels herangezogen. Insbesondere der Einsatz von Spielen in kooperativen Lernsettings verspricht eine lohnenswerte Kombination zu sein, um kognitive, motivationale, soziale und emotionale Lernziele zu erreichen. Das Modell der didaktischen Rekonstruktion bildete den theoretischen und methodischen Rahmen, sowohl bei der Entwicklung als auch bei der Evaluation des Spiels. Unter Nutzung erprobter Spielmechaniken des existierenden Gesellschaftsspiels "Codenames" erfolgte die Umsetzung der Gamification in Form des neuen Spiels zum Lernen, respektive zum Vertiefen und Vernetzen von Fachbegriffen im Physikunterricht. Auf dem präsentierten Poster werden das Gesellschaftsspiel und erste Erfahrungen zum Einsatz des entwickelten Spiels in Schulen vorgestellt.

DD 15.2 Tue 14:00 ELP 6: Foyer

Handlungsorientierte Elektrizitätslehre — •Daniel Hecht — PH Weingarten

Es wird ein Unterrichtskonzept vorgestellt, das die klassischen Elektrik-Inhalte der Sekundarstufe I im Kontext "Wie funktionieren Roboter?" behandelt. Arduino wird als ein zentrales Werkzeug eingeführt, weil sich Arduino als vielseitig einsetzbares Instrument auch im weiteren Physikunterricht bewährt. In dieser Studie soll untersucht werden, welche Erlebnisse Schülerinnen und Schüler beim elektrotechnischen Tüfteln haben. Die phänomenologische Erfahrungsforschung könnte aufschlussreichen Zugang zu individuellen Erlebnissen ermöglichen und die Potenziale praxisnaher Elektrizitätslehre herausstellen.

DD 16: Lehr-Lernforschung – Poster

Time: Tuesday 14:00–15:00 Location: ELP 6: Foyer

DD 16.1 Tue 14:00 ELP 6: Foyer

Modelle des einfachen Stromkreises in der Sekundarstufe I in Baden-Württemberg — •Katharina Leibfarth und Jan-Philipp Burde — Universität Tübingen, Tübingen, Deutschland

Die einfachen Stromkreise stellen entgegen ihres Namens ein schwieriges und unanschauliches Thema des Physikunterrichts dar. Die zugrundeliegenden physikalischen Größen in Stromkreisen sowie deren Zusammenhänge entziehen sich der direkten Wahrnehmung, sodass es naheliegt, diese mit Modellen bzw. Analogien zu veranschaulichen. Unklar ist bislang die Frage, welche Modelle im Anfangselektrizitätslehreunterricht der Sekundarstufe I Baden-Württembergs Einsatz finden. Anhand von Unterrichtstagebüchern, in welchen Physiklehrkräfte ihren Unterricht dokumentierten, wurde der Modelleinsatz von 17 Lehrkräften analysiert. Dabei wurde untersucht, wie viele und welche Stromkreismodelle Lehrkräfte einsetzen und für welche Inhalte diese genutzt werden. Weiterhin wird auf dem Poster dargestellt, welche Modelle in gängigen Schulbüchern Verwendung finden.

DD 16.2 Tue 14:00 ELP 6: Foyer

Der Einfluss von Visualisierungen auf die Güte von Likertskalen oder wie Umfragen unbewusst das Antwortverhalten von Teilnehmenden beeinflussen können — •Teresa Tewordt und Lisa Stinken-Rösner — Universität Bielefeld

Gerade bei Erhebungen mit jüngeren Lernenden werden bei Fragebögen, die auf Likert-Skalen beantwortet werden, die Antwortniveaus häufig mit Icons veranschaulicht. Dadurch soll den Lernenden ein Gefühl für die Antwortniveaus vermittelt werden (Fühner, 2022). Durch die Nutzung von Visualisierungen besteht jedoch gleichzeitig die Gefahr, dass das Antwortverhalten der Teilnehmenden verzerrt wird. Dadurch wird die Güte des Erhebungsinstrumentes gegebenenfalls vermindert. In dieser Studie wird der Frage auf den Grund gegangen, in welcher Weise verschiedene Formen der Visualisierungen Unterschiede im Antwortverhalten von Lernenden bewirken. Hierfür wurden über 600 Lernende im Alter von 10-12 Jahren befragt, nachdem sie das Schülerlabor teutolab-physik besucht haben. Die Fragebögen erheben das Interesse beim Experimentieren (Fechner, 2009) und unterscheiden sich ausschließlich in den unterstützenden Visualisierungsformen. Die Zuordnung der verschiedenen Visualisierungen in Form von Smileys, Daumen, Handybalken oder einer Farbskala zu den Teilnehmenden fand randomisiert statt. In dem Beitrag wird diskutiert, ob und inwiefern Differenzen im Antwortverhalten, in Abhängigkeit von der vorgegebenen Visualisierungsform, identifiziert werden können.

DD 16.3 Tue 14:00 ELP 6: Foyer

Transfer bei analogen Problemsituationen — •Marco Seiter und Heiko Krabbe — Ruhr-Universität Bochum, Deutschland

Transfer bezeichnet die Auswirkungen vom Lernen in einem auf das Lernen in einem anderen Kontext (Perkin & Salomon, 1992). Das Ziel von Bildung besteht im Transfer, da sich die Kontexte des Lernens später von möglichen Anwendungskontexten unterscheiden können. Der Transfer von Wissen aus dem Physikunterricht fällt Lernenden dabei oft schwer (Barnett & Ceci, 2002). Eine Möglichkeit zur Förderung von Transfer besteht in der Verwendung von Analogien durch Abstraktion von Prinzipien (z.B. Gick & Holyoak, 1980, 1983). In dieser Studie wurde untersucht, ob die Ergebnisse früherer Studien (Gick & Holyoak, 1980) mit anderen Analogien reproduziert werden können.

Den Probanden wurde zunächst eine fiktive Problemsituation ohne physikalischen Bezug mit einer Lösung vorgestellt. Im Anschluss wurde eine zur ersten Situation analoge Problemsituation mit physikalischem Alltagsbezug gestellt, zu der so viele Lösungen wie möglich generiert werden sollten. Es wurde der Hinweis gegeben, die erste Situation als Hilfe zu verwenden. Drei Interventionsgruppen erhielten zur ersten Problemsituation je eine unterschiedliche Lösung, die Kontrollgruppe löste nur das zweite Problem. Jede Lösung zum ersten Problem enthielt eine Kernidee, welche auch auf das Zielproblem übertragen werden konnte. Zur Auswertung wurden die Lösungen der Probanden nach den enthaltenden Kernideen kodiert. So kann untersucht werden, ob und inwiefern es zu einem Transfer kommt. Auf dem Poster werden erste Ergebnisse vorgestellt.

DD 16.4 Tue 14:00 ELP 6: Foyer

Lernen durch Lehren - Eine Gelegenheit zur Reflexion von Schülervorstellungen? — •Celina Halbleib, Markus Elsholz und Thomas Trefzger — Physik und ihre Didaktik, Universität Würzburg

Präkonzepte zu physikalischen Lerninhalten nehmen für den Lernprozess der Schüler:innen einen zentralen Stellenwert ein. Oftmals gelingt es im Unterricht nicht in ausreichendem Maße, inadäquate Vorstellungen in physikalisch anschlussfähige Vorstellungen zu überführen. Der Beitrag untersucht zum einen die Frage, inwieweit Schüler:innen der Sekundarstufe 2 nach wie vor physikalisch inadäquate Vorstellungen zu Themengebieten der Sekundarstufe 1 zeigen. Weiterhin wird untersucht, ob die Schüler:innen durch die Methode "Lernen durch Lehren" - konkret: durch das Erstellen von Lernvideos - vorhandene problematische Vorstellungen erkennen, reflektieren und gegebenenfalls korrigieren. Im Rahmen einer studentischen Abschlussarbeit wurden dazu Lernprodukte von N= 6 Schüler:innen der Sekundarstufe 2 im Hinblick auf bekannte Lernendenvorstellungen zu den Themenbereichen Mechanik und Optik analysiert. Datengrundlage der Analyse sind Storyboards, die von den Schüler:innen als Grundlage für die Realisierung von Lernvideos erstellt wurden. Sie enthalten die zentralen Abbildungen und die zur Aufnahme vorgesehenen Texte. Die Storyboards liegen sowohl in einer selbstständig erarbeiteten Erstfassung sowie in überarbeiteter Form vor, die nach dem Feedback der Lehrkraft entstand. Der Beitrag fasst erste Analysen des Materials zusammen und reflektiert die Rolle der Lehrkraft bei der Lernbegleitung der Schüler:innen.

DD 16.5 Tue 14:00 ELP 6: Foyer

Arbeitsblattvorlagen als Mittel zur differenzierten Förderung der Variablenkontrollstrategie — •Tobias Winkens und Heidrun Heinke — RWTH Aachen University

Die richtige Wahl der auftretenden Variablen beim Experimentieren ist für Schüler:innen keineswegs eine Selbstverständlichkeit. Beobachtungen zeigen vielfach unsystematische oder teilsystematische Vorgehensweisen. Einen Ansatzpunkt, um Schüler:innen individuelle Lerngelegenheiten zum Erlernen und Festigen der wichtigen Variablenkontrollstrategie (VKS) zu unterbreiten, bieten die unterschiedlichen Kompetenzfacetten und Teilfähigkeiten der VKS aufgrund der verschiedenen zugeordneten Schwierigkeitsniveaus. Damit bietet die Vermittlung der VKS einen guten Anlass zur Umsetzung einer binnendifferenzierten Förderung der Schüler:innen bezüglich ihrer experimentellen Kompetenzen. Begründet darauf sind teilfähigkeitsspezifische Vorlagen für Arbeitsblätter entwickelt worden. Mit den Vorlagen können Lehrkräfte eigene experimentelle Settings zur Förderung der VKS einsetzen, indem sie selbstgewählte Experimente und die dort auftretenden Variablen in die Arbeitsblattvorlagen anstelle von Platzhaltern implementieren und damit gleichzeitig anhand von einheitlichen experimentellen Materialien Aufgaben mit unterschiedlichen Schwierigkeitsgraden kreieren. Neben der konzeptuellen Vorstellung der Vorlagen soll auf dem Poster ein Einblick in eine erste Evaluation der Materialien mit Lehramtsstudierenden gegeben werden. Der Fokus der Evaluation, bei der die Probanden vorgegebene Experimente in die Vorlagen implementieren, liegt vor allem auf der Usability der entwickelten Arbeitsblattvorlagen.

DD 16.6 Tue 14:00 ELP 6: Foyer

Computerbasiertes Feedback auf physikalische Problemlöseantworten mithilfe großer Sprachmodelle — •Fabian Kieser und Peter Wulff — Pädagogische Hochschule Heidelberg

Die Fähigkeit, Probleme zu lösen, gilt als eine Schlüsselfähigkeit im 21. Jahrhundert, speziell im Bereich der Physik. Problemlösen ist ein komplexer kognitiver Prozess, der darauf abzielt, durch den Einsatz verschiedener Operationen einen Ausgangszustand in einen gewünschten Zielzustand zu transformieren. Um diesen Prozess umfassend zu erfassen, sind offene physikalische Problemlöseaufgaben viel wichtiger als geschlossene Aufgaben wie beispielsweise Multiple-Choice-Items. Das Bewerten von schriftlichen Antworten der Schülerinnen und Schüler auf physikalische Problemlöseaufgaben und das Bereitstellen individueller Rückmeldungen kann jedoch für Lehrende viel Zeit in Anspruch nehmen. Das Feedback von Lehrpersonen spielt eine entscheidende Rolle bei der Entwicklung des konzeptionellen Verständnisses von Lernenden. In diesem Beitrag prüfen wir die Möglichkeiten von großen generativen Sprachmodellen zur computergestützten Erstellung individueller Rückmeldungen für schriftliche Schülerantworten auf konzeptuelle Physikfragen. Wir untersuchen die Effektivität spezieller Prompting-Strategien, um herauszufinden, inwiefern generative Sprachmodelle dazu in der Lage sind, die Problemlösefähigkeiten von Schülerinnen und Schülern in physikalischen Aufgaben zu diagnostizieren und zielgerichtet Feedback zu generieren.

DD 16.7 Tue 14:00 ELP 6: Foyer

Das Zeichnen als Erkenntnismethode bei naturwissenschaftlichen Inhalten — •Peter Michael Westhoff und Susanne Heinicke — Universität Münster

Im digitalen Zeitalter und der zunehmend multimedialen Ausstattung der Lernenden sind Lehrkräfte immer öfter mit der Frage konfrontiert, ob Inhalte oder Sachverhalte z.B. von der Tafel, Experimentieraufbauten oder Erarbeitungsergebnisse schnell und einfach abfotografiert oder zeitaufwändiger abgezeichnet werden sollen. Nun stellt sich jedoch die Frage: Ist das Zeichnen für den Lernprozess hilfreicher und ist der zeitliche Mehraufwand damit sinnvoll investiert? Aus der Geschichte der Naturwissenschaften wissen wir, dass Zeichnungen und Abbildungen eine entscheidende Rolle im naturwissenschaftlichen Erkenntnisprozess spielen. Auch in der aktuellen PISA-Studie wird ein besonderer Fokus auf kreative Methoden und Fähigkeiten der Lernenden gelegt. Im laufenden Promotionsprojekt sollen die Lernförderlichkeit des Zeichnens im Physikunterricht in Kombination zu den für den kreativen Lernprozess relevante Persönlichkeitsmerkmale wie bspw. Interesse an Kreativität und Zeichnen untersucht werden. In diesem Beitrag werden erste Ergebnisse vorgestellt.

DD 17: Außerschulisches Lernen – Poster

Time: Tuesday 14:00–15:00 Location: ELP 6: Foyer

DD 17.1 Tue 14:00 ELP 6: Foyer

Physik mobil in Jugendzentren — •Michael Komorek, Kai Bliesmer und Jonas Tischer — Carl von Ossietzky Universität Oldenburg

Jugendzentren bilden weiße Flecken auf der MINT-Bildungslandkarte. Kinder und Jugendliche, die dort ihre Freizeit verbringen und sich aufgehoben fühlen, haben meist wenig Zugang zu naturwissenschaftlich-technischen Angeboten jenseits der Schule. Die Corona-Beschränkungen verschärften diese Situation weiter. Seit 2022 erreicht das mobile Schülerlabor phymobil_OL Kinder und Jugendlichen in Jugendeinrichtungen, teilfinanziert durch das BMBF (Projekt Ease Corona). phymobil_OL schafft an zehn Jugendzentren und Mädchenhäusern physikalische Denk-, Experimentier- und Konstruktionsangebote am Nachmittag, auch zu den Themen Energie und Klima. Auf dem Poster wird berichtet, wie die Physik-Angebote des mobilen Schülerlabors angenommen werden und welches Denken und Handeln sie anregen. Berichtet wird auch über die Logik des 'free choice learning' (Falk & Dierking, 2007), die an Jugendzentren herrscht und die ein Umdenken bei der Strukturierung der mobilen Schülerlabor-Angebote erfordert, sowie über Möglichkeiten, in offen strukturierten, non-formalen MINT-Bildungssituationen Daten zu erheben.

DD 17.2 Tue 14:00 ELP 6: Foyer

Zentrale Motive der MINT-Identitätsverhandlung. Studiendesign und Forschungsfragen — Markus Elsholz[1], Agnes Birner[1], •Florian Frank[1] und Thomas Trefzger[2] — [1]M!ND-Center, Universität Würzburg — [2]Physik und ihre Didaktik, Universität Würzburg

Die Entscheidung junger Menschen, sich intensiver mit Themen aus dem MINT-Bereich auseinanderzusetzen und darüber hinaus ihre eigene berufliche Perspektive in MINT-Berufen zu sehen, wird von vielfältigen Faktoren in schulischen und außerschulischen Kontexten beeinflusst. Der Beitrag skizziert eine Studie, die Motive junger Menschen für oder gegen ein außerschulisches Engagement im MINT-Bereich beleuchtet. Das zentrale Forschungsinteresse liegt in der Frage, wie junge Menschen bei der Verhandlung ihrer MINT-Identität zielgerichtet unterstützt werden können und welche Rolle außerschulische Angebote dabei spielen. Neben einer quantitativen quasilängsschnittlichen Erhebung zentraler Erwartungs- und Wertkonstrukte wird eine Teilstichprobe über einen längeren Zeitraum begleitet. Die daraus gewonnen qualitativen Daten erlauben Einblicke in individuelle Abwägungs- und Entscheidungsprozesse und lassen Rückschlüsse auf die Bedarfe junger Menschen zu, die bei der Ausgestaltung außerschulischer Angebote und Impulse berücksichtigt werden sollten.

DD 17.3 Tue 14:00 ELP 6: Foyer

Lehr-Lern-Labor zur Photolumineszenz-Spektroskopie im Irak didaktisch rekonstruiert — •Kai Bliesmer[1], Martin Esmann[1], Lukas Lackner[1] und Diyar Sadiq[2] — [1]Carl von Ossietzky Universität Oldenburg — [2]University of Zakho, Irak

Vorgestellt wird ein Lehr-Lern-Labor (Priemer & Roth, 2020) für Schülerinnen und Schüler von ca. 16-18 Jahren zum Themengebiet der Photolumineszenz-Spektroskopie. Es ist entlang eines Exit-Games ausgestaltet, das mit Video-Vignetten zur naturwissenschaftlichen Erkenntnisgewinnung angereichert ist. Anlass für die Entwicklung des Lehr-Lern-Labors ist ein vom Deutschen Akademischen Austauschdienst gefördertes Projekt, in dem die Universität Oldenburg mit der Universität Zakho im Irak auf dem Gebiet der Nano-Optik zusammenarbeitet. Das Lehr-Lern-Labor gehört zum Transferkonzept des Projekts und dient einer auf Public Understanding of Science ausgerichteten Wissenschaftskommunikation, also der universitären Third Mission (Compagnucci & Spigarelli,

2020). Das Lehr-Lern-Labor wurde im Zusammenarbeit zwischen Fachphysik und Physikdidaktik zunächst in Deutschland auf der Grundlage des Modells der Didaktischen Rekonstruktion (Duit et al., 2012) ausgestaltet, wobei sich die didaktische Strukturierung an den drei Leitlinien Kontextstrukturierung, Autonomieorientierung und Problemorientierung richtet, die aus der Selbstbestimmungstheorie der Motivation von Deci und Ryan (2012) abgeleitet wurden. Das entwickelte Lehr-Lern-Labor wird sodann in Zusammenarbeit mit den irakischen Kolleginnen und Kollegen zur Durchführung im Irak adaptiert.

DD 17.4 Tue 14:00 ELP 6: Foyer

Physik(unterricht) und Smartphonenutzung aus der Perspektive von Schüler*innen — •Barbara Leibrock — MExLab Physik, Universität Münster

Wie können Smartphones didaktisch sinnvoll eingesetzt werden? Diese Frage erforschten im BMBF-geförderten Projekt smart for science zwischen 2019 und 2023 Arbeitsgruppen der Fachdidaktiken Physik, Chemie und Mathematik in Kooperation mit dem außerschulischen Lernort MExLab ExperiMINTe, der Fachrichtung Psychologie und dem Institut für Kommunikationswissenschaft der Universität Münster. Dafür wurden in den drei Fächern Workshops für die Sekundarstufe I erstellt, in denen die Forschenden beobachteten, inwiefern die Nutzung von Smartphones die Motivation, Konzentration und Lernleistung der Jugendlichen beeinflusst, aber auch zu Ablenkung führt.

Neben den Untersuchungen vor und während der Workshops wurden im Anschluss an den Physikworkshop die Jugendlichen selbst in Gruppendiskussionen zu ihrer Meinung über die Nutzung des Smartphones im Unterricht und zu ihrem Bild der Physik befragt. Das Poster stellt den Ablauf der Erhebungen und Auswertungen, sowie Indizien und Ergebnisse aus diesen Gruppendiskussionen vor.

DD 18: Bildung für nachhaltige Entwicklung – Poster

Time: Tuesday 14:00–15:00 Location: ELP 6: Foyer

DD 18.1 Tue 14:00 ELP 6: Foyer

Massenmörderinnen Vera und Yvonne: Teillösungen und Kärtchenvarianten als Variation der Mystery-Methode — •Anna Herold, Jonathan Grothaus und Thomas Trefzger — Emil-Hilb-Weg 22, 97074 Würzburg

Yvonne und Vera verursachten 2019 den Tod von 6900 Menschen. Doch für ihre Taten ist eigentlich jemand ganz anderes verantwortlich. Wie kam es zu den Opfern? Wer trägt die Verantwortung?

Im Rahmen der Mystery-Methode untersuchen Schüler:innen die zum Klimawandel führenden Störungen des Erdsystems und die Betroffenheit der Menschen in Deutschland von Klimawandelfolgen. Im Lösungsprozess wird auch nach Verantwortlichen für den Klimawandel und dessen Folgen gesucht.

Ergänzend zum Vortrag von Grothaus et al. werden in diesem Beitrag die Besonderheiten dieser Mystery Entwicklung, sowie exemplarische Lösungen von Schüler:innen präsentiert. Zur Reduktion der Komplexität des Themenfeldes "Störung des Erdsystems" wird die Mystery-Methode variiert und es werden vor der kompletten Bearbeitung des Mysterys Teillösungen entwickelt. Die Rückkopplung von schmelzendem Meereis und der sinkenden Albedo, der Treibhauseffekt und die Rolle der Ozeane als Kohlenstoffspeicher werden vorher schon als Lernsicherung bearbeitet und dann in die komplette Concept Map des Mystery integriert. Die vielschichtige Antwort auf die Frage nach der Verantwortlichkeit wird in drei Kärtchenvarianten aufgeteilt, wobei die Verantwortlichkeit des Individuums, der Industrienationen und eine politische Ebene thematisiert und anschließend diskutiert werden.

DD 19: Hauptvortrag 3: Reese

Time: Tuesday 15:10–16:00 Location: ELP 6: HS 2

Invited Talk DD 19.1 Tue 15:10 ELP 6: HS 2

Umweltkrise = Verhaltenskrise? Individuelle und systemische Katalysatoren nachhaltigen Handelns — •Gerhard Reese — RPTU Kaiserslautern-Landau

Verhalten ist immer eine Funktion des sozialen und gesellschaftlichen Umfelds. Gerade die globalen Krisen (z.B. Klimawandel, Verlust biologischer Vielfalt) erfordern zwar individuelle, aber doch vor allem systemische Veränderungen. Dieser Vortrag beleuchtet die Interaktion zwischen Individuum und systemischen Ebenen sowie die Hebel, die den proaktiven Umgang mit den globalen Krisen begünstigen können.

DD 20: Lehr-Lernforschung III

Time: Tuesday 16:30–17:50 Location: ELP 1: SR 3.21

DD 20.1 Tue 16:30 ELP 1: SR 3.21

Decoding Disruptions: die Potentiale einer neuen Forschungsmethode zur Untersuchung von Störungsinterventionen im Experimentierunterricht. Eine ASSG-Analyse — •Luca Keim und Niklas Litzenberger — Institut für Physik, Mainz

Der Umgang mit Unterrichtsstörungen ist besonders für junge Lehrkräfte sehr herausfordernd. Um dem entgegenzuwirken, versucht man zwischen Forschung und Praxis zu vermitteln und Maßnahmen zur Störungsbewältigung zu geben, die hauptsächlich aus Erfahrungswissen geschöpft werden. Dabei haben jedoch empirische Befunde über die Effektstärken von Interventionen bei auftretenden Störungen im Unterricht noch viel Potential weiter ausgeschöpft zu werden.

Um diese Potentiale weiter auszubauen, nutzen wir eine neue Forschungsmethode, um solche Effektstärken messen zu können. Diese neue vielversprechende Advanced State Space Grid (ASSG) Methode ist in der Lage, Verhaltensänderungen von Indikatoren vor und nach einer Interaktion zu messen. In einer Pilotstudie untersuchen wir dessen Analysemöglichkeiten in einem störungsreichen Planspielunterricht. Erste Erkenntnisse über effektive Interventionsmöglichkeiten im Experimentierunterricht und Potentiale dieser neuen Methode werden im Rahmen des Vortrags diskutiert.

DD 20.2 Tue 16:50 ELP 1: SR 3.21

Decoding Dynamics: die neue Forschungsmethode ASSG zur Analyse zeitabhängiger Interaktionen im Unterricht — •Niklas Litzenberger und Andreas Pysik — Institut für Physik, Mainz

Unterricht zeichnet sich durch komplexe dynamische Interaktionen aus. Dies stellt die Unterrichtsforschung vor eine methodische Herausforderung, wenn diese Dynamik erfasst werden soll. Häufig werden bislang Methoden eingesetzt, die auf globale Einschätzungen des Unterrichts abzielen, wobei Aussagen über zeitabhängige dynamische Prozesse ausbleiben.

Ziel der neuen Advanced State Space Grids (ASSG) Methode ist es daher durch mathematisch fundierte, numerische und grafische Elemente solche dynamischen Prozesse messbar zu machen. Dadurch ist es möglich einen tieferen Einblick in die Zusammenhänge zwischen Unterrichtsaspekten zu erhalten. Beispielsweise lassen sich zeitabhängige Verhaltensänderungen von Lehrkräften, Lernenden oder Gruppen numerisch erfassen und neue Zusammenhänge zwischen verschiedenen Verhaltensaspekten finden, um Effektstärken von Interventionen zu messen. Insbesondere eignen sich auch rein maschinell aufgenommene Daten von Eye-Tracking oder Machine Learning, um Zusammenhänge zwischen beispielsweise Blickmustern und Arbeitsfortschritten zu finden.

Im Zuge des Vortrages wird die Methode vorgestellt und mögliche Implikationen aufgezeigt, welche künftige Studien durch einen öffentlich zugänglichen Python-Code nutzen können.

DD 20.3 Tue 17:10 ELP 1: SR 3.21

Lehren über Energie unterstützen mit Dashboards — •Marcus Kubsch[1], Onur Karademir[2], Adrian Grimm[3], Hendrik Drachsler[2], Nikol Rummel[4] und Knut Neumann[3] — [1]Freie Universität Berlin — [2]DIPF — [3]Ruhr-Universität Bochum — [4]IPN

Ein zentrales Wirkpotential von Künstlicher Intelligenz ist die Möglichkeit Individualisierung zu skalieren. Individualisierung, das heißt die Passung von Lehr-Lern-Settings zu den Charakteristiken der Lernenden, gilt als eine wichtige Determinante für Lernerfolg. Hierbei gibt es prinzipiell zwei Wirkwege: Basierend auf einer kontinuierlichen Erfassung der Lernstände kann die Lernumge-

bung automatisch adaptiert werden (z.B. automatisches Feedback, Anpassung der Aufgabenschwierigkeit). Der andere Weg geht über die Lehrkraft. Hier werden der Lehrkraft Informationen zum Lernstand aufbereitet dargestellt und diese kann basierend hierauf ihr unterrichtliches Handeln an die Lerngruppe anpassen. Die Darstellung der Informationen geschieht dabei in Form von so genannten Dashboards. Wie Dashboards für die effektive Anwendung gestaltet sein müssen, was effektive Anwendungsszenarien sind, und in wie weit sich Dashboards dann tatsächlich auf den Lernerfolg auswirken ist jedoch noch weitgehend unerforscht. Im Vortrag wird eine Studie vorgestellt, in welcher Lehrkräften ein Dashboard für eine Unterrichtseinheit zum Energiekonzept zur Verfügung gestellt wurde. Zentrale Befunde zum Nutzungsverhalten der Lehrkräfte sowie der Lernförderlichkeit werden präsentiert und diskutiert.

DD 20.4 Tue 17:30 ELP 1: SR 3.21

Entwicklungsvalidierung von Anleitungen zum selbstständigen Arbeiten im Physikunterricht — •Roland Berger[1], Maria Wevers[2] und Martin Hänze[2] — [1]Universität Osnabrück — [2]Universität Kassel

Die Entwicklung von hochwertigen schriftlichen Anleitungen zum selbstständigen Arbeiten im Physikunterricht ist herausfordernd. Denn die Anleitungen sollten so gestaltet werden, dass es zu keinem Abbruch der Lernbemühungen kommt, sondern eine fokussierte Verarbeitung der Lerninhalte unterstützt wird.

In einem Forschungsprojekt zu wünschenswerten Erschwernissen explorieren Schülerinnen und Schüler der 12. Jahrgangsstufe die Bewegung von Ladungsträgern in Magnetfeldern mithilfe eines Computerspiels anhand einer schriftlichen Anleitung. Wir haben die Anleitung in zwei Schritten validiert.

Im ersten Schritt wurden 14 Paare von Schülerinnen und Schülern beim Explorieren teilnehmend beobachtet. Dabei wurden schwierigkeitserzeugende Merkmale der Anleitung registriert, und die Anleitung auf dieser Grundlage fortlaufend weiterentwickelt. Im Rahmen einer quantitativen Studie (N = 75) wurde in einem zweiten Schritt gezeigt, dass die finale Form der Anleitung zum erfolgreichen Entdecken der Dreifingerregel geeignet ist.

Dieser Ansatz zur Validierung von Anleitungen könnte auch in anderen Lernumgebungen hilfreich sein, die auf selbstständiger Arbeit der Lernenden basieren, zum Beispiel bei der Entwicklung von Anleitungen für Schülerversuche.

DD 21: Hochschuldidaktik – Mathematik

Time: Tuesday 16:30–17:50 Location: ELP 1: SR 3.22

DD 21.1 Tue 16:30 ELP 1: SR 3.22

Digitale Übungsaufgaben zur Lehre von mathematischen Methoden in physikgeprägten Studiengängen — •Jonas Gleichmann, Hans Kubitschke und Jörg Schnauss — Universität Leipzig, Institut für Didaktik der Physik

Studierende in physikgeprägten Studiengängen benötigen ein gewisses Maß an mathematischen Fähigkeiten und Fertigkeiten, um physikalische Probleme lösen zu können. Diese algorithmischen Methoden werden meist in einem Modul in den ersten beiden Semestern gelehrt, wobei ein wesentlicher Teil des Lernprozesses durch die Abgabe von Übungsaufgaben realisiert wird. Wir möchten einen Ansatz vorstellen, wie diese Aufgaben digital im STACK-Format gestellt werden können. Mithilfe eines Computer-Algebra-Systems werden die Aufgaben randomisiert, wodurch sie individuell wiederholbar sind und nicht abgeschrieben werden können. Gleichzeitig reduziert sich der Korrekturaufwand für die Lehrenden, da das System die Aufgaben automatisch korrigiert und den Studierenden ein schnelles und individuelles Feedback gibt. Die freigewordenen Kapazitäten durch verringerten Korrekturaufwand können so für individuellere Betreuung genutzt werden. Nach drei Jahren Einsatz der digitalen Aufgaben möchten wir über erste Ergebnisse berichten.

DD 21.2 Tue 16:50 ELP 1: SR 3.22

Einfluss eines mathematischen Vorkurses in physikgeprägten Studiengängen — Jonas Gleichmann, •Hans Kubitschke und Jörg Schnauss — Universität Leipzig, Institut für Didaktik der Physik

Der Übergang vom schulischen zum akademischen Lernen stellt Studierende vor besondere Herausforderungen, speziell im Bereich Mathematik. Für die physikalischen Studiengänge bietet die Universität Leipzig einen mathematischen Vorkurs an, welcher auf dessen Lernerfolg hin analysiert wurde. Es wurden entsprechende Tests entwickelt, eine Prä-Post-Studie durchgeführt und die Prüfungsergebnisse während des ersten Studienjahres verfolgt. Dabei konnten wir sowohl kurz- als auch mittelfristige Effekte bei den Studierenden feststellen. Darüber hinaus konnten wir Veränderungen in der Selbsteinschätzung der mathematischen Fähigkeiten der Studierenden erwirken, sodass die Studieneingangsphase mit einem realistischen Abbild der eigenen mathematischen Fähigkeiten begonnen wurde. Die Ergebnisse deuten auf einen positiven Einfluss des Vorkurses auf die Studienleistungen in den ersten beiden Semestern hin.

DD 21.3 Tue 17:10 ELP 1: SR 3.22

Modulübergreifendes Blended Learning in der Mathematikausbildung zur Experimentalphysik im Lehramtsstudium Physik — •Lydia Kämpf und Frank Stallmach — Universität Leipzig, Institut für Didaktik der Physik

An der Universität Leipzig ist im Lehramtsstudium Physik die mathematische Ausbildung durch Seminare in die ersten beiden Experimentalphysik-Module integriert. Die Physikvorlesung gibt den zeitlichen und motivationalen Rahmen für diese Mathematischen Methoden Seminare vor. In unserem Vortrag stellen wir das modulübergreifende Konzept der Mathematischen Methoden Seminare vor und berichten von den Erfahrungen des ersten Entwicklungsjahres und forschungsbasierten Weiterentwicklungsideen.

Die Kernidee des Konzepts besteht in der just-in-time Vermittlung der für die Physik erforderlichen mathematischen Fähigkeiten im Flipped Classroom Format. Die Wissensvermittlung findet im Selbststudium durch jeweils zwei interaktive Lernvideos statt. Im jeweils ersten Video werden die rein mathematischen Themen eingeführt und durch integrierte Aufgaben erstgefestigt. Im zweiten Video erfolgt eine erste physikalische Anwendung, auf welches das Präsenzseminar durch weitere vertiefende Aufgaben aufbaut.

Am Beispiel des Lehr-Lern-Szenarios zu komplexen Zahlen zeigen wir in einer Vergleichsstudie, dass das vermittelte Wissen ins Langzeitgedächtnis übertragen wird und anwendbar bleibt.

DD 21.4 Tue 17:30 ELP 1: SR 3.22

Welche Mathematik- und Physikaufgaben sind relevant für den Einstieg ins Physikstudium? Die Sicht der Physikdozierenden — •Dennys Gahrmann[1], Irene Neumann[2] und Andreas Borowski[1] — [1]Universität Potsdam — [2]Leibniz-Institut für die Pädagogik der Naturwissenschaften und Mathematik (IPN)

Fachliches Vorwissen stellt einen der wichtigsten Prädiktoren für das Physikstudium dar. Etablierte Studieneingangstests nutzen vorrangig Mathematikaufgaben, die vor allem Rechenfähigkeiten abbilden. Es gibt jedoch zunehmend Forderungen nach der Integration von Mathematikaufgaben höherer Komplexität. Komplexität wird dabei durch das vierstufige Modell nach Rach et al. (2021) definiert, wobei Studieneingangstests vor allem Mathematikaufgaben der geringsten Stufe (Faktenwissen und prozedurales Wissen) beinhalten. Für die Auswahl relevanter Physikaufgaben in der Studieneingangsphase gibt es bislang noch keine Einschätzung von Physikdozierenden des ersten Semesters. Die vorliegende Studie greift diese Forderung nach einer Bewertung von Mathematikaufgaben unterschiedlicher Komplexität und einer Bewertung unterschiedlicher Physikaufgaben durch eine systematische Erhebung der Perspektiven von Dozierenden im ersten Semester auf. Zu diesem Zweck wurden 130 Aufgaben aus etablierten Tests der Mathematik und Physik von $N_M = 84$ und $N_{Ph} = 22$ Physikdozierenden bezüglich der Frage „Wie relevant ist es aus Ihrer Sicht, dass Studierende die folgende Aufgabe zu Beginn des Studiums lösen können, um erfolgreich ins Physikstudium zu starten?“ eingeschätzt.

DD 22: Neue / digitale Medien

Time: Tuesday 16:30–17:50 Location: ELP 1: SR 3.25

DD 22.1 Tue 16:30 ELP 1: SR 3.25

Der digitale Dozent: ChatGPT als Co-Pilot in der Lehrpersonenbildung — •Jens Damköhler, Wolfgang Lutz und Thomas Trefzger — Julius Maximilians-Universität, Würzburg, Deutschland

Die rasante Entwicklung künstlicher Intelligenz (AI) beeinflusst spätestens seit Einführung von ChatGPT Ende 2022 auch Diskussionen über den Einsatz im Bildungsbereich. Während Studierende wie Lehrende grundsätzlich offen gegenüber der Nutzung von AI scheinen, sind viele Überlegungen zum konkreten Einsatz in der universitären Lehre geprägt von Unsicherheit und fehlender Überzeugungskraft. Im Lehr-Lern-Labor Physik an der Universität Würzburg widmet sich ein Projekt der Untersuchung von Möglichkeiten, einen AI-Chatbot auf Basis des bekannten Modells ChatGPT einzusetzen. Dabei werden gezielt die Vorteile von AI als virtuellem Gesprächspartner genutzt, um die Studierenden bei der strukturierten Reflexion ihrer ersten Unterrichtserfahrungen zu beglei-

ten und zu unterstützen. Das Vorhaben knüpft an ein Dissertationsprojekt zum Thema Reflexionsprozesse an, indem den Studierenden ein ergänzendes Treatment zur Förderung der Reflexivität angeboten wird. Der Vortrag gibt Einblicke in grundsätzliche Überlegungen zur Nutzung von AI im Bildungsbereich und stellt anschließend das Vorhaben vor. Darüber hinaus sollen erste Einblicke in Ergebnisse eines Vortests unter Lehramtsstudierenden zu Akzeptanz und AI Literacy gewährt werden.

DD 22.2 Tue 16:50 ELP 1: SR 3.25

PUMA : Optiklabor - Eine webbasierte AR-Simulation für die Sekundarstufe I — •Stefan Kraus und Thomas Trefzger — Julius-Maximilians-Universität Würzburg

Ein kostenloser Optik-Experimentierkasten, den man Schülerinnen und Schülern mit nach Hause geben kann, der jederzeit zum Experimentieren einlädt, der haptische und virtuelle Elemente verbindet, bei dem man nichts beschädigen, aber über die Grenzen der realen Welt hinaus experimentiert werden kann. Diesen Anspruch verfolgt das PUMA : Optiklabor. **P**hysik**u**nterricht **m**it **A**ugmentierung - dieses Projekt des Lehrstuhls für Physik und ihre Didaktik der Universität Würzburg widmet sich in verschiedenen Teilgebieten der Physik den Möglichkeiten, die Augmented Reality (AR) bieten kann. Das Optiklabor besteht aus einer webbasierten AR-Simulation, bei der über Karten, die auf den Tisch gelegt werden, Laser und Gegenstände wie Spiegel und Linsen eingeblendet werden. Diese betrachten die Schülerinnen und Schüler durch ihr Smartphone oder Tablet-PC, auf dem sie lediglich eine Website öffnen, jedoch keine App installieren müssen. Die Applikation wird im Rahmen eines Design-Based-Research-Projekts entwickelt, das in zwei Phasen den Einsatz durch die Lehrkräfte und die Nutzung durch die Jugendlichen im Anfangsunterricht der Sekundarstufe I evaluiert. Parallel steht die technische Eignung für den Unterricht im Studieninteresse. Der Vortrag stellt die Applikation und das Studiendesign vor und lädt zum Ausprobieren und konstruktiven Austausch ein.

DD 22.3 Tue 17:10 ELP 1: SR 3.25

Digitale Messwerterfassung beim zentralen elastischen Stoß unter Einbeziehung von Reibungseffekten: Eine präzise Analyse von Erhaltungsgrößen — •Saskia Riedel und Frank Stallmach — Universität Leipzig, Institut für Didaktik der Physik

Der Einsatz digitaler Medien bietet zahlreiche Vorteile für das Experimentieren im Physikunterricht. Neben motivationalen Aspekten digitaler Messwerterfassung können Messdaten von Experimenten in Echtzeit und mit hoher Genauigkeit aufgenommen, visualisiert und analysiert werden. Das Experiment soll besonders in der Sekundarstufe II als zentrale empirische Methode verstanden und fachliche Inhalte wie physikalische Basiskonzepte vernetzt werden. Wir zeigen, wie die fachliche Vernetzung des Reibungsbegriffes und Kraftstoßes mit den Bewegungsgesetzen und Erhaltungsgrößen Impuls und Energie im Unterricht implementiert werden kann, indem wir die oft vernachlässigten Reibungseffekte beim zentralen elastischen Stoß berücksichtigen. Hierfür werden die Daten des Orts- und Kraftsensors zeitsynchron erfasst und daraus Geschwindigkeit-Zeit- und Kraft-Zeit-Diagramme ermittelt. Die beobachtete Impulsänderung wird durch den Kraftstoß und Reibungseffekte bewirkt, die aus den Messdaten durch Integration bzw. lineare Regression bestimmbar sind. Der Vortrag stellt die Messwerterfassung mit drahtlosen Smart Carts, die Datenanalyse zur Untersuchung von Erhaltungsgrößen unter Einbezug von Reibung und die Einsatzmöglichkeiten im schulischen und universitären Kontext vor. Im Vergleich zu bisherigen Messverfahren für den zentralen elastischen Stoß werden Vor- und Nachteile dieses Herangehens diskutiert.

DD 22.4 Tue 17:30 ELP 1: SR 3.25

Optik-Schülerexperimente in verschiedenen Modi: Realexperimente, Simulationen und beides kombiniert — •Salome Flegr und Jochen Kuhn — Ludwig-Maximilians-Universität München, Deutschland

Experimentieren spielt eine zentrale Rolle im Physikunterricht. Optik-Schülerexperimente wie das Experiment zu Abbildungen durch Sammellinsen in der Mittelstufe werden üblicherweise mit Realexperimenten durchgeführt. In den vergangenen Jahren haben jedoch auch interaktive Simulationen an Bedeutung für dieses Experiment gewonnen. Sie erlauben, abseits der rein phänomenologischen Ebene wie sie im Realexperiment beobachtet werden kann, auch konzeptuelle Aspekte beobachtbar zu machen. So können das abbildende Lichtbündel und die Konstruktionsstrahlen sichtbar gemacht werden. Bisherige Forschung hat gezeigt, dass Realexperimente und Simulationen, wenn möglich, nicht gegeneinander ausgespielt werden sollten, sondern als Ergänzung zueinander betrachtet werden sollten (Wörner et al., 2022). In der Vergangenheit wurde die Kombination von Realexperimenten und Simulationen jedoch vor allem als Sequenz untersucht und nicht gleichzeitig. In einer Studie mit über 150 Schülerinnen und Schülern der achten Klasse wurden die folgenden Lernbedingungen untersucht: Lernen mit dem Realexperiment, Lernen mit der interaktiven Simulation am iPad und Lernen mit einer Kombination aus Realexperiment und Simulation gleichzeitig. Es wurden Prä- und Posttests zum Konzeptverständnis durchgeführt. Die Ergebnisse der Studie werden auf der DPG Tagung 2024 vorgestellt.

DD 23: Bildung für nachhaltige Entwicklung

Time: Tuesday 16:30–17:50 Location: ELP 1: SR 2.26

DD 23.1 Tue 16:30 ELP 1: SR 2.26

eMobility for Kids - das Lernwerkstattformat für 12-15-jährige — •Andreas Daberkow und Barbara Wild — Hochschule Heilbronn, Fakultät für Technik, Max-Planck-Straße 39, 74081 Heilbronn

Das elektrische Fahren leistet einen Beitrag zu einer klimaschonenden Mobilität. Viele SchülerInnen haben bislang wenig Berührung mit angewandten Lehrformaten zur Energie und Elektrizität. Dies war die Motivation, ein praxisnahes Lehrformat zu schaffen, welches immer die Verbindung zu den Physik-Lehreinheiten der Schule hat. Erste Ergebnisse liegen vor und werden im Beitrag vorgestellt.

In 2023 wurden 3 Zweitageskurse "eM4K" mit jeweils 12 SchülerInnen veranstaltet. In 3 Teams baut jedes Team ein vierrädriges Elektrofahrzeug auf. Am Tag 2 des Seminars werden die selbst gebauten Fahrzeuge auf einem Geschicklichkeitsparcour selber gefahren. In begleitenden kurzen Lehreinheiten werden die Themen

- Elektrizität und Energie (Elektrischen Leistung und Arbeit, Praxisbezug Reichweite und Ladezeit)
- Physik der Kräfte (Reibschluss/Formschluss)
- Fahrphysik in der Ebene (Geometrie der Kreisfahrt mit Geschwindigkeits/Beschleunigungsvektoren)

mit den SchülerInnen reflektiert. Das hier vorgestellte Format ist idealerweise in 2-3 Tageskurseinheiten oder 4-6 Halbtageseinheiten lehrbar. Es schlägt eine wichtige Brücke zur Anwendung "klimafreundliche Mobilität" und soll die Schülerinnen für eine Verbindung von physikalischen Grundlagen mit einer nachhaltigen Mobilität begeistern.

DD 23.2 Tue 16:50 ELP 1: SR 2.26

Blaue Energie und Entsalzung – Neue Energie für die Gesellschaft — •Andreas Härtel — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, D-79104 Freiburg im Breisgau

Eine Leitperspektive der KMK-Bildungsstandards und vieler Bildungspläne ist die Bildung für nachhaltige Entwicklung. Dieser Leitlinie folgend und getreu dem Motto *begeistern kann nur, wer selbst für ein Thema "brennt"* (Großmann, Hertel, DPG Studie 2014, S. 22) habe ich meine Forschung zur Umwandlung von Wärme in elektrische Energie mittels kapazitiver Prozesse (Energy Environ. Sci. 8:2396, 2015) in den Fokus einer Unterrichtseinheit gestellt. Auch wenn die Verknüpfung verschiedener Themen aus den Bildungsplänen neu und ungewohnt für die Schüler:innen war, konnten wir doch erfolgreich über Entropie in Kondensatoren und thermodynamische Kreisprozesse sprechen, und wie diese mit dem Mischen von Süß- und Salzwasser in Flussmündungen zusammenhängen – einer alternativen Energiequelle für sogenannte blaue Energie. Im zugehörigen Umkehrprozess kann Trinkwasser durch Entsalzung gewonnen werden. Damit trifft die Thematik auf das Interesse der Schüler:innen an der Entwicklung zukunftsweisender Technologien mit Relevanz für die Menschheit und den Klimawandel (Merzyn, Guter Physikunterricht, Beiträge zur DPG-Frühjahrstagung, 2015).

In meinem Vortrag werde ich den physikalischen Prozess der beschriebenen Energieumwandlung erklären und dabei aufzeigen, wie dieser Inhalte für Schüler:innen elementarisiert werden kann. Außerdem gebe ich einen Ausblick für weitere fachdidaktische Aufarbeitungen zur Thematik.

DD 23.3 Tue 17:10 ELP 1: SR 2.26

Ein einfaches Modell für Vorhersage der CO2 Konzentrationen in der Atmosphäre in Abhängigkeit der globalen Emissionen — •Wolfgang Eberhardt[1] und Michael Vollmer[2] — [1]TH Berlin — [2]TU Brandenburg

Wir präsentieren ein sehr einfaches Modell um zeitabhängige CO2 Konzentrationen in der Atmosphäre abzuschätzen. Dafür leiten wir eine lineare Differentialgleichung 1. Ordnung ab, die auf aktuellen Daten des Global Carbon Project und den Mauna Loa Daten der atmosphärischen CO2 Konzentrationen basiert. Das Modell wird erstens getestet für die Periode 1960 bis 2021 mit guter quantitativer Übereinstimmung zu den entsprechenden Messdaten. Zweitens werden zwei typische IPCC Szenarien mit guter qualitativer Übereinstimmung der Ergebnisse diskutiert. Drittens werden Ergebnisse für einige neue Emissionsszenarien vorgestellt und diskutiert. Trotz einiger Nachteile in Bezug auf absolu-

te quantitative Vorhersagen im Vergleich zu komplexeren Modellen hat unser Ansatz zwei wichtige Vorteile. Es kann erstens von Studierenden bereits sehr einfach mit programmierbaren Tabellenkalkulationsprogrammen wie Excel benutzt werden. Zweitens können als Eingangsdaten genutzte Emissionsszenarien beliebig verändert werden. Die entsprechenden Ergebnisse können sofort für tiefergehende Diskussionen zum Thema Kohlenstoffkreislauf und Klimawandel in Bachelor- und Masterstudiengängen verwendet werden.

[1] M. Vollmer, W. Eberhardt, eingereicht bei Eur. J. Phys.

DD 23.4 Tue 17:30 ELP 1: SR 2.26

Massenmörderinnen Vera und Yvonne: Systemwissen und Umweltpsychologie in einem Mystery über Klimawandelfolgen — •Jonathan Grothaus, Anna Herold und Thomas Trefzger — Universität Würzburg

”Yvonne und Vera verursachten 2019 den Tod von 6900 Menschen. Doch für ihre Taten ist eigentlich jemand ganz anderes verantwortlich. Wie kam es zu den Opfern und wer trägt die Verantwortung für die Toten?” Der Vortrag stellt ein Mystery vor, das anhand der obigen Leitfrage die Verantwortung für lokale Folgeschäden des Klimawandels untersucht. Im Lösungsprozess des Anordnens von Informationskärtchen in einer Concept Map werden psychologische Determinanten von Handeln mit Erdsystemwissen verknüpft. Vorgestellt wird hier der Ansatz über die Lösungskärtchen (zu Hitzewellen und Übersterblichkeit) die persönliche Betroffenheit und regionale Nähe der Folgen zu adressieren. Beides sind umweltpsychologische Variablen, die helfen können, die Knowledge-Action-Gap zu überbrücken. Die Komplexität der Verantwortung wird über lerngruppenweise unterschiedliche Varianten der Lösungskärtchen diskutiert, die die Rolle und Schuld des Individuums, der Industrienationen und der (deutschen) Politik aufbringen.

Gewissermaßen ungewöhnlich versucht das Mystery, eingesetzt als didaktische Rahmenstruktur einer Lerneinheit zum Klimawandel, eine umweltpsychologisch fundierte Handlungsmotivierung mit einer Systemwissenssicherung zu vereinen. Inwiefern dieser Ansatz gelingt, und welche Schwächen im etablierten Schülerlaboreinsatz (n ca. 500 SuS) auftreten, soll kritisch erläutert werden.

DD 24: Quantenphysik III

Time: Tuesday 16:30–17:50 Location: ELP 1: SR 2.28

DD 24.1 Tue 16:30 ELP 1: SR 2.28

Untersuchung der Verwendung multipler Repräsentationen in Hochschulkursen zu Quantentechnologien — •Eva Rexigel[1], Jonas Bley[1], Alda Arias[1], Linda Qerimi[2], Stefan Küchemann[2], Jochen Kuhn[2] und Artur Widera[1] — [1]RPTU Kaiserslautern-Landau, Kaiserslautern — [2]LMU München, München

Zur Vermittlung quantentechnologischer Inhalte kann auf multiple externale Repräsentationen, wie Dirac/Bra-Ket Notation, Blochkugel, oder Realexperiment, zurückgegriffen werden. Jede Repräsentation bietet unterschiedliche Vor-, Nachteile und Anforderungen beim Lernen und Problemlösen. Es ist jedoch unklar, inwiefern diese Repräsentationen in Hochschullehre eingesetzt werden. Im Rahmen einer Online-Umfrage wurden deshalb Hochschuldozent*innen der Quantentechnologien zum Einsatz von Repräsentationen in ihren Veranstaltungen befragt. Die Ergebnisse zeigen, dass mathematisch-symbolische Repräsentationen universell verwendet werden, unabhängig von Kompetenz- und Aufgabenbereich, fachlicher Ausrichtung und akademischem Niveau der Studierenden. Qubits werden dabei in allen untersuchten Veranstaltungen nicht nur anhand einer einzelnen, sondern mithilfe multipler Repräsentationen charakterisiert. Der inhaltliche Übergang zu Multi-Qubit Zuständen geht jedoch mit einer signifikanten Abnahme der Anzahl verwendeter Repräsentationen einher. Die Analysen verdeutlichen die Notwendigkeit eines flexiblen Umgangs mit multiplen Repräsentationen beim Lernen zu Quantentechnologien und die Relevanz eines angemessenen Umgangs mit den charakteristischen mathematisch-symbolischen Repräsentationen.

DD 24.2 Tue 16:50 ELP 1: SR 2.28

Graphical representations in quantum physics: exploring the effects of learning from qubit visualizations and developing a new classification system for visual representations — •Linda Qerimi[1,2,3], Stefan Küchemann[1], Sarah Malone[4], Silke Stähler-Schöpf[2], Sascha Mehlhase[2,3], Tatjana Wilk[5], and Jochen Kuhn[1] — [1]LMU, Munich — [2]MPQ, Garching near Munich — [3]MQV, Munich — [4]Saarland University, Saarbrücken — [5]MCQST, Munich

In quantum physics, it is particularly important to choose representations that are transferable to mathematics in order to provide learners with material for sustainable teaching of quantum physics. Therefore, in a first study with 45 participants in two groups, we investigated learning gains using two different qubit representations. The results showed significant learning gains in both groups. It remains unclear which mechanisms are responsible for the increase in learning. Thus we developed a new categorization system based on representation research and quantum physical imagination research. Using Ainsworth's (2006) Design Functions and Tasks framework as a basis, we extended it to include other relevant aspects of quantum physics representations. The categorization system is evaluated by quantum physics experts on the basis of four qubit representations. They will be asked to rate each qubit representation using the category system. Our goal is to categorize representations according to their resulting profiles into clusters that allow decisions for the selection and design of representations for appropriate and effective learning of quantum physics content.

DD 24.3 Tue 17:10 ELP 1: SR 2.28

Low-Cost-Analogieexperimente zum BB84-Protokoll aus dem 3D-Drucker — •Tim Overwin[1], Nils Haverkamp[2], Alexander Pusch[2], Rainer Müller[1] und Stefan Heusler[2] — [1]Institut für Fachdidaktik der Naturwissenschaften, Abt. Physik und Physikdidaktik, TU Braunschweig, Deutschland — [2]Institut für Didaktik der Physik, Universität Münster

Eine aktuelle Anwendung der Quantenphysik, welche auch im Schulkontext von Relevanz ist, ist die Quantenkryptographie - genauer das BB84-Protokoll.

In diesem Vortrag werden verschiedene experimentelle Umsetzungen vorgestellt, anhand derer das Protokoll modellhaft sowie anschaulich nachvollzogen werden kann, und ihre unterschiedlichen Vor- und Nachteile diskutiert.

Diese experimentellen Umsetzungen lassen sich kostengünstig mithilfe eines 3D-Druckers nachbauen.

DD 24.4 Tue 17:30 ELP 1: SR 2.28

Low-Cost-Experimente mit NV-Zentren in Diamant - Didaktisch optimierter Aufbau mit Steuerung und Auswertung am Tablet — •Nils Haverkamp[1], Alexander Pusch[1], Markus Gregor[2] und Stefan Heusler[1] — [1]Institut für Didaktik der Physik, Universität Münster — [2]Fachbereich Physikingenieurwesen, Fachhochschule Münster

Im Physikunterricht der Oberstufe werden zur Quantenphysik typischerweise nur Analogieexperimente (bspw. der Quantenradierer), semiklassisch erklärbare Experimente (bspw. der Photoeffekt) oder digitale Pendants zu Experimenten (Simulationen, Bildschirmexperimente, etc.) durchgeführt. Dies liegt u.a. daran, dass Experimente, die auf echte Quanteneffekten beruhen, aktuell zu teuer und kompliziert aufzubauen sind. Diamanten mit Stickstoff-Fehlstellen (NV-Zentren) zeichnen sich dadurch aus, dass sie vergleichsweise günstig verfügbar sind und bei Raumtemperatur echte Quanteneffekte zeigen können. Aus diesen Gründen haben NV-Zentren aktuell auch in Forschung und Wirtschaft eine starke Relevanz. In diesem Vortrag wird ein didaktisch optimierter experimenteller Aufbau vorgestellt, der sich kostengünstig nachbauen lässt. Die Steuerung und Auswertung erfolgt über ein digitales Endgerät wie z.B. ein Tablet.

DD 25: Mitgliederversammlung

Time: Tuesday 18:00–20:00 Location: ELP 6: HS 2

Alle Mitglieder des Fachverbands Didaktik der Physik sind herzlich eingelanden.

DD 26: Anregungen

Time: Wednesday 11:00–11:20 Location: ELP 1: SR 3.21

DD 26.1 Wed 11:00 ELP 1: SR 3.21

Sichtweiten - so weit das Auge trägt — •Michael Vollmer — TH Brandenburg

Kann man Helgoland vom 50 km entfernten deutschen Festland aus sehen, die Berge der Hohen Tatra in der Slowakei aus über 200 km Entfernung von Südostpolen oder gar den Mont Blanc vom über 500 km entfernten Köln? Die Antworten hängen von der Erdgeometrie, Lichtbrechung und Streuung in der Atmosphäre und nicht zuletzt von der Wahrnehmungspsychologie ab [1,2].

[1] M. Vollmer, Physik in unserer Zeit 54/5, 222-230 (2023)
[2] M. Vollmer, Physik Journal 22/3, 28-33 (2023)

DD 27: Hochschuldidaktik – Sachwissen

Time: Wednesday 11:00–12:20 Location: ELP 1: SR 3.22

DD 27.1 Wed 11:00 ELP 1: SR 3.22

Vernetztes Wissen zum Energiekonzept von Studierenden der Naturwissenschaften — •Dennis Dietz und Claus Bolte — Freie Universität Berlin

Das interdisziplinär bedeutsame Energiekonzept spielt eine zentrale Rolle für das Verständnis komplexer naturwissenschaftlicher Sachverhalte (u.a. Chen, 2014). Um ein erfolgreiches Erlernen von vertiefenden Inhalten des Energiekonzepts auch an der Hochschule zu gewährleisten, ist es im Sinne der konstruktivistischen Lerntheorie unabdingbar, dass Dozierende die Lernvoraussetzungen ihrer Studierenden kennen und möglichst akkurat antizipieren (u.a. Renkl, 2020). Aus diesem Grund haben wir das Wissen von Studienanfänger*innen mit naturwissenschaftlichem Fach zum Energiekonzept mit Blick auf dessen Vernetzung - ein bedeutsames Qualitätsmerkmal von Wissen (de Jong & Ferguson-Hessler, 1996) - systematisch untersucht. Dazu haben wir insgesamt 106 Studierende der FU Berlin zu Beginn des Wintersemesters 2023/24 in den Modulen "Grundlagen der Physikalischen Chemie" sowie "Atombau und Chemische Bindung" gebeten, ein Essay über das Energiekonzept zu verfassen. Diese Essays haben wir qualitativ-inhaltsanalytisch mit einem theoriebasiert konstruierten und empirisch erprobten Modell - dem Modell zur Analyse der Vernetzung von Begriffselementen (Akronym: MAVerBE) - untersucht (Dietz & Bolte, 2022; Dietz, 2023). In unserem Beitrag werden wir ausgewählte Ergebnisse dazu vorstellen, wie komplex und korrekt die Studierenden Begriffselemente des Energiekonzepts sinnstiftend miteinander vernetzt haben.

DD 27.2 Wed 11:20 ELP 1: SR 3.22

Die Bra-Ket Notation als Bildersprache für quantenphysikalische Prozesse — •Thomas Filk — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

Die Dirac'sche Bra-Ket-Notation ist in mehrfacher Hinsicht auf die Bedürfnisse der Quantentheorie abgestimmt: Sie ermöglicht es, Zusammenhänge zwischen Vektoren bzw. Operatoren in basisunabhängiger Form oder auch in wechselnden Basissystemen auszudrücken, und sie ist in einfacher Weise auf sogenannte „uneigentliche" Basissysteme (wie die Orts- und Impulsbasis) in unendlich dimensionalen Hilbert-Räumen erweiterbar. Da diese Schreibweise in der Schule derzeit keine oder kaum Verwendung findet, ziehen viele Lehrkräfte oft umständlichere oder nur für spezielle Basissysteme angepasste Schreibweisen vor. Gerade im Zusammenhang mit moderner Quantentechnologie, beispielsweise der Quantenkryptographie, sind Basiswechsel jedoch entscheidend und solche Schreibweisen sind dann eher verwirrend.

In meinem Vortrag möchte ich die Bra-Ket-Schreibweise als symbolische Schreibweise für quantenmechanische Prozesse interpretieren, z.B. die Präparation eines Systems in einem bestimmten Zustand, das Testen auf einen bestimmten Zustand, das Durchlaufen eines Filters oder eines Doppelspalts oder eines Mach-Zehnder-Interferometers und andere Prozesse. Ähnlich wie bei Feynman-Graphen haben die Darstellungen zwar einerseits eine sehr konkrete mathematische Bedeutung, andererseits erlauben sie aber auch eine Veranschaulichung der Prozesse. Außerdem wird in dem Vortrag der Bezug zu ähnlichen Ansätzen hergestellt.

DD 27.3 Wed 11:40 ELP 1: SR 3.22

Ist Kraft Dynamik? — •Grit Kalies[1] und Duong D. Do[2] — [1]HTW University of Applied Sciences, Dresden, Germany — [2]The University of Queensland, Brisbane, Australia

Die Kraft wird als Dynamik interpretiert, und das Gebäude der Physik ist auf Kraftwechselwirkungen aufgebaut. In Schule und Universität wird gelehrt, dass es die Kraft ist, die Veränderungen hervorruft. Sie ist es, die aktiv Körper verschiebt und beschleunigt, z.B. deren Höhe und Geschwindigkeit ändert. Die Idee einer wirkenden Kraft beherrscht so viele Theorien, dass der Physikhistoriker Max Jammer Mitte des 20. Jahrhunderts einschätzte, die Kraft sei die bedeutendste Variable der Physik [1]. Ein anderer Zugang zur Dynamik folgt aus der Einführung der Impulsänderungsarbeit [2]. Diese Arbeit ändert den Impuls eines Körpers, also zugleich dessen Geschwindigkeit und Masse, wodurch sich jede Kollision über simultane Prozesse beschreiben lässt. Dynamik existiert dann nur, wenn ein Prozess in der Zeit stattfindet: eine Energieübertragung. Nur sie kann etwas ändern und bewirken, die Kraft hingegen ist keine Energieübertragung. Wir skizzieren die vielen Vorteile im Verständnis der Natur und der didaktischen Vermittlung von physikalischen Grundgrößen wie Kraft, potentielle Energie, Enthalpie und Entropie, wenn man allein Prozesse als Dynamik beschreibt, wie in der Thermodynamik üblich. 1. M. Jammer: Concepts of Force, Harper Torchbook, New York, 1962; 2. G. Kalies, D. D. Do: Momentum work and the energetic foundations of physics, AIP Adv. 13 (2023), 065121, 055317, 095322, 095126.

DD 27.4 Wed 12:00 ELP 1: SR 3.22

Untersuchung über Fehlvorstellungen in der Hydrodynamik und Entwicklung evidenzbasierter Lehrmaterialien — •Max Vincent Uzulis und Christian Kautz — Technische Universität Hamburg (TUHH)

Das Fach Strömungsmechanik spielt auch in technischen Studiengängen eine wichtige Rolle. Ein tieferes Verständnis der teilweise sehr komplexen Zusammenhänge in den ingenieur-wissenschaftlichen Anwendungen setzt eine solide Grundlage in der Physik der Fluide voraus. Bereits diese Grundlagen bereiten den Studierenden allerdings erhebliche Schwierigkeiten. Um einen besseren Einblick in die auftretenden Probleme beim Verständnis der Hydrodynamik zu erhalten und daraus resultierend evidenzbasierte Lehrmaterialien zu entwickeln, wurde eine Grundlagenveranstaltung zur Strömungsmechanik didaktisch beforscht. Mit Hilfe diagnostischer Multiple-Choice-Tests sowie schriftlicher Kurztests mit offenen Fragen wurde das Konzeptverständnis der Studierenden untersucht. Die Auswertung dieser Tests offenbarte teilweise gravierende Fehlvorstellungen. Es wurden unter anderem Missverständnisse beim Gebrauch der Bernoulli-Gleichung sowie Probleme beim Verständnis der Potentialtheorie, der Wirbelstärke und der mathematischen und grafischen Darstellung von Strömungen festgestellt. Diese Ergebnisse bilden die Grundlage für die geplante Umgestaltung der Lehrveranstaltung im kommenden Semester.

DD 28: Experimente und Praktika

Time: Wednesday 11:00–12:00 Location: ELP 1: SR 3.25

DD 28.1 Wed 11:00 ELP 1: SR 3.25

Dynamic Competence Development through Project-Based Learning in Physics Education — •Franz-Josef Schmitt — Institute of physics, Martin-Luther-Universität Halle-Wittenberg

This study presents a novel, fluid competence level-oriented project laboratory integrated into the advanced practical courses of our Bachelor and Master's programs in Physics. This innovative approach empowers students to evolve progressively in their self-devised project experiments, marking a shift from traditional pedagogical methods to a more dynamic, student-centered learning paradigm. Central to this approach is the students' engagement in formulating and developing an obligatory project idea. Notably, the program offers flexibility for students to expand their projects into extended versions (XL or XXL) based on the merit of their ideas and progress. The project laboratory's design involves a cyclical process of development, implementation, documentation, and improvement while continuously mentored. A distinctive feature of this approach is the gradual replacement of basic experiments, initially assigned at the semester's start, with the student-developed projects depending on the students' own engagement. After that the new experiments are taken over as novel

standard laboratory experiments. This transition not only fosters a more personalized learning experience but also aligns with contemporary educational needs and inherently encourages creativity, critical thinking, and deeper engagement in the subject matter.

DD 28.2 Wed 11:20 ELP 1: SR 3.25

Erster cw-Rubin Experimental (Klasse 1)-Laser für Schule und Praktika — •Ilja Rückmann und Walter Luhs — Uni Bremen, FB 1, Otto-Hahn-Allee 1, 28359 Bremen

Neben dem dem Quantenoptik-Grundversuch zur Messung des Zeitverhaltens der Rubin-Fluoreszenz wird der erste cw-Rubin Experimental-Laser vorgestellt.

Obwohl heute Laser in allen Bereichen eine wichtige Rolle spielen, wird seine Funktionsweise im Unterricht nur eingeschränkt besprochen. Da der Rubinlaser entgegen der üblichen Lehrbuchmeinung auch im cw-Betrieb funktioniert, wurde nun ein Experimental(Klasse 1)-Laser für Schule und Praktika entwickelt.

Der cw-Rubin Experimental-Laser wird mit Steckernetzteil oder Powerbank betrieben. Zuerst muss der Resonator justiert werden, dabei hilft ein Schirm oder das Raspberry-PI Kamerasystem. Der Laser verfügt über einen Experimentierbereich, in den Elemente, wie Schirm, Kamera, Gitter, Polfilter, etc. eingesteckt werden können. Eine Elektronik erkennt die Elemente und sorgt für die Abschaltung bei nicht sicherer Anordnung. Dadurch und durch die Führung des Strahls in einem Plexiglasrohr kann keine Laserstrahlung austreten.

Mit dem nur 40 cm langen cw-Rubin Experimental-Laser können bis 13 Experimente durchgeführt werden, die bisher nur ein offener und teurer He-Ne Laser Aufbau ermöglichte. So können u.a. durch Änderung der Resonatorlänge TEM-Moden mit dem Kamerasystem beobachtet und TEMoo Gauss-angepasst werden.

DD 28.3 Wed 11:40 ELP 1: SR 3.25

CLEOPATRA - Elementarteilchenforschung im Klassenzimmer — •Laura Rodríguez Gómez, Annika Hoverath, Jochen Kaminski, Klaus Desch und Johannes Streun — Physikalisches Institut, Universität Bonn

Dem Physikunterricht der gymnasialen Oberstufe fehlt es an forschungsnahen Realexperimenten. Besonders betroffen sind Bereiche wie Strahlung, Materie und Kernphysik. Dadurch kann nur schwer ein Einblick in Forschungsprozesse geboten werden. In diesem Vortrag wird das CLEOPATRA-Projekt vorgestellt, das einen Einblick in moderne Teilchenphysik bieten soll. Als Experiment wird ein bestimmter Teilchendetektor - eine sogenannte Zeitprojektionskammer - verwendet. Dieser Detektortyp wird auch an großen Experimenten der Grundlagenforschung eingesetzt. Mit ihm ist es möglich, Teilchenspuren in drei Dimensionen und quasi in Echtzeit zu rekonstruieren und zu visualisieren. Die so entstehenden Daten können digital ausgewertet werden, sodass anhand dieses Experiments Konzepte des Arbeitens mit digitalen Datenmengen vermittelt werden können. Über die Fertigstellung des Experiments hinaus wird eine Unterrichtsreihe mit dem Detektor entwickelt, die Vorschläge zum Einsatz des Experiments im Schulalltag macht und Materialien für die Unterrichtspraxis enthält. Dieser Vortrag stellt den Detektor sowie ein erstes didaktisches Konzept für dessen Einsatz im Schulunterricht vor. Es wird erörtert, wie ein echter Forschungsdetektor für den Schulunterricht zugänglich gemacht werden kann.

DD 29: Workshop: Maschinelles Lernen in der naturwissenschaftsdidaktischen Forschung

Time: Wednesday 11:00–12:30 Location: ELP 1: SR 2.26

DD 29.1 Wed 11:00 ELP 1: SR 2.26

KI in der Physikdidaktik: Grundlagen und erste Anwendungen — •Peter Wulff[1] und Marcus Kubsch[2] — [1]Pädagogische Hochschule Heidelberg — [2]Freie Universität Berlin

Im Workshop werden Grundlagen von KI mit Fokus auf physikdidaktische und naturwissenschaftsdidaktische Forschung eingeführt. Die Grundlagen werden mit Hilfe von ausgewählten Beispielen vertieft. Der Workshop richtet sich an Teilnehmende, die noch wenig Vorwissen im Thema haben und Interesse an der Anwendung von KI in der eigenen Forschung, bspw. in Form von maschinellen Lernen oder computerbasierter Sprachverarbeitung. Ein eigener Laptop mit Internetverbindung ist empfehlenswert, um die Beispiele selbst ausführen zu können.

DD 30: Astronomie

Time: Wednesday 11:00–12:20 Location: ELP 1: SR 2.28

DD 30.1 Wed 11:00 ELP 1: SR 2.28

Das Stellarium Gornergrat: Aktuelle Entwicklungen und zukünftige Perspektiven — •Simon F. Kraus[1], Stéphane Gschwind[2], Marvin zur Mühlen[1], Andreas Müller[2], David Picon[2], Timm Riesen[3], Leon Rohde[1] und Oliver Schwarz[1] — [1]Didaktik der Physik, Universität Siegen — [2]University of Geneva, Faculty of Science / Physics Section and Institute of Teacher Education — [3]University of Bern, Center for Space and Habitability

Auf dem Gornergrat nahe Zermatt wird seit vielen Jahren das Stellarium Gornergrat als astronomischer Lernort betrieben. Neben Vor-Ort-Beobachtungen besteht die Kernaufgabe in der Bereitstellung des Teleskops für robotische, d. h. von ferne geplante und automatisiert ausgeführte, Beobachtungen. Diese Beobachtungen sind jeweils eingebettet in Aufgabenstellungen für verschiedene Schulstufen, deren didaktische Zielsetzungen wiederum auf den Schweizer Lehrplan 21 abgestimmt sind.

Im Vortrag wird ein Kurzüberblick über die bisherige Arbeit sowie ein Einblick in die aktuellen und zukünftigen Entwicklungen von neuen Lehr-Lern-Materialien gegeben. Ein inhaltlicher Schwerpunkt wird in der Verbindung von historischem Datenmaterial mit aktuellen Beobachtungen liegen. Anknüpfend an jüngste Erfolge der Fachastronomie soll beispielsweise der Frage nachgegangen werden, ob sich Veränderungen der Farbe einzelner Sterne auf historischen Zeitskalen beobachten lassen und, falls ja, bei welchen Sternen solche Entwicklungen überhaupt zu erwarten sind.

DD 30.2 Wed 11:20 ELP 1: SR 2.28

Students Learn a Solution to the Barn-Problem in Special Relativity — •Paul Sawitzki[1,4] and Hans-Otto Carmesin[1,2,3] — [1]Athenaeum, Stade — [2]Studienseminar Stade — [3]Universität Bremen — [4]Universität Heidelberg

We consider a ladder and a barn, whereby the ladder is longer than the barn in a common frame of rest. However, when the ladder moves in the rest frame of the barn, then the length of the ladder is smaller than the length of the barn, due to length contraction. Thus, the ladder would fit into the barn in the barn's frame, but not in the ladder's frame. This is the barn paradox. We show how this paradox is solved. More generally, we discuss the relevance of different measures of length in relativity. The results will be compared with accelerator experiments. By solving the paradox, central conceptual issues of relativity are addressed. This provides a deeper understanding of relativity and is therefore didactically valuable. We also discuss other proposed explanations of the paradox.

DD 30.3 Wed 11:40 ELP 1: SR 2.28

Students Learn the Fundamental Exact Unification of Gravity, Relativity, Quanta and Elementary Charge — •Hans-Otto Carmesin — Athenaeum Stade — Studienseminar Stade — Universität Bremen

The modern worldview is provided by the expansion of space at the macroscopic level, and by fundamental interactions at the microscopic level. However, Einstein, Rosen and Podolsky (1935) identified an apparent discrepancy of both levels. Similar discrepancies are: Einstein's (1948) spukhafte Fernwirkung, the cosmological constant problem (Nobbenius 2006), nonlocality (Aspect 1982). How are these discrepancies overcome? We show how students can solve it in an exact and elegant manner: Based on basic relations in geometry and analysis, the fundamental dynamics of volume are analyzed & derived. With it, the above mentioned fundamental theories of physics are derived: the postulates of quantum physics, general relativity, the mechanisms of propagation of fundamental interactions. On that basis, the above discrepancies are solved. Our results are precise accordance with observation and fully derived from physical principles [1-3]. Experiences from teaching in research clubs and general study courses at a university are presented. [1] Carmesin, H.-O. (2023): Geometrical and Exact Unification of Spacetime, Gravity and Quanta. Berlin: Verlag Dr. Köster. [2] Carmesin, H.-O. (2024): Fundamental Exact Unification of Gravity, Relativity, Quanta and Charge. Berlin: Verlag Dr. Köster. [3] More info: https://www.researchgate.net/profile/Hans-Otto-Carmesin

DD 30.4 Wed 12:00 ELP 1: SR 2.28

Didaktische Rekonstruktion für fächerverbindende Aufgaben — •Eleen Hammer und Holger Cartarius — AG Fachdidaktik der Physik und Astronomie, Friedrich-Schiller-Universität Jena

Die Didaktische Rekonstruktion hat sich seit den 90er Jahren als bedeutender Ansatz in der naturwissenschaftlichen Didaktik etabliert. Ihr Hauptziel besteht darin, Fachinhalte schülergerecht zu vermitteln, indem sie die Perspektiven des

Fachs und der Lernenden miteinander verbindet. Das übliche Modell, oft als Dreieck dargestellt, fokussiert auf die Synthese von Fach- und Schülerperspektiven in einem einzelnen Fach.

Dieser Vortrag widmet sich dem Vorhaben, wie die Didaktische Rekonstruktion angepasst werden kann, um fächerverbindende Aufgaben zu entwickeln. Die bekannte Dreiecksdarstellung muss erweitert werden, um den Anforderungen beider Fächer nachzukommen. Dabei entsteht eine neue Modellstruktur.

Es wird ein praktisches Beispiel vorgestellt, das zeigt, wie Astronomie und Mathematik erfolgreich anhand des Modells in Aufgaben miteinander verknüpft werden konnten.

DD 31: Vorträge Lehrerpreise

Time: Wednesday 11:20–12:20 Location: ELP 1: SR 3.21

Prize Talk DD 31.1 Wed 11:20 ELP 1: SR 3.21

Satellitenfunk, MoonBounce und Atmosphärenforschung: Die modernste Technologie in der Schule — •Safia Ouazi — Robert-Havemann-Gymnasium, Berlin, Deutschland — Trägerin des DPG-Lehrerpreises 2024

Seit Jahren bemüht sich das Robert-Havemann-Gymnasium, um Schüler für die Ingenieur- und Naturwissenschaften zu begeistern, sie zu inspirieren und ihre Begabungen zu fördern.

Dieses unterstützende und anregende Umfeld ermöglichte mir, das Projekt einer jährlichen MoonBounce-Veranstaltung mit Hunderten von Teilnehmern aus Berliner Schulen ins Leben zu rufen. Das Ziel ist, Botschaften bis zum Mond zu senden und die reflektierten Funksignale aufzufangen. Im September 2023 wurde unsere MoonBounce-Veranstaltung in Mitarbeit mit dem Max-Planck-Institut für Radioastronomie aus Bonn organisiert. Der kommende MoonBounce-Tag wird in Kooperation mit einer Erdfunkstelle stattfinden.

Eine Brücke zwischen Schulen und Forschungseinrichtungen erlaubt dem Physik Unterricht, auf dem Stand der Technik und den aktuellen Kenntnissen zu bleiben. Meine Teilnahme am SOFIA-Mitflug, die Planung von Schülerexperimenten an einem außerschulischen Orten, wie dem Max-Planck-Institut für Mikrostrukturphysik in Halle, die Beschaffung eines Massenspektrometers von der Freien Universität Berlin sind Beispiele dafür.

Die internationale Dimension wird durch die Partnerschaft mit einer französischen Schule verwirklicht. Im Mai 2024 starten zeitgleich zwei Stratosphärenballons mit Sensoren. Das Ziel ist, eine Messkampagne zur Luftqualität und einen Funkkontakt über Satelliten zu realisieren.

Prize Talk DD 31.2 Wed 11:50 ELP 1: SR 3.21

Rückblick auf 40 Jahre Physikunterricht mit Sonderaktivitäten — •Heinz-Werner Oberholz — Gymnasium Wolbeck, Münster — Träger des DPG-Lehrerpreises 2024

Nach 40 Jahren Physikunterricht mit Leidenschaft und 11 Jahren Ruhestand erwartet Sie kein Bericht über eine aktuelle Arbeit. Stattdessen liefert der Vortrag eine multimediale Reise durch die beruflich aktive Zeit, Sprünge von Projektinseln zu Themenlandschaften, experimentelle Entwicklungen und Innovationen, Veröffentlichungen und thematische Vertiefungen.

Einige Beispiele: Ein zu seiner Zeit neues Gerät zur Attraktivierung des Oberstufenunterrichts, ein neues Schülerübungssystem zur Wellenlehre, anspruchsvolle Projekte (z.B. Sprungtemperatur eines Hochtemperatur-Supraleiters, Energieeinsparungsprojekt), prämierte *Jugend forscht*-Arbeiten, Einbeziehen neuer Erkenntnisse (didaktische, neurobiologische) und technischer Möglichkeiten zur Verbesserung des Unterrichts.

Alles unter dem Leitmotiv: *Verstehen macht glücklich*.

DD 32: Lehreraus- und -fortbildung – Poster

Time: Wednesday 14:00–15:00 Location: ELP 6: Foyer

DD 32.1 Wed 14:00 ELP 6: Foyer

Verschränkung von Fachwissenschaft und Fachdidaktik in den Modulen der Lehramtsstudiengänge Physik an der Universität Erlangen-Nürnberg — •Antonia Bauer und Philipp Bitzenbauer — FAU Erlangen-Nürnberg

Vor dem Hintergrund der DPG-Lehramtsstudie wird diskutiert, wie die Physiklehrkräftebildung weiterentwickelt werden kann, um die Studienzufriedenheit und den Studienerfolg zu erhöhen bzw. Abbruchquoten oder die Häufigkeit von Studienfachwechseln zu reduzieren. Dabei werden vor allem Maßnahmen zur stärkeren Ausrichtung des Studiums am Berufsziel der Studierenden erörtert, wobei insbesondere die Verzahnung von fachwissenschaftlichen und fachdidaktischen Inhalten innerhalb der Module des Lehramtsstudiums Physik vielversprechend erscheint. So kann beispielsweise der Bezug der vermittelten Inhalte zum Physikunterricht in der Schule hergestellt oder für begrifflich-konzeptionelle Fragestellungen sensibilisiert werden. An der Friedrich-Alexander-Universität Erlangen-Nürnberg wurde eine Neukonzeption der einführenden Experimentalphysik-Vorlesungen 1 (Mechanik und Wärmelehre) und 2 (Elektrizitätslehre und Optik) vorgenommen: Fachwissenschaftliche und fachdidaktische Inhalte sollen - wie an anderen Standorten bereits praktiziert - ab dem ersten Fachsemester in gemeinsamen Lehrveranstaltungen vermittelt werden; nicht nebeneinander, sondern miteinander verschränkt. Das Poster stellt die Entwicklung des Konzepts, seine Kernideen sowie erste Rückmeldungen der Studierenden vor.

DD 32.2 Wed 14:00 ELP 6: Foyer

Vielfältige Lehrkräfte-Fortbildungen für vielfältige phyphox-Experimente — Ahmad Asali[1], Jirka Müller[2], Jens Noritzsch[1], •Lukas Mientus[2], Andreas Borowski[2] und Heidrun Heinke[1] — [1]RWTH Aachen — [2]Universität Potsdam

Das Zentrum D4MINT ist ein Zusammenschluss von Akteur:innen aus verschiedenen Fächern und Hochschulen. Darin arbeiten auch physikdidaktische Arbeitsgruppen aus der RWTH Aachen und der Universität Potsdam in einem Design-Based Research-Ansatz an der Entwicklung, Evaluation und Verbreitung von Lehrkräfte-Fortbildungen (LFB) zur Förderung experimenteller Kompetenzen und speziell zu Smartphone-gestützten Experimenten unter Nutzung der an der RWTH entwickelten App phyphox. Es werden eine Reihe von kleinformatigen Modulen entwickelt, die in den LFB eingesetzt werden. Sie stellen vollständige Lehrpakete für eine LFB dar und beinhalten digitale Medien zur Vorbereitung, Erläuterung, Durchführung und Auswertung der Experimente sowie eine Analyse der Messunsicherheiten und Erklärung der Sensorik. Die LFB werden für verschiedene Komplexitätsniveaus von Smartphone-gestützten Experimenten angeboten und dynamisch organisiert, so dass Lehrkräfte abhängig von Interesse und Vorkenntnissen die gewünschte Fortbildung nutzen können. Die Experimente reichen von einfachen Experimenten mit geräteinternen Sensoren und wenigen Zusatzmaterialien bis hin zu neuartigen Experimenten mit externen Sensoren, entwickelt von Lehrkräften. Auf dem Poster werden exemplarische Fortbildungsmaterialien vorgestellt.

DD 32.3 Wed 14:00 ELP 6: Foyer

NOS im Fokus: Forschung zu Vorstellungen von Physiklehrkräften — •Linda Zwick und Rita Wodzinski — Universität Kassel

Im Kasseler SFB ELCH ist ein Transferprojekt eingebunden, das über Fortbildungen das Wissenschaftsverständnis von Lehrkräften fördern möchte. Im Rahmen dieses Projekts sollen die drei folgenden Aspekte von *nature of science* (NOS) in besonderer Weise adressiert werden: (1) Erkenntnisgewinnung als Prozess und als Ziel wissenschaftlicher Forschung, (2) das dynamische Zusammenspiel von Theorien und Experimenten in der Physik sowie (3) die Zusammenarbeit und Kollaboration in der wissenschaftlichen Gemeinschaft.

Im Rahmen der Fortbildung entwickeln die Lehrkräfte gemeinsam mit Physiker:innen des SFB Unterrichtsmaterialien für die Sekundarstufe II. Dabei wird aus Forschungsperspektive der Frage nachgegangen, inwieweit sich Vorstellungsänderungen bei den Lehrkräften bezüglich der ausgewählten NOS-Aspekte im Verlauf und nach der Fortbildung ergeben und wie Elemente der Fortbildung darauf Einfluss nehmen.

Die Poster-Präsentation des Forschungsprojekts umfasst das Fortbildungskonzept, das Forschungsdesign sowie Ausschnitte der Testinstrumente zu den drei ausgewählten NOS-Aspekten.

DD 32.4 Wed 14:00 ELP 6: Foyer

Planung von Experimenten für den Physikunterricht - Vielfalt geplanter Experimente in verschiedenen Ausbildungsphasen — •Sven Levetzow und Heidi Reinholz — Universität Rostock

Die Ausbildung von Lehramtsstudierenden hat die Entwicklung der professionellen Kompetenz als Lehrkraft zum Ziel. Dabei gilt die Planung von Unterricht als eine der zentralsten Aufgabe von Lehrkräften. Sie muss im Rahmen der Ausbildung eingeführt, erprobt und reflektiert werden. Für Lehramtsstudierende in der ersten und zweiten Ausbildungsphase ist die Planung und Durchführung von Experimenten dabei unerlässlich, da es eine grundlegende Erkenntnisquelle für den Unterricht darstellt. Dieser Bedeutung des Experimentes und der Not-

wendigkeit, dieses in Planungsgesprächen umfangreich zu diskutieren, müssen sich ebenfalls Mentorinnen und Mentoren bewusst sein, da ihnen eine Schlüsselrolle bei der Professionalisierung angehender Lehrkräfte zugesprochen wird. Im speziellen Fokus dieses Posters steht die vergleichende Analyse geplanter Experimente in Bezug auf experimentelle Teilkompetenzen zu verschiedenen Zeitpunkten der Lehramtsausbildung.

DD 32.5 Wed 14:00 ELP 6: Foyer

Adaptive Lehrerfortbildung zum quantenmechanischen Weltbild — Lukas Blessing, Kim Kappl, •Philipp Scheiger und Ronny Nawrodt — Physik und ihre Didaktik, Universität Stuttgart

Durch die Stärkung der Quantenmechanik in den Bildungsstandards 2016 der Kultusministerkonferenz werden physikalische Inhaltsbereiche für den Schulunterricht relevant, die vorher nicht in allen Bildungs- und Lehrplänen der Länder standen. Eine Herausforderung dabei ist, dass das quantenmechanische Weltbild hinsichtlich der Begriffe Realität und Lokalität für manche Lehrkräfte nie ein Thema in den Fachvorlesungen des Studiums war. Folglich ist es im Rahmen von Lehrerfortbildungen von entscheidender Bedeutung, den Lehrkräften die Möglichkeit zu geben, sich sowohl fachlich als auch fachdidaktisch mit diesem Thema auseinanderzusetzen. Innerhalb des Verbundprojekts MINT-ProNed wird daher eine Lehrerfortbildung im Blended-Learning-Ansatz entwickelt, die das Thema auf verschiedenen Ebenen behandelt und somit adaptiv auf die individuellen Bedürfnisse der Lehrkräfte zugeschnitten werden kann. Ziel der verschiedenen Anforderungsebenen sind die Anschlussfähigkeit an bereits bestehende und gut funktionierende Lehrkonzepte wie den Wesenszügen der Quantenmechanik aus dem MILQ-Konzept, die Vermittlung von vertieftem Hintergrundwissen für Lehrkräfte und die Einordnung des Nobelpreises von 2022 sowie der verschiedenen Interpretationsformen der Quantenmechanik. In diesem Beitrag wird das Konzept der Lehrerfortbildung vorgestellt werden.

DD 32.6 Wed 14:00 ELP 6: Foyer

Mangelnde Implementation physikdidaktischer Innovationen - Ursachen aus Sicht der Lehrkräfte — •Jakub Knebloch, Christian Hengel, Julie Kyas, Andreas Hansch und Thomas Wilhelm — Institut für Didaktik der Physik, Goethe-Universität Frankfurt

Seit fünfzig Jahren werden in der Physikdidaktik fortlaufend neue Ideen, neue Unterrichtskonzepte und neue Unterrichtsmaterialien entwickelt. In retrospektiver Betrachtung lässt sich feststellen, dass ein Großteil der Innovationen nicht, kaum oder erst sehr spät im Klassenzimmer ankamen. Entweder blieben die Vorschläge den Lehrkräften unbekannt oder sie wurden nicht im Unterricht umgesetzt, obwohl sie bekannt waren.

Um die Ursachen zu ergründen, wurden halboffene Interviews mit Physiklehrkräften durchgeführt, in denen sie mittels vorbereiteter Leitfragen ihre Überlegungen zu den Ursachen der beschriebenen Problematik und zu Verbesserungsmöglichkeiten äußern sollten. In dem Vortrag werden die Ergebnisse der Leitfadeninterviews dargelegt.

Die Ergebnisse werden außerdem in einem Kooperationsprojekt mit dem Hessischen Kultusministerium exemplarisch als Ausgangspunkt für die Entwicklung eines Materialangebots für Lehrkräfte genutzt, das die Implementation von Videoanalyse mit iPads in die Unterrichtspraxis erleichtern soll.

DD 33: Sprache und Physikunterricht – Poster

Time: Wednesday 14:00–15:00 Location: ELP 6: Foyer

DD 33.1 Wed 14:00 ELP 6: Foyer

Eine Software zur Reduzierung von schwierigen Wörtern in Unterrichtsmaterialien — •Thomas Sean Weatherby und Thomas Wilhelm — Goethe-Universität, Frankfurt am Main

Ein essentielles Bestandteil des naturwissenschaftlichen Schulunterrichts ist das Erlernen des damit verbundenen Begriffe, worauf man nicht verzichten kann. Wenn Lehrmaterialien jedoch unnötigerweise ungewöhnliche Wörter verwenden, werden die Konzepte, die erklärt wollen sollen, weniger zugänglich. Auf diesem Poster werden eine Software und die dahinterstehende Theorie vorgestellt. Die Software bekommt als Eingabe einen Text und ein Alter und liefert als Ergebnis eine Liste von Wörtern des Textes, die die Lernenden in dem angegebenen Alter wahrscheinlich nicht kennen werden. Auf diese Weise können Lehr- und Forschungskräfte solche Listen erstellen, um diese Wörter a) bewusst im Unterricht zu erklären oder b) bei der Überarbeitung des Textes möglichst zu vermeiden. Die Theorie wird von der Definition der grundlegenden linguistischen Begriffe, der Definition und Bestimmung des Wortschatzumfangs bis hin zu deren Anwendung und der Implementierung unter Verwendung der Python-`wordfreq`-Bibliothek behandelt. Ebenso wird gezeigt, wo und wie man die Software bekommen und verwenden kann.

DD 34: Physikdidaktik und Inklusive – Poster

Time: Wednesday 14:00–15:00 Location: ELP 6: Foyer

DD 34.1 Wed 14:00 ELP 6: Foyer

Das Projekt SENSE.: Entwicklung einer Roadmap für STEAM Education — •David Bockstahler — PH Weingarten

Im Rahmen des von der EC geförderten Projekts SENSE. arbeitet ein Konsortium verschiedener Partner im eurasischen Raum an der Entwicklung einer ”Roadmap” für STEAM [Science, Technology, Engineering, Arts, Mathematics] Bildung in Europa. Um eine Anwendbarkeit weit über den Kontext der formellen Bildung hinaus zu gewährleisten, befinden sich neben Hochschulen und Bildungsnetzwerken auch NGOs, Unternehmen aus dem künstlerisch-kreativen Bereich und externe Experten in der internationalen Runde. Basierend auf dem Erfahrungswissen der Beteiligten und gestützt auf phänomen- /sinnesbasierte Zugänge zu naturwissenschaftlichem Unterricht wurde unter Einbezug vielfältiger Anspruchsgruppen ein pädagogisches Modell entwickelt, das nun an verschiedenen Standorten implementiert und evaluiert wird. Ein besonderes Augenmerk liegt dabei auf Fragen der sozialen Teilhabe sowie auf zukunftsfähiger Lernraumgestaltung. Aus den Ergebnissen sollen Empfehlungen für eine Roadmap abgeleitet werden, welche es Anwendern ermöglichen kann, STEAM Education fruchtbar in ihren Kontext einzubinden. Diese Roadmap wird von einer digitalen Plattform begleitet, die Unterstützungstools, Materialien, Publikationen und ein Netzwerk von Gleichgesinnten bieten möchte.

DD 35: Hochschuldidaktik – Poster

Time: Wednesday 14:00–15:00 Location: ELP 6: Foyer

DD 35.1 Wed 14:00 ELP 6: Foyer

Lernsequenzen zur grundlegenden Experimentalphysik - Gestaltung, Einsatz und Evaluation — Astrid Ludwig und •Heiko Krabbe — Ruhr-Universität Bochum, Deutschland

Die Wiederholung und Konsolidierung von Lerninhalten ist essenzieller Teil der Wissenskonstruktion im Studienfach Physik. Im Rahmen des Projekts ALepa wurden Lernsequenzen erstellt, um die Studierenden bei eben diesen Prozessen zu unterstützen. Die Themenbereiche umfassen hierbei die gesamten Inhalte der Grundvorlesungen zur klassischen Experimentalphysik. Bei der Entwicklung der Lernsequenzen wurde besonderes Augenmerk auf interaktive Elemente und adaptive Nutzungsmöglichkeiten gelegt. Mithilfe interaktiver Videosequenzen so wie eingebetteter Fragen und Antworten wird die Variabilität erhöht und die Studierenden somit anhaltend und nachhaltig motiviert. Ausführliche Beschreibungen der Lernziele zu Beginn jeder Lernsequenz, in Kombination mit aussagekräftigen Übersichtsfolien zu den jeweiligen Unterthemen, lassen Studierende schnell erkennen, ob eine Lernsequenz als Ganzes oder in Teilen für ihr Lernen relevant ist.

Das Poster stellt den Aufbau der Lernsequenzen detailliert dar. Es werden verschiedene Einsatzszenarien diskutiert und Evaluationsergebnisse vorgestellt.

DD 35.2 Wed 14:00 ELP 6: Foyer

Online Frühstudiumsprogramm zur Experimentalphysik an der Universität Stuttgart — •Simon Koppenhöfer und Ronny Nawrodt — Physik und ihre Didaktik, Universität Stuttgart

Für besonders begabte Schülerinnen und Schüler (SuS) wird an vielen Universitäten ein Förderprogramm im Rahmen des Früh- bzw. Schülerstudiums angeboten. Hier können die SuS bereits ab beispielsweise Klasse 10 an Grundvorlesungen teilnehmen. Für viele ist eine solche Teilnahme aufgrund des großen Zeitbedarfs und einer weiten Anreise nur schwer möglich. Häufig fehlen darüber hinaus mathematische Grundlagen, wenn Physikvorlesungen für die Begabtenförderung gewählt werden.
Dieser Beitrag präsentiert ein erprobtes Konzept für ein Online Frühstudium, das an der Universität Stuttgart erfolgreich etabliert wurde. Basierend auf Vorlesungsaufzeichnungen wird in einem maßgeschneiderten Begleitseminar online sowohl mathematische Grundlagen als auch physikalische Inhalte der Vorlesung und der Übungsaufgaben besprochen.
Am Ende können die SuS an einer Abschlussprüfung auf Universitätsniveau teilnehmen. Der erfolgreich abgeschlossene Kurs wird bei einem späteren Studium im MINT-Bereich vollständig anerkannt und schafft so in der Studieneingangsphase Freiräume für weitere individuelle Vertiefungen.

DD 35.3 Wed 14:00 ELP 6: Foyer

Evaluation des Einsatzes von Smartphone-Experimentier- und Programmieraufgaben im Übungsbetrieb — Simon Z. Lahme[1], Dominik Dorsel[2], Christoph Stampfer[2], Pascal Klein[1], •Heidrun Heinke[2] und Sebastian Staacks[2] — [1]Georg-August-Universität Göttingen — [2]RWTH Aachen University

Im Projekt Physik.SMART, gefördert durch die Stiftung Innovation in der Hochschullehre, soll exemplarisch für verschiedene Adressatengruppen demonstriert werden, wie Smartphone-basierte Studierenden-Experimente die tradierte Physiklehre an Hochschulen grundlegend verändern können. Mit der App phyphox, einfachem Zusatzequipment und externen Sensorboxen wird eine breite Vielfalt kostengünstiger, digital gestützter Experimentieraufgaben in allen Teilgebieten der Physik bereitgestellt, die zusätzlich um Python-Programmieraufgaben ergänzt werden. Solche Aufgaben wurden im WS 2023/24 systematisch auf den Übungsblättern zur einführenden Vorlesung Experimentalphysik I an der RWTH Aachen mit ca. 300 Studierenden eingesetzt und in Kooperation mit der Universität Göttingen evaluiert. Die Studierenden bearbeiteten diese Aufgaben wie die klassischen Übungsaufgaben jeweils innerhalb einer Woche in Gruppen von bis zu drei Personen. Es folgte jeweils eine kurze Evaluation mit einem Online-Fragebogen, z.B. bezüglich Adäquatheit, Schwierigkeit und Verbesserungsmöglichkeiten. Zudem wurden in einer abschließenden Umfrage affektive Wirkungen des Projektes, z.B. bezüglich Neugier, Interesse, Autonomieerleben und Zugehörigkeitsgefühl untersucht. Auf dem Poster werden das Evaluationskonzept und erste Ergebnisse präsentiert.

DD 35.4 Wed 14:00 ELP 6: Foyer

Relevanz und Anforderungen experimenteller Kompetenzen in fachlichen Bachelorarbeiten — •Dane-Vincent Schlünz[1,2], Daniel Laumann[1,2], Robert Schmidt[1] und Markus Donath[1] — [1]Physikalisches Institut — [2]Institut für Didaktik der Physik, Universität Münster

Eine Bachelorarbeit stellt für Physikstudierende die erste Auseinandersetzung mit authentischen Forschungsprozessen dar. In der Experimentalphysik umfasst dies die Arbeit an komplexen Versuchsaufbauten in einer Forschungsgruppe mit fachlich-methodischen Herausforderungen, für welche Studierende experimentelle Kompetenzen benötigen.

Im Rahmen einer Interviewstudie mit ProfessorInnen (N=11) sowie Postdocs/Promovierenden (N=10) der Universität Münster werden die Relevanz experimenteller Kompetenzen für eine Bachelorarbeit und eine Einschätzung typischer Probleme von Studierenden erhoben. Die Auswertung mittels qualitativer Inhaltsanalyse zeigt bzgl. der Relevanz, dass je nach Ziel der Bachelorarbeit mehrheitlich Kompetenzen der Durchführung und Auswertung eines Experiments als obligatorisch angesehen werden. Die zu Beginn der Bachelorarbeit bei den Studierenden vorhandene Ausprägung der Kompetenzen in diesen Bereichen wird zumeist als ausbaufähig oder unzulänglich eingestuft. Aus diesen Einschätzungen lassen sich Schwerpunkte für die experimentelle Ausbildung wie z. B. das Berücksichtigen von Messunsicherheiten, das Interpretieren, Diskutieren und Präsentieren von Ergebnissen oder Kompetenzen wie das Troubleshooting am Aufbau und das Entwickeln von Versuchsstrategien ableiten.

DD 35.5 Wed 14:00 ELP 6: Foyer

Datenmanagement und FAIR-Data im physikalischen Anfänger*innen-Praktikum — •Rebekka Murati, Alexander Schreider, Cedric Kessler, Johannes Marczinkowski, Ralph Ernstorfer und Nina Owschimikow — Institut für Optik und Atomare Physik, Technische Universität Berlin

In der modernen Wissenschaft werden Daten in einem nie dagewesenen Umfang erzeugt. Diese können nicht mehr klassisch in Form übersichtlicher Tabellen dargestellt werden, sondern liegen als Dateien vor, die, um nutzbar zu sein, umfangreich dokumentiert werden müssen. Der Umgang mit großen Datenmengen wird dadurch zu essenziellem professionellem Know-how, dessen Grundprinzipien durch die Einigung auf FAIR-Kriterien [1] fachübergreifend sind, und damit zum wichtigen Ausbildungsinhalt für Physikstudierende. Im Rahmen des physikalischen Anfängerinnen-Praktikums an der TU Berlin wird seit Sommersemester 2023 die Integration von Datenmanagement und FAIR-Data Prinzipien in das Praktikum entwickelt. Neben der Vermittlung der Grundprinzipien des Datenmanagements ist ein Umstieg von Papierlaborbüchern auf elektronische Laborbücher erfolgt. Innerhalb der Einträge werden diejenigen Daten und Parameter, die die Studierdenden als wichtige Metadaten erachten, markiert und in einer standardisierten, für ein Computerprogramm lesbaren Art dokumentiert. Die dokumentierten Daten werden dann automatisiert an den Rohdatensatz angehängt. Dieser Prozess sichert die Wiederverwendbarkeit der Daten für Dritte, was in ausgewählten Experimenten geübt wird.

DD 35.6 Wed 14:00 ELP 6: Foyer

Management von Versuchsdaten über die Möglichkeiten des Papierlaborbuch hinaus am Beispiel von openBIS — •Cedric Kessler, Johannes Marczinkowski, Stefan Mohn, Rebekka Murati, Valentina Alberini, Antonia Pérez-Cerezo, Andrea Merli, Christian Hennig, Ralph Ernstorfer und Nina Owschimikow — Institut für Optik und Atomare Physik, Technische Universität Berlin

OpenBIS [1] ist eine freie Software zur elektronischen Laborbuchführung inklusive Datenspeicherung und Verwaltung von Laborinformationen. Entwickelt von der ETH Zürich mit Schwerpunkt in Bioinformationswissenschaften, wird die Open-Source Software von vielen Arbeitsgruppen in unterschiedlichsten Bereichen verwendet. Über eine lokal gehostete Webseite werden individuell anpassbare Laborbuchvorlagen ausgefüllt und mit Proben, Equipment sowie anderen Laborbüchern verknüpft. Zugehörige (Mess-) Daten können manuell oder vom Instrument automatisch mit relevanten Metadaten hochgeladen werden. Zugriff erfolgt über eine Python, Java und JavaScript API und ermöglicht die einfache Integration in den Auswertungsprozess. Die vollumfängliche Anpassbarkeit ermöglicht verschiedene Didaktikkonzepte zur Anleitung der Studierenden von vorgegebenen Feldern bis zur Freitexteingabe für erfahrungsbasiertes Lernen.

[1] Barillari, C., Et al. (2016). openBIS ELN-LIMS: an open-source database for academic laboratories. Bioinformatics (Oxford, England), 32(4), 638 - 640.

DD 36: Praktika und neue Praktikumsversuche – Poster

Time: Wednesday 14:00–15:00 Location: ELP 6: Foyer

DD 36.1 Wed 14:00 ELP 6: Foyer

HEXBUGs zur Modellierung von (aktiver) Brown'scher Bewegung — •Michael Himpel — Institut für Physik, Universität Greifswald

Die als Spielzeug entwickelten HexBugs sind kleine Roboter mit Vibrationsmotor, die sich selbst durch diese Vibration fortbewegen können. Sie werden in der Forschung genutzt um aktive Brown'sche Teilchen im Experiment zu simulieren.

In diesem Beitrag wird gezeigt, wie man mit den HexBugs asymmetrische Zahnräder antreiben kann. Dies ist ein Musterbeispiel für den Unterschied zu "normaler" Brown'scher Bewegung, die im Zeitmittel keinen Impuls auf ein Zahnrad übertragen kann.

DD 36.2 Wed 14:00 ELP 6: Foyer

Datenauswertung im LIGO-Experiment: Matched Filtering im Analogie-Experiment — •Michael Daam[1,2], Antje Bergmann[1], Carsten Rockstuhl[1] und Ronny Nawrodt[2] — [1]Institut für Theoretische Festkörperphysik, Karlsruher Institut für Technologie — [2]5. Physikalisches Institut, Universität Stuttgart

Seit 2015 werden mit Detektoren wie dem LIGO-Experiment Gravitationswellen vermessen, z.B. solche, die bei der Verschmelzung schwarzer Löcher entstehen. Matched Filtering ist dabei eine wichtige Methode, um im kontinuierlichen Datenstrom des Detektors die zeitlich begrenzten Signale zu identifizieren, obwohl deren Amplitude das Rauschen häufig kaum übersteigt.

Für unser LIGO-Analogie-Experiment (DD 45.2, DPG-Frühjahrstagung 2021) haben wir ein frei verfügbares Programm entwickelt, das Lernenden ohne Programmierkenntnisse grundlegende Einblicke in die Datenauswertung in der Gravitationswellenastronomie ermöglicht. Von einer graphischen Benutzeroberfläche aus kann auf wichtige Funktionen des Python-Pakets PyCBC (doi:

10.5281/zenodo.10137381) zugegriffen werden. So können Gravitationswellen nachempfundene Signale erzeugt und als Input im Analogie-Experiment verwendet werden. Nach der Messung werden die experimentellen Daten mit solchen Signalen verglichen, um Gravitationswellen von Störimpulsen zu unterscheiden und die Massen der beteiligten schwarzen Löcher abzuschätzen. Die Ergebnisse werden graphisch veranschaulicht. Im Beitrag wird diese Software vorgestellt und die Integration in das bestehende Analogie-Experiment erklärt.

DD 36.3 Wed 14:00 ELP 6: Foyer

Eine Grundpraktikumstaugliche Demonstration der Kramers-Kronig-Relation — •Clarissa Ludwig[1,2], Harald Kübler[1] und Ronny Nawrodt[2] — [1]Universität Stuttgart, Physikalisches Institut — [2]Universität Stuttgart, Physik und ihre Didaktik

Studierende des B.A. und B.Sc. Physik behandeln die normale und anomale Dispersion von elektromagnetischen Wellen im Zusammenhang mit der Absorption eines Mediums häufig nur kurz in den Vorlesungen zur Experimentalphysik. Eine entsprechende Vertiefung dieses Themas kann mit einem passenden Grundpraktikumsversuch geboten werden. Damit einher geht der von H. A. Kramers und R. Kronig erstmals formulierte mathematische Zusammenhang zwischen der Absorption und der Dispersion eines Mediums, der heute als die Kramers-Kronig-Relationen bekannt ist. In diesem Beitrag wird solch ein Grundpraktikumsversuch vorgestellt, wobei der Fokus auf der Bestimmung der Dispersionskurven von Farbstofflösungen liegt. Diese werden hier sowohl mittels numerischer Methoden aus den Transmissionsspektren als auch mithilfe eines Prismenspektrometers bestimmt. Bei der direkten Bestimmung mithilfe des Spektrometers kommt eine Webcam zum Einsatz, die neben dem sichtbaren Teil des Spektrums auch Zugang zum Nahinfrarotbereich erlaubt.

DD 36.4 Wed 14:00 ELP 6: Foyer

Einführung in die Datenauswertung mit Python im physikalischen Praktikum für Lehramt- und Nebenfachstudierende — •Maximilian Kühlkamp, Ralf Detemple, Dominik Dorsel und Heidrun Heinke — RWTH Aachen University

In einer Zeit, in der die programmiersprachenbasierte Datenauswertung die Naturwissenschaften dominiert und informatische Grundkonzepte in der schulischen Bildung immer wichtiger werden, ist es auch für angehende Physik-Lehrkräfte wichtig, in diesen Bereichen ausreichende Kompetenzen zu erwerben. Auf Grundlage dessen wurde ein Modul zur Datenauswertung mit Python für Lehramtsstudierende im physikalischen Praktikum entwickelt. In diesem Praktikumsversuch sollen die Lehramtsstudierenden mit Jupyter-Notebooks in die Grundlagen der Datenauswertung mit Python eingeführt und unter Verwendung eines Scaffolding-Ansatzes zum selbstständigen Umgang mit Python in zukünftigen Auswertungen befähigt werden. Das entwickelte Modul wurde probeweise auch im Nebenfachpraktikum für Studierende der Chemie und Biologie eingesetzt und wurde dort von 75 Teilnehmenden durchgeführt und evaluiert.

DD 37: Präsentation von Experimenten – Poster

Time: Wednesday 14:00–15:00 Location: ELP 6: Foyer

DD 37.1 Wed 14:00 ELP 6: Foyer

Laborino - Das Schulexperiment neu gedacht — •Christian Schulze, Jasmin Andersen und Dietmar Block — Institut für Experimentelle und Angewandte Physik, Kiel, Deutschland

Der Laborino wird von uns gerne als Hosentaschenlabor bezeichnet, weil er wegen seiner kompakten und robusten Bauform in fast jedem Experiment einen geeigenten Platz findet. An Hand von einigen Beispielexperimenten möchten wir mit diesem Beitrag einen konkreten Eindruck vermitteln, wie vielfältig der Laborino in den meisten Schulexperimenten gewinnbringend eingesetzt werden kann. Dabei können mithilfe der digitalen Datenverarbeitung physikalische Zusammenhänge in wenigen Sekunden in Echtzeit demonstriert werden. Welche didaktischen Besonderheiten sich daraus ergeben und was unsere ersten Erfahrungen aus der Praxis sind, möchten wir gerne mit ihnen diskutieren und bieten ihnen dazu am Poster die Gelegenheit den Laborino auszuprobieren.

DD 37.2 Wed 14:00 ELP 6: Foyer

Laborino: Die smarte Messbox für Schule und Universität — •Dietmar Block, Jasmin Andersen und Christian Schulze — IEAP der CAU Kiel, Leibnizstr. 15, 24098 Kiel

Beim Laborino handelt es sich um eine kleine, leichte und robuste Messbox auf Basis eines Arduino Nano, die sehr einfach in verschiedenste Schulexperimente integriert werden kann. Sie übermittelt die Messdaten von diversen Sensoren via Bluethooth an ein beliebiges Smartdevice, auf dem die App Phyphox installiert ist. Die App Phyphox von der RTWH Aachen ist sowohl unter Lehrerinnen und Lehrern als auch Schülerinnen und Schülern weit verbreitet und sehr intuitiv zu bedienen. Eine Besonderheit des Laborinos ist seine umfangreiche Ausstattung mit verschiedensten Sensoren. Dabei können nicht nur die fest verbauten internen Sensoren genutzt werden, sondern durch ein Stecksystem sehr einfach auch weitere externe Sensoren eingebunden werden. In diesem Beitrag wird die Bedienung des Laborinos vorgestellt, sowie die Eigenschaften und Leistungsmerkmale der Sensoren für physikalische Fragestellungen im Schulunterricht bewertet. Als Open-Educational-Ressource sind alle Baupläne, Software und Anwendungsbeispiele frei im Internet unter www.laborino.de verfügbar.

DD 37.3 Wed 14:00 ELP 6: Foyer

Eine Box, viele Möglichkeiten: Experimentieren im Kontext Klima — •Christopher Jörgens, Cornelia Geller und Hendrik Härtig — Universität Duisburg-Essen

Wie der Physikunterricht entscheidend zur Klimabildung beitragen kann, ist ein wichtiger Bestandteil physikdidaktischer Forschung geworden, da die komplexen Zusammenhänge im Kontext Klima durch geeignete Lernmaterialien zugänglich gemacht werden müssen. Mit dem Ziel, mit Lernmaterialien in diesem Kontext vor allem fachmethodische Kompetenzen zu fördern, haben wir ein Klimamodell in einer Box entwickelt. Dieses soll die komplexen Einflüsse verschiedener Klimafaktoren - wie z.B. den Sonnenstand, den Wind oder den Anteil des Kohlenstoffdioxids - auf die Temperaturentwicklung simulieren. Die Variation entsprechender Klimafaktoren kann dabei einzeln und in Kombinationen erfolgen. Die Box liefert mittels mehrerer Sensoren Messdaten, die mit Hilfe der Phyphox-App graphisch dargestellt werden. Auf dem Poster werden neben den Variationsmöglichkeiten in und an der Box auch die Messvorrichtung und erste Messergebnisse präsentiert. Darauf aufbauend diskutieren wir mögliche Einsatzszenarien für das Experimentieren im Unterricht.

DD 38: Astronomie – Poster

Time: Wednesday 14:00–15:00 Location: ELP 6: Foyer

DD 38.1 Wed 14:00 ELP 6: Foyer

Insightful exact three-dimensional representation of curved spacetime — •Hans-Otto Carmesin — Athenaeum, Stade — Studienseminar Stade — Universität Bremen, Fachbereich 1

Astrophysics, general relativity and curved spacetime motivate students. However, so far, it was not possible to represent three-dimensional curved spacetime in an exact manner. But now, such an exact and **clarifying** representation is possible: From the usual algebraic description using a metric tensor, changes of lengths and of volume are derived. These are represented with help of transparent plastic material in a three-dimensional and exact manner.

This representation is **realistic**, as the above changes of lengths can be measured. It is **valuable**, as students can derive the cosmological constant Λ, though Einstein was unable to derive Λ from his ingenious general relativity. Perlmutter (1998) measured that value of Λ.

Similarly, deriving & using the dynamics of the above volumes, students can unify relativity, gravity and quanta.

Our results are in precise accordance with observation and fully derived from physical principles [1,2]. Experiences from teaching in research clubs and general study courses at a university are presented.

[1] Carmesin, H.-O. (2023): Geometrical and Exact Unification of Spacetime, Gravity and Quanta. Berlin: Verlag Dr. Köster.

[2] More info: https://www.researchgate.net/profile/Hans-Otto-Carmesin

DD 38.2 Wed 14:00 ELP 6: Foyer

Students Learn to Derive Universal Properties of Gravitons — •Hans-Otto Carmesin — Athenaeum, Stade — Studienseminar Stade — Universität Bremen, Fachbereich 1

Gravitation is omnipresent. However, it has been criticized since Newton (1686) that the **propagation** of the gravitational interaction has not yet been explained. But this propagation can now be derived by students in an elegant & exact manner: Based on the usual algebraic structure of general relativity, the dynamics of volume are analyzed & derived. These dynamics are **realistic**, as they can be

measured. They are **meaningful**, as they imply universal properties of the dynamics of volume and gravity at various interconnected levels, at the level of: quanta [1], curvature of spacetime, tensors and spins, fields and potentials, the density of dark energy, the expansion of space since the Big Bang, the object that transmits gravity - the graviton.

The graviton is **insightful**, as it interconnects the above fields of knowledge about gravity, and tests are provided. Thereby, all results are in precise accordance with observation and fully derived from physical principles [2,3]. Experiences from teaching in research clubs and general study courses at a university are presented.

[1] Carmesin, H.-O. (2023): Students Exactly Derive Quantization and its Universality. PhyDid B, pp. 39-44.
[2] Carmesin, H.-O. (2023): Geometrical and Exact Unification of Spacetime, Gravity and Quanta. Berlin: Verlag Dr. Köster.
[3] More info: https://www.researchgate.net/profile/Hans-Otto-Carmesin

DD 38.3 Wed 14:00 ELP 6: Foyer

Students Learn to Derive the Energy Density of Volume — •Hans-Otto Carmesin — Athenaeum, Stade — Studienseminar Stade — Universität Bremen, Fachbereich 1

Volume is essential in everyday live - it basically describes the amount of space. However, Einstein (1917) proposed a *cosmological constant* Λ, which seems to assign an energy density to space, the *dark energy*. In fact, Perlmutter (1998) discovered the acceleration of the expansion of the universe, and this acceleration provides a value of Λ, though Einstein was unable to predict the value of Λ with his ingenious theory of general relativity. But here, we show how students can derive the energy density u_{vol} of volume and the theoretical value of the cosmological constant Λ_{theo} in an elegant and exact manner: Based on the usual algebraic structure of general relativity, the dynamics of volume are analyzed & derived. These dynamics are **realistic**, as they can be measured. They are **meaningful**, as they imply the process of formation of volume as well as the density of volume. Thereby, the derived values of u_{vol} and Λ_{theo} are in precise accordance with observation and fully derived from physical principles [1-3]. Experiences from teaching in research clubs and general study courses at a university are presented.

[1] Carmesin, H.-O. (2021): Quanta of Spacetime Explain Observations, Dark Energy, Graviton and Nonlocality. Berlin: Verlag Dr. Köster.
[2] Carmesin, H.-O. (2023): Geometrical and Exact Unification of Spacetime, Gravity and Quanta. Berlin: Verlag Dr. Köster.
[3] More info: https://www.researchgate.net/profile/Hans-Otto-Carmesin

DD 38.4 Wed 14:00 ELP 6: Foyer

Students Analyze the Impact of the H_0 Tension of the Worldview — •Hans-Otto Carmesin — Athenaeum, Stade — Studienseminar Stade — Universität Bremen, Fachbereich 1

The modern worldview is based on the expansion of space (Einstein 1917, Hubble 1929). Friedman (1922) & Lemaitre (1927) used Einstein's general relativity to derive a time evolution of that expansion. They used the Hubble constant H_0, a key parameter for the rate of expansion. But Riess (2022) observed at the 5 σ confidence level that H_0 is not constant: This problem is named H_0 tension. What impact does it have on the worldview? We show how students can derive the source of the H_0 tension: Based on the usual algebraic structure of Einstein's ingenious general relativity, the dynamics of volume are analyzed & derived. These dynamics are used to analyze the H_0 tension: The increase of heterogeneity in the universe causes an increase of $H_0(t)$ with time. $H_0(t)$ is derived and implies that the age of the universe is 500 000 000 years smaller than expected before. Our results are precise accordance with observation and fully derived from physical principles [1-3]. Experiences from teaching in research clubs and general study courses at a university are presented.

[1] Carmesin, H.-O. (2021): Quanta of Spacetime Explain Observations, Dark Energy, Graviton and Nonlocality. Berlin: Verlag Dr. Köster.
[2] Carmesin, H.-O. (2023): Geometrical and Exact Unification of Spacetime, Gravity and Quanta. Berlin: Verlag Dr. Köster.
[3] More info: https://www.researchgate.net/profile/Hans-Otto-Carmesin

DD 38.5 Wed 14:00 ELP 6: Foyer

Students Learn to Derive the Universal Elementary Charge — •Hans-Otto Carmesin — Athenaeum, Stade — Studienseminar Stade — Universität Bremen, Fachbereich 1

Electricity is omnipresent. However, its key quantity the elementary charge - has not been explained before 2021 [1]. We show how students can derive it: Based on the usual algebraic structure of Einstein's ingenious general relativity, the dynamics of volume and of its excitation states, quanta of spacetime, QST, are analyzed & derived [2]. An elementary particle mass forms from volume. That process is analyzed via the QST: A triple of QST forms such a mass at lowest energy. Each QST has a ω_i. These cause six forced oscillations. These form the electric field. The triple forms the electric charge, in precise accordance with observation: relative deviation 10^{-8}. Our results are precise accordance with observation and fully derived from physical principles [1-4]. Further results are outlined, e. g. about the electroweak interaction. Experiences from teaching in research clubs and general study courses at a university are presented.

[1] Carmesin, H.-O. (2021): The Elementary Charge Explained by Quantum Gravity. Berlin: Verlag Dr. Köster.
[2] Carmesin, H.-O. (2021): Cosmological and Elementary Particles Explained by Quantum Gravity. Berlin: Verlag Dr. Köster.
[3] Carmesin, H.-O. (2023): Geometrical and Exact Unification of Spacetime, Gravity and Quanta. Berlin: Verlag Dr. Köster.
[4] More info: https://www.researchgate.net/profile/Hans-Otto-Carmesin

DD 38.6 Wed 14:00 ELP 6: Foyer

Students Learn to Solve the Cosmological Constant Problem — •Hans-Otto Carmesin — Athenaeum, Stade — Studienseminar Stade — Universität Bremen, Fachbereich 1

Electricity and volumes are omnipresent. However, the theory of quantum electrodynamics predicts an energy density of the electromagnetic field u_{QED} that is a factor of 10^{122} larger than the observed energy density of volume u_{vol}, this is the cosmological constant problem, CCP. u_{vol} is essentially the observed dark energy. We show how students can solve it in an exact and elegant manner: Based on the usual algebraic structure of Einstein's ingenious general relativity, the dynamics of volume are analyzed & derived. With it, the energy density u_{vol} is derived and identified as a kinetic energy density. The potential energy density of $u_{\text{vol,pot}}$ compensates u_{vol} and implies energy conservation during the expansion of space. Moreover, the volume dynamics show that u_{QED} is compensated by its potential energy density $u_{\text{QED,pot}}$, this solves the CCP. Moreover, the Casimir force is derived.

Our results are in precise accordance with observation and fully derived from physical principles [1,2]. Experiences from teaching in research clubs and general study courses at a university are presented.

[1] Carmesin, H.-O. (2023): Geometrical and Exact Unification of Spacetime, Gravity and Quanta. Berlin: Verlag Dr. Köster.
[2] More info: https://www.researchgate.net/profile/Hans-Otto-Carmesin

DD 38.7 Wed 14:00 ELP 6: Foyer

Students Learn to Derive Nonlocality form Fundamental Physics — •Hans-Otto Carmesin — Athenaeum, Stade — Studienseminar Stade — Universität Bremen, Fachbereich 1

Quantum cryptography is an exciting new communication technology. It uses Einstein's (1948) Spukhafte Fernwirkung: Nonlocality. How does nonlocality work? We show how students can solve it in an exact and elegant manner: Based on the usual algebraic structure of Einstein's ingenious general relativity, the dynamics of volume are analyzed & derived. With it, the postulates of quantum physics are derived. Thereby, the physical meaning of the wave function is clarified. With it, two physical transformations of the states in Hilbert space are derived: the time evolution via the Schrödinger equation, and the swapping of solutions of that equation. It is shown that this swapping is not limited by the velocity of light and thus provides nonlocality.

Our results are precise accordance with observation and fully derived from physical principles [1,2]. Experiences from teaching in research clubs and general study courses at a university are presented.

[1] Carmesin, H.-O. (2023): Geometrical and Exact Unification of Spacetime, Gravity and Quanta. Berlin: Verlag Dr. Köster.
[2] More info: https://www.researchgate.net/profile/Hans-Otto-Carmesin

DD 38.8 Wed 14:00 ELP 6: Foyer

Lauf der Planeten: Die Rolle von Embodiment bei der Veränderung mentaler Modelle — •Maximilian Alexander Loch[1,3], Malte S. Ubben[2] und Emmanuel Rollinde[3] — [1]Institut für Didaktik der Physik - Universität Münster, Münster, Deutschland — [2]Institut für Fachdidaktik der Naturwissenschaften - Abteilung Physik und Physikdidaktik - Technische Universität Braunschweig, Braunschweig, Deutschland — [3]Laboratoire de Didactique André Revuz CY Cergy Paris Université, Paris, Frankreich

Nach der Durchführung einer Pilotstudie, deren Ziel es war, herauszufinden, welche beispielhaften mentalen Modelle über das Sonnensystem bei Schülern existieren, haben wir die Studie auf eine Stichprobengröße von 100 Lernenden der Klassen 5 bis 13 mit 93 Prätests und 78 Posttests erweitert. Wir beobachteten, welche Auswirkungen der Einsatz von Embodied Learning im Rahmen des Erasmus+ Projektes "Aristarchus" haben könnte, das sich auf die Vermittlung astronomischer Grundlagen mit dem "Human Orrery" konzentriert. Dies geschah durch die Durchführung von Prä- und Posttests, deren Hauptbestandteil es war, das Sonnensystem vor und nach den im Rahmen des Aristarchus-Projekts durchgeführten Lernsequenzen zu zeichnen. Anhand der Ergebnisse haben wir induktiv eine Reihe von Items entwickelt, um die Zeichnungen zu klassifizieren, ihre Entwicklung zu analysieren und die zuvor vorgeschlagenen Klassifizierungen zu verfeinern. Während die Gestalt eines mentalen Modells leicht mit einer Zeichnung erfasst werden kann, kann das funktionale Verständnis nur teilweise dargestellt werden und wird Gegenstand zukünftiger Studien sein.

DD 38.9 Wed 14:00 ELP 6: Foyer

Analysis of Gravitational Instabilities in Stars Using a Model Sequence — •Lina Jarck[1] and Hans-Otto Carmesin[1,2,3] — [1]Athenaeum, Stade — [2]Studienseminar Stade — [3]Universität Bremen, Fachbereich 1

In a student research club, we investigate gravitational instabilities in stars. To do so, we develop a progressive sequence of models with increasing predictive power. Throughout our model sequence, we utilize the appropriate model for each specific inquiry. The models also provide opportunities for verification and comparison. First, we apply a model of Sun with variable density as a function of radius. As this function is widely known, we test our model. For further progression and validation of our method, we construct a model with variable density for White Dwarfs, where the Chandrasekhar limit confirms our results. Progressively, we develop a model with variable density for Neutron Stars and black holes. We represent the results within a specially created phase diagram. In this diagram, the states of stars are shown as a function of radius and mass. In the diagram, there are Neutron Stars, a transition-line to possible Quark-Gluon-Stars, and a transition-line to black holes.

DD 39: Sonstiges – Poster

Time: Wednesday 14:00–15:00 Location: ELP 6: Foyer

DD 39.1 Wed 14:00 ELP 6: Foyer

Themen der Nanowissenschaften und -technologien im Unterricht: Ein systematisches Literaturreview — •Judith Schmid[1], Fabian Hennig[1], Joaquin M. Veith[2] und Philipp Bitzenbauer[1] — [1]FAU Erlangen-Nürnberg — [2]Universität Leipzig

Dieses Poster gibt einen Überblick über (i) empirisch evaluierte Unterrichtskonzepte, (ii) für den Unterricht entwickelte Experimente und (iii) in der Literatur dokumentierte Schülervorstellungen zu Themen der Nanowissenschaften und -technologien. Mittels einer Datenbankrecherche (über SCOPUS und Web of Science) wurden elf empirische Studien zum Lehren und Lernen nanowissenschaftlicher Themen im naturwissenschaftlichen Unterricht identifiziert, die zwischen 2012 und 2021 veröffentlicht wurden. Der Literaturüberblick zeigt, dass es in der Literatur zwar einige in der Praxis erprobte Unterrichtskonzepte zu verschiedenen Themen der Nanowissenschaften und -technologien gibt, dass aber gerade multimediale Lernumgebungen, z.B. unter Nutzung von Virtual Reality oder Augmented Reality, in diesem thematischen Kontext bisher wenig genutzt werden, obwohl sie sich im Hinblick auf den unterrichtlichen Umgang mit den in der Literatur berichteten Schülervorstellungen als vielversprechend erwiesen haben. Stattdessen konzentrierte sich die fachdidaktische Entwicklungsarbeit bisher vor allem auf die Bereitstellung von im Unterricht durchführbaren Experimenten zu Themen der Nanowissenschaften und -technologien.

DD 39.2 Wed 14:00 ELP 6: Foyer

Offene Fragen zur Relevanz soziodemografischer Merkmale für Interesse und Selbstkonzept im Kontext des schulischen Lehrens und Lernens in den Naturwissenschaften — •Novid Ghassemi und Marcus Kubsch — Freie Universität Berlin

Internationale Vergleichsstudien haben wiederholt gezeigt, dass in Deutschland ein besonders starker Zusammenhang zwischen den sozioökonomischen Voraussetzungen, häufig konfundierter Migrationserfahrung, und dem schulischen Erfolg von Schüler*innen bestehen. Diese Problematik scheint von den Naturwissenschaftsdidaktiken in Deutschland bislang wenig aufgegriffen worden zu sein: Während zum Beispiel erste Erkenntnisse für Zusammenhänge zwischen Geschlecht und Interesse sowie Selbstkonzept für das Fach Physik vorliegen, liegen kaum Informationen zur Bedeutsamkeit weiterer soziodemografischer Merkmale vor. Hier mangelt es sowohl an empirischen Kenntnissen über grundlegende Zusammenhänge als auch an angemessenen Unterrichtskonzeptionen. Nicht zuletzt sollten diese Aspekte zwar als Querschnittsthemen in die formale Lehrer*innenbildung integriert sein, ob möglicherweise spezifisch naturwissenschaftsdidaktische Aspekte bereits in ausreichendem Umfang berücksichtigt werden, ist jedoch fraglich.

DD 39.3 Wed 14:00 ELP 6: Foyer

Offene Fragen zur Relevanz soziodemografischer Merkmale für Interesse und Selbstkonzept im Kontext des schulischen Lehrens und Lernens in den Naturwissenschaften — •Novid Ghassemi und Marcus Kubsch — Freie Universität Berlin

Internationale Vergleichsstudien haben wiederholt gezeigt, dass in Deutschland ein besonders starker Zusammenhang zwischen den sozioökonomischen Voraussetzungen, häufig begleitet von Migrationserfahrungen, und dem schulischen Erfolg von Schüler*innen bestehen. Diese Problematik scheint von den Naturwissenschaftsdidaktiken in Deutschland bislang wenig aufgegriffen worden zu sein: Während zum Beispiel erste Erkenntnisse für Zusammenhänge zwischen Geschlecht und Interesse sowie Selbstkonzept für das Fach Physik vorliegen, liegen kaum Informationen zur Bedeutsamkeit weiterer soziodemografischer Merkmale vor. Hier mangelt es sowohl an empirischen Kenntnissen über grundlegende Zusammenhänge als auch an angemessenen Unterrichtskonzeptionen. Nicht zuletzt sollten diese Aspekte zwar als Querschnittsthemen in die formale Lehrer*innenbildung integriert sein, ob möglicherweise spezifisch naturwissenschaftsdidaktische Aspekte bereits in ausreichendem Umfang berücksichtigt werden, ist jedoch fraglich.

DD 39.4 Wed 14:00 ELP 6: Foyer

Titel: Konzeption, Entwicklung und Evaluation eines Laserlabors für Schüler:innen — •Roman Gruchow, Lukas Maczewsky und Heidi Reinholz — AG Didaktik der Physik, Universität Rostock

Das Lehr-Lern-Labor (LLL) PhySch (Physik und Schule) an der Universität Rostock bietet fachlich breit aufgestellte und methodisch vielfältig gestaltete Projekte für Schüler:innen an. Aktuell wird die Konzeption für ein Laserlabor und deren Umsetzung im Design-Based Research Verfahren entwickelt.

Die Module des Projektangebotes wurden zunächst ausgehend von einer Analyse möglicher inhaltlicher Schwerpunkte der Laserphysik geplant und den Studierenden als Arbeitsgrundlage bereitgestellt. Anschließend entwickeln die Studierenden daraus im Rahmen des LLLs das Projekt für Schüler:innen. Dabei wird untersucht, inwiefern Inhalte und Konzepte der Laserphysik durch Studierende an Schüler:innen vermittelt werden können. Dafür wurden beispielsweise durch Akzeptanzinterviews Lernschwierigkeiten auf Studierendenebene in Bezug auf die Inhalte der Laserphysik analysiert. In einem nächsten Schritt werden die Module durch die Studierenden als LLL-Angebote durchgeführt. Das Laserlabor wird durch eine Evaluation begleitet, bei der die Motivation der teilnehmenden Schüler:innen mittels Fragebogen in Prä-Post-Testung erhoben werden. Dies soll im Sinne des DBR zu einer iterativen Verbesserung des Angebotes führen.

DD 40: Hauptvortrag 4 (Georg-Kerschenstein-Preis): Müller

Time: Wednesday 15:10–16:00 Location: ELP 6: HS 2

Prize Talk DD 40.1 Wed 15:10 ELP 6: HS 2

Quantenphysik in der Schule: Neue Perspektiven durch Quantentechnologien — •Rainer Müller — TU Braunschweig — Träger des Georg-Kerschensteiner-Preises 2024

Die Quantenphysik ist seit vielen Jahren als Thema in der Oberstufe fest etabliert. Fachdidaktisch fundierte Unterrichtskonzepte wie die Wesenszüge der Quantenphysik haben sich etabliert und auch Eingang in die Bildungsstandards gefunden. Mit den Quantentechnologien eröffnen sich nun neue Möglichkeiten für den Quantenphysik-Unterricht. Bereiche wie Quantenkommunikation und Quantencomputing sind direkte Anwendungen der Quantenphysik, in denen sie technologisch nutzbar gemacht wird. Das eröffnet Perspektiven für einen kontextorientierten Unterricht der Quantenphysik.

DD 41: Workshop: Studienreformforum

Time: Wednesday 16:00–17:30 Location: ELP 1: SR 3.21

DD 41.1 Wed 16:00 ELP 1: SR 3.21

Workshop: Vom Sinn des Physikstudiums — •Stefan Brackertz[1], Annemarie Sich[1], Barbara Obwaller[4], Lisa Lehmann[2], Amr El Miniawy[3], Robert Bartz[1], Philipp Bönninghaus[1] und Jonathan Moeller[2] — [1]Universität zu Köln, Fachschaft Physik — [2]TU Dresden, Fachschaft Physik — [3]HU Berlin, Fachschaftsinitiative Physik — [4]Universität Innsbruck, Studienvertretung Physik

”Welchen Sinn hat das Physikstudium eigentlich?” - Diese Frage kann etwa aus einem persönlichen Motivationstief heraus entstehen oder aus Diskussionen bezüglich der Auswahl der Inhalte, die im Physikstudium unbedingt vorkommen müssen. Auch für die Frage, wie Lehre an Hochschulen gestaltet sein sollte, ist sie relevant. Natürlich ist mit der Frage ”Welchen Nutzen hat ein Physikstudium?” auch die Frage ”Welchen Nutzen haben Physiker:innen?” untrennbar verbunden. Um es provokant auszudrücken: Was hat die Gesellschaft davon, dass Studierende fünf (teils weit mehr) Jahre ihres Lebens mit diesem Studium verbringen? Der Sinn der Hochschule wird immer wieder auch politisch diskutiert, doch präzisiert auf die Physik blieb die Debatte bislang wenig systematisch. Im Workshop wollen wir über diese Sinnfrage sprechen und verschiedene Standpunkte reflektieren.

Extraterrestial Physics Division
Fachverband Extraterrestrische Physik (EP)

Miriam Sinnhuber
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Overview of Invited Talks and Sessions

(Lecture halls ELP 1: HS 1.22 and ELP 6: HS 2; Poster ELP 6: Foyer)

Plenary Talk of the Extraterrestial Physics Division

PV VII	Thu	9:00– 9:45	ELP 6: HS 3+4	**Progress in solar flare modeling** — •Rony Keppens

Invited Talks

EP 1.1	Mon	14:30–15:00	ELP 1: HS 1.22	**Gravity wave vertical coupling from the troposphere to the thermosphere** — •Markus Rapp, Bernd Kaifler, Natalie Kaifler, Andreas Dörnbrack, Sonja Gisinger, Robert Reichert, Stefanie Knobloch, Hella Garny
EP 2.3	Tue	15:00–15:30	ELP 1: HS 1.22	**Interdisciplinary science through space plasma physics: the example of Jupiter's radiation belts** — •Elias Roussos
EP 2.8	Tue	17:00–17:30	ELP 1: HS 1.22	**Learning more about planets: What we expect from PLATO** — •Heike Rauer
EP 3.1	Wed	11:00–11:30	ELP 1: HS 1.22	**Arne Richter, Rekonnexion und das ebenso wechselhafte Schicksal der AEF** — •Jörg Büchner
EP 3.2	Wed	11:30–12:00	ELP 1: HS 1.22	**The Sun in Focus: Current Findings and Challenges in Solar Physics** — •Markus Roth
EP 3.3	Wed	12:00–12:30	ELP 1: HS 1.22	**Vortical motions in the solar atmosphere: observations, physics, cause and effect** — •Oskar Steiner, José Roberto Canivete Cuissa, Fabio Riva, Gangadharan Vigeesh

Invited Talks of the joint Symposium Plasmas in the Solar System (SYPS)

See SYPS for the full program of the symposium.

SYPS 1.1	Thu	11:00–11:30	ELP 6: HS 4	**Energetic Particles in the Turbulent Heliosphere** — •Horst Fichtner
SYPS 1.2	Thu	11:30–12:00	ELP 6: HS 4	**Persistent solar wind forcing of the F2-region ionosphere observed at Tromsø** — •Claudia Borries, Pelin Iochem
SYPS 1.3	Thu	12:00–12:30	ELP 6: HS 4	**In-orbit diagnostics for artificial plasmas created by electric propulsion systems: The Heinrich Hertz Satellite Mission** — •Thomas Trottenberg
SYPS 1.4	Thu	12:30–13:00	ELP 6: HS 4	**Plasma-based space propulsion: status and scientific challenges** — •Kristof Holste

Sessions

EP 1.1–1.8	Mon	14:30–17:50	ELP 1: HS 1.22	**Near-Earth Space and Space Weather**
EP 2.1–2.13	Tue	14:30–18:45	ELP 1: HS 1.22	**Planets in their Environment**
EP 3.1–3.3	Wed	11:00–12:30	ELP 1: HS 1.22	**Sun and Heliosphere I with Arne-Richter Lecture**
EP 4	Wed	12:45–13:45	ELP 1: HS 1.22	**Members' Assembly / Mitgliederversammlung**
EP 5.1–5.6	Wed	14:15–15:45	ELP 1: HS 1.22	**Astrophysics**
EP 6.1–6.9	Wed	16:30–18:30	ELP 6: Foyer	**Postersession**
EP 7.1–7.13	Thu	14:00–17:45	ELP 6: HS 2	**Sun and Heliosphere II**

Members' Assembly of the Extraterrestial Physics Division

Wednesday 12:45–13:45 ELP 1: HS 1.22

Sessions

– Invited Talks, Contributed Talks, and Posters –

EP 1: Near-Earth Space and Space Weather

Time: Monday 14:30–17:50 Location: ELP 1: HS 1.22

Invited Talk EP 1.1 Mon 14:30 ELP 1: HS 1.22

Gravity wave vertical coupling from the troposphere to the thermosphere — •Markus Rapp, Bernd Kaifler, Natalie Kaifler, Andreas Dörnbrack, Sonja Gisinger, Robert Reichert, Stefanie Knobloch, and Hella Garny — Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany

It is now well established that momentum and energy transport by gravity waves as well as its interaction with the mean flow is a key driver of middle atmospheric circulation. The latter in turn has important consequences for the middle atmospheric mean state. Unfortunately, though, gravity wave dynamics covers a very large range of spatial and temporal scales such that a comprehensive characterization both in terms of observations and modelling is still a major scientific challenge. This paper reviews efforts in both observations and modelling over the past 10 years during which ground based, airborne and satellite borne gravity wave observations were combined with models to shed light on several fundamental aspects of gravity wave dynamics and wave-mean flow interaction. Comprehensive data sets of gravity wave observations were collected from the Arctic to the South Pole which were used to characterize gravity wave processes and their role in climate. Examples will be presented and an outlook will be given how we plan to extend these studies into the thermosphere in order to gain better understanding of the role of neutral atmosphere vertical coupling for driving space weather phenomena.

EP 1.2 Mon 15:00 ELP 1: HS 1.22

A possible cause for the October effect in the D-region — •Vivien Wendt[1], Helen Schneider[1], Daniela Banys[1], Marc Hansen[1], Mark Clilverd[2], and Tero Raita[3] — [1]Institute of Solar-Terrestrial Physics, DLR, Neustrelitz, Germany — [2]British Antarctic Survey, Cambidge, UK — [3]Sodankylä Geophysical Observatory, University of Oulu, Sodankylä, Finland

Radar waves with very low frequency (VLF) are reflected in the D-region, the lower edge of the ionosphere. The D-region (60 - 90km) is influenced by the solar zenith angle and space weather from above and by the mesosphere's dynamic and chemical processes. During October there is a sharp decrease of the daytime VLF amplitude between transmitter and receiver combinations whose great circle paths lie in polar latitudes. Until now we do not know what causes the October effect. Space weather phenomena can be ruled out as a cause since their time scales are too short or too long. The solar zenith angle can also be ruled out as a similar behavior is not observed in spring. Thus, there is an assumption that dynamical processes in the mesosphere play a major role. Previous studies showed that a strong warming occurs in the lower mesosphere shortly before the October effect is observed. While the characteristics of this warming help us to explain why the October effect occurs during daytime only, the warming alone cannot explain the sharp decrease in the VLF daytime amplitude. We suspect and confirm that the water vapor in the lower mesosphere, having similar characteristics as the warming and the VLF amplitude decrease, plays a crucial role in the formation mechanism of the October effect.

EP 1.3 Mon 15:20 ELP 1: HS 1.22

The CHerenkov Atmospheric Observation System (CHAOS) for the 2024 Balloon Experiments for University Students (BEXUS) Campaign — •Hannes Ebeling, Ava Pohley, Pierre Bornfleth, Hannah Sophie Grimm, Janna Martens, Jasper Mess, Justus Mickausch, Clara Pittschellis, Nicolas Rohrbeck, and Tom Ruge — Christian-Albrechts-Universität, Kiel, Germany

The Earth is continuously exposed to high-energy charged particles, so-called Galactic Cosmic Rays (GCRs). When these particles hit the Earth's atmosphere, they create a cascade of secondary particles. CHAOS uses a new detector design developed at the Department of Extraterrestrial Physics at Kiel University by a team of students to measure the different particle species of the primary GCRs above the so-called Regener-Pfotzer Maximum. To perform these measurements a combination of multiple solid state detectors and a bismuth germanium oxide (BGO) scintillator is used to measure the energy depositions of the particles. The use of an additional Cherenkov aerogel scintillator allows to separate between electrons and protons. Because electrons are much lighter than ions, electrons with energies above ~ 1.1 MeV will trigger the Cherenkov detector whereas ions with the same energy are much slower and will not trigger the Cherenkov detector. In this talk we present the design and functionality of CHAOS as well as its current status. CHAOS is supposed to fly on a stratospheric balloon as part of the BEXUS program in fall 2024. More information about CHAOS can be found at `https://www.bexus.org/`.

EP 1.4 Mon 15:40 ELP 1: HS 1.22

EPP-climate link by reactive nitrogen polar winter descent revisited: MIPAS v8 reprocessing and future benefits by the EE11 candidate mission CAIRT — •S. Bender[1], B. Funke[1], M. López Puertas[1], M. Garcia-Comas[1], T. von Clarmann[2], M. Höpfner[2], B.-M. Sinnhuber[2], M. Sinnhuber[2], Q. Errera[3], G. Poli[4], and J. Ungermann[5] — [1]IAA-CSIC, Spain — [2]KIT, Germany — [3]BIRA, Belgium — [4]IAP "Nello Carrara", Italy — [5]FZJ, Germany

Polar winter descent of NOy produced by energetic particle precipitation (EPP) in the mesosphere and lower thermosphere affects polar stratospheric ozone by catalytic reactions. This, in turn, may affect regional climate via radiative and dynamical feedbacks. NOy observations by MIPAS/Envisat during 2002–2012 have provided observational constraints on the solar-activity modulated variability of stratospheric EPP-NOy. These constraints have been used to formulate a chemical upper boundary condition (UBC) for climate models in the context of solar forcing recommendations for CMIP6. Recently, a reprocessed MIPAS version 8 dataset has been released. We assess how the changes in this new data version impact the EPP-NOy quantification and the formulation of the UBC.

ESA's Earth Explorer 11 candidate Changing Atmosphere Infra-Red Tomography (CAIRT) will observe the atmosphere from about 5 to 115 km with an across-track resolution of 30 to 50 km within a 500 km wide field of view. CAIRT will provide NOy and tracer observations with unprecedented spatial resolution. We assess its potential to advance our understanding of the EPP-climate link in the future.

30 min break

EP 1.5 Mon 16:30 ELP 1: HS 1.22

Atmosphere-Magnetosphere Coupling During Geomagnetic Storms — •Alina Grishina[1,2], Yuri Shprits[1,2,3], Alexander Drozdov[3], Miriam Sinnhuber[4], Florian Haenel[4], Dedong Wang[1], Mátyás Szabó-Roberts[1], Jan Maik Wissing[5], and Stefan Bender[6] — [1]GFZ German Research Centre for Geosciences, Potsdam, Germany — [2]University of Potsdam, Potsdam, Germany — [3]University of California, Los Angeles, Los Angeles, CA, USA — [4]Karlsruhe Institute of Technology, Karlsruhe, Germany — [5]DLR German Aerospace Center Neustrelitz, Neustrelitz, Germany — [6]Instituto de Astrofísica de Andalucía, CSIC, Granada, Spain

The electron and ion flux in the near-Earth environment can change by orders of magnitude during geomagnetically active periods, which can lead to intensification of particle precipitation into the Earth's atmosphere. In our study, we concentrate on ring current electrons, and investigate precipitation mechanisms and their effect on the atmosphere using a numerical model. We validate our results against observations from the Polar Operational Environmental Satellites (POES) mission, as well as the Van Allen Probes. We calculate the altitude-dependent atmospheric ionization rates, and validate them against Atmospheric Ionization during Substorm (AIMOS 2.1-Aisstorm) and Special Sensor Ultraviolet Spectrographic Imagers (SSUSI) values, which shows good agreement at high geomagnetic latitudes during the storm time.

EP 1.6 Mon 16:50 ELP 1: HS 1.22

Atmospheric impact of extreme solar eruptions — •Miriam Sinnhuber[1], Thomas Reddmann[1], Jan Maik Wissing[2], and Ilya Usoskin[3] — [1]Karlsruher Institut für Technologie — [2]DLR Neustrelitz — [3]University of Oulu, Finland

Large solar eruption - solar flares and coronal mass ejections - can have a significant impact on the chemical composition and dynamics of the polar middle atmosphere. For solar events of the space age since 1957, this is well quantified and understood. However, evidence for much larger events has been derived from paleonuclide records within the last 10000 years. Here, we show results from model experiments comparing the well-known "Halloween" solar storm of October 2003 with an extreme event of AD774/775. Both events had a significant impact on atmospheric composition which lasted for several months. Due to its harder spectrum and larger fluxes, this impact affected lower atmospheric layers during and after the AD774 event. Due to radiative-dynamical feedbacks, both events affected atmospheric temperatures and dynamics as well with larger changes during the event and during polar summer for the stronger AD774 event. However, during polar winter, the preconditioning of the atmosphere seems to play a role as well.

EP 1.7 Mon 17:10 ELP 1: HS 1.22

The Atmospheric Ionization during Substorm Model (AISstorm 2.1) — •Jan Maik Wissing[1] and Olesya Yakovchuk[2] — [1]DLR Neustrelitz — [2]Universität Rostock

AISstorm derives the global atmospheric ionization due to particle precipitation based on in-situ particle measurements. The model covers auroral precipitation as well as solar particle events on an altitude range of about 250km down to 16km for protons and down to 70km for electrons. Alpha particle ionization is included as well but on a smaller altitude range. The overall structure splits up into an empirical model that determines the 2D precipitating particle flux and a numerical model that determines the ionization profile of single particles. The combination of these two results in a high resolution 3D particle ionization rate pattern. The AISstorm is the successor of the Atmospheric Ionization Module Osnabrück (AIMOS).

The main benefit of the updated ionization rates are higher dynamics during substorms and during the onset of geomagnetic storms in particular in the mesosphere - in agreement with observations.

The internal structure of the model has been completely revised in AISstorm with the main aspects being: a) an internal magnetic coordinate system, b) including substorms characteristics, c) higher time resolution, d) higher spatial resolution, e) energy specific separate handling of auroral precipitation, polar cap precipitation and crosstalk affected areas, f) better MLT resolution.

The contribution will compare the new ionization rates to AIMOS 1.6, AISstorm 2.0 and the HEPPA III multi-model study.

EP 1.8 Mon 17:30 ELP 1: HS 1.22

Solar Wind monitoring for Space Weather impact prediction — •Jens Berdermann[1], Erik Schmölter[1], Martin Kriegel[1], and Henrike Barkmann[2] — [1]German Aerospace Center (DLR), Institute for Solar-Terrestrial Physics — [2]German Aerospace Center (DLR), German Remote Sensing Data Center

Applications in safety-critical communication, precise navigation and remote sensing require comprehensive information on the current and future state of the ionosphere. Of particular interest are monitoring and prediction of solar activity driven disturbances, which significantly impact the operation of these services. This in turn requires a sufficiently good database as well as powerful models and simulation tools. Additionally, early knowledge of the relevant sources of ionospheric disturbances, primarily solar radiation and wind, are necessary for forecasting. Therefore, near real time solar wind data are crucial for assessing and predicting the impact of space weather on the ionosphere and on technical systems. DLR is part of the Real Time Solar Wind network coordinated by the US National Oceanic and Atmospheric Administration, and therefore responsible for receiving the DSCOVR satellite in the European sector. We will provide information about the solar wind receiving facility, data acquisition and the product processing at the Ionosphere Monitoring and Prediction Center of DLR in Neustrelitz. In addition, we present storm events from the current space weather situation near solar maximum and their effects on the ionosphere and technical systems. Finally, we give a brief outlook on upcoming solar wind missions and future forecasting products.

EP 2: Planets in their Environment

Time: Tuesday 14:30–18:45 Location: ELP 1: HS 1.22

EP 2.1 Tue 14:30 ELP 1: HS 1.22

Conformal mapping for the astrophysical flow and magnetic field problems — •Yasuhito Narita[1], Daniel Schmid[2], and Henry Holzkamp[1] — [1]Institut für Theoretische Physik, TU Braunschweig, Germany — [2]Space Research Institute, Austrian Academy of Sciences, Graz, Austria

Determining the plasma flow and magnetic field in the magnetosehath domain is a challenge both in space and astrophysical plasmas. We develop a novel algorithm of the conformal mapping to exactly transform the Kobel-Flückiger magnetosheath scalar potential onto a user-specified, arbitrary geometry of the magnetosheath domain. The algorithm starts with the outer and innter boundary models (e.g., bow shock and magnetopause locations in the case of planetary magnetospheres). The shell variable v is constructed by smoothly interpolating between the two boundaries, and the connector variable u (connecting between the two boundaries in an orthogonal fashion to the shell variable) is determined by evaluating the gradient of the shell variable along the shell segment under the Cauchy-Riemann relations. The conformal mapping method is computationally by far inexpensive, and retains the exactness character of the steady-state magnetosheath solution. The method has a wide range of applications such as validating the numerical simulations, planning the space (planetary and heliospheric) missions, and even estimating the solar wind condition from the magnetosheath data.

EP 2.2 Tue 14:45 ELP 1: HS 1.22

MHD jump condition tool for planetary and astrophysical shock problems — •Daniel Schmid[1] and Yasuhito Narita[2] — [1]Space Research Institute, Graz, Austria — [2]Institut für Theoretische Physik, Technische Universität Braunschweig, Braunschweig, Germany

Shock waves in the collisionless astrophysical plasmas are known to form in planetary, heliospheric, and interstellar systems. One of the common challenges in the observational shock studies is to determine the shock parameters such as the upstream flow speed, the density jump, the angle of the upstream magnetic field to the shock normal, and the plasma beta, given by the ratio between thermal and magnetic pressure. We develop a novel analysis tool by incorporating the pertubative Grabble-Cairns solution of the magnetohydrodynamic (MHD) jump condition into the de Hoffmann-Teller frame. The tool determines the density jump across the shock and the upstream Alfven Mach number as a function of the magnetic field jump and the plasma beta. A particular example where the analysis tool can be helpful are planetary missions with limited plasma data where only the magnetic field data are available with a sufficient time resolution for the shock wave analysis. The tool is successfully tested against the magnetic field and plasma data of Cluster mission's shock crossing of the Earth's bow shock. We further apply the tool to BepiColombo's flyby magnetic field data at Mercury, and discuss the possibility of the tool inversion to determine the magnetic field jump for the astrophysical shocks in interstellar space.

Invited Talk EP 2.3 Tue 15:00 ELP 1: HS 1.22

Interdisciplinary science through space plasma physics: the example of Jupiter's radiation belts — •Elias Roussos — Max Planck Institute for Solar System Research, Goettingen, Germany

In this presentation I will use the example of Jupiter's radiation belts for demonstrating the interdisciplinary character of space plasma physics investigations. The choice of Jupiter is not random: Jupiter is a planet of superlatives and its magnetosphere is no exception to that. The planet's magnetosphere acts as a very powerful charged particle accelerator, giving rise to the most hazardous particle radiation environment in our solar system: Jupiter's radiation belts. The radiation belts of Jupiter trap electrons, protons and heavy ions with energies characteristic for cosmic rays, albeit at intensities orders of magnitude higher that the latter. What our existing measurements indicate is that particle acceleration, transport and loss processes operating at Jupiter are unparalleled in our solar system and offer us insights into the dynamics of astrophysical magnetospheres that we only probe remotely. At the same time, material interactions resulting from collocation of the belts with jovian moons and rings has far reaching implications, ranging from space weathering to astrobiology. Any plans to explore Jupiter cannot thus ignore the links between the different and seemingly diverse components of this system, explaining why Jupiter's space environment is always in the spotlight, even for non-space physics focused missions to the planet.

EP 2.4 Tue 15:30 ELP 1: HS 1.22

MHD simulations of Europa's interaction with the jovian magnetosphere: insights from the Juno flyby — •Sebastian Cervantes[1], Joachim Saur[1], Stefan Duling[1], Stephan Schlegel[1], Jamey Szalay[2], Frederic Allegrini[3], and Jack Connerney[4,5] — [1]Universität zu Köln, Institut für Geophysik und Meteorologie, Cologne, Germany — [2]Princeton University, Princeton, USA — [3]Southwest Research Institute, San Antonio, USA — [4]Space Research Corporation, Annapolis, USA — [5]NASA Goddard Space Flight Center, Greenbelt, USA

We model the plasma interaction of Jupiter's magnetosphere with Europa and its atmosphere for the conditions of the flyby performed by NASA's Juno spacecraft. We apply the three-dimensional magnetohydrodynamic (MHD) single fluid PLUTO code based on Mignone et al., [2007], and we include in our model electromagnetic induction in a subsurface water ocean, collisions between ions and neutrals, plasma production due to electron impact ionization, and loss due to dissociative recombination. We model the effect of the recently detected electron beams by Allegrini et al. [2023] as sheets of locally enhanced electron impact ionization. We compare our simulations with the magnetic field and the total ion number density measurements from the magnetometer and the JADE detector onboard Juno, respectively. Our results show that the electron beams are essential in the plasma interaction by producing large variations of the magnetic field consistent with the magnetometer data, and by filling the wake with newly ionized plasma downstream of Europa.

EP 2.5 Tue 15:45 ELP 1: HS 1.22

Europa's asymmetric electron temperature — •Stephan Schlegel and Joachim Saur — University of Cologne, Cologne, Germany

Far ultraviolet emissions of Jupiter's moon Europa have been used as a diagnostic for its atmosphere and plasma environment. Hubble Space Telescope observations have shown time and spacial variability of the OI1356 oxygen line. The observations suggest that the side of Europa facing the dense plasma sheet is brighter at this wave length. The brightness is associated with electron density,

electron temperature and neutral particle density along the line of sight. Therefore, the question arises, which effect controls this asymmetry in the brightness.

We conducted a study of the electron temperature and density around Europa. For that purpose we carried out simulations of the system that solve the ideal MHD equations and inferred the electron temperature. In our study, the electrons are cooled down by the interaction with the atmosphere and are reheated by heat conduction along the magnetic field lines. The asymmetry in available thermal energy between the plasma sheet facing and opposite site leads to a fast cooling of the latter and leads to an asymmetry in electron temperature. This could explain the asymmetries in the HST observations.

EP 2.6 Tue 16:00 ELP 1: HS 1.22

Permittivity sensor to investigate the ice crust of the Jovian moon Europa — •Fabian Becker, Enrico Ellinger, and Klaus Helbing — Bergische Universität Wuppertal, Wuppertal, Deutschland

The icy moons in our solar system are attracting increased interest for the next space missions. This is due to the large deposits of liquid water, which are located under an ice crust and could be a possible habitat for extraterrestrial life. After the phase of satellite missions, which explore moons such as Europa, Ganymed, Callisto or Enceladus from orbit, it would be the next step to develop missions for landing and exploring the ice crust and the big oceans.

Our concept to look inside the crust or travel through the big ice layer to the liquid water is using melting probes. For these probes, a sensor system was developed to measure the permittivity ε_r of the surrounding ice. The primary goal is to correct radar data to plan the trajectory of the melting probe, where the radar antennas are integrated inside the melting head. Furthermore, it could bring first insights into the structure and composition of the moon's crust.

The concept is based on reflection measurements at an open coaxial output. The entire measuring system is integrated into a compartment of the melting probe, which is pressure-neutral. This has already been fully assembled in the project TRIPLE-FRS. The first tests were done in terrestrial cryospheres such as alpine glaciers.

EP 2.7 Tue 16:15 ELP 1: HS 1.22

Detectability of Local Water Reservoirs in Europa's Surface Layer Under Consideration of Coupled Induction — •Jason Winkenstern and Joachim Saur — Institute of Geophysics and Meteorology, University of Cologne, Cologne, Germany

Jupiter's icy moon Europa is a primary target for the study of ocean worlds. Its subsurface ocean is expected to be subject to asymmetries on global scales (tidal heating) and local scales (chaos regions, fractures). We approximate local asymmetries by considering a reservoir of liquid water entrapped in Europa's icy crust and investigate the possibility to resolve the resulting induced magnetic field of such a small-scale body with magnetometer measurements. The consideration of two conductive bodies introduces non-linear magnetic field coupling between them, for which we develop an analytical model to describe these coupling processes. With the Europa Clipper spacecraft launching this year, we calculate the induction response at 25 km altitude to assess detectability with the next generation's mission. Additionally, we investigate the detectability at Europa's surface to motivate a potential future lander mission.

30 min break

Invited Talk EP 2.8 Tue 17:00 ELP 1: HS 1.22

Learning more about planets: What we expect from PLATO — •Heike Rauer — Institut für Planetenforschung, DLR — Freie Universität Berlin

Exoplanet statistics from missions like Kepler/K2 and TESS have revealed a large diversity among extrasolar planets but also showed structure in the distribution of planets like, e.g., the so-called radius valley. While these data already provide significant inputs to planet formation and evolution models, our knowledge on well-known low-mass/small planets is restricted to orbital periods much less than 100 days. Low-mass planets on intermediate orbits remain to be explored. PLATO, the ESA M3 mission, is designed to detect and characterize extrasolar planets by photometric transits with a focus on small planets around bright stars, including terrestrial planets in the habitable zone of solar-like stars. With the complement of radial velocity observations from ground, planets will be characterized for their radius, mass, and age with high accuracy. The mission will provide a large-scale catalogue of well-characterized small planets up to intermediate orbital periods. In parallel, PLATO will study (host) stars using asteroseismology, allowing us to determine the stellar properties with high accuracy. The talk will provide an overview of our current knowledge on small exoplanet properties and an outlook to the expected impact from the PLATO mission.

EP 2.9 Tue 17:30 ELP 1: HS 1.22

ANDES - The high resolution spectrograph for the ELT and its calibration unit(s): Current baseline Design — •Philipp Huke[1], Ansgar Reiners[2], Michael Debus[2], Sebastian Schäfer[2], Richard McCracken[3], Derryck Reid[3], Yuk Shan Cheng[3], Kamalesh Dadi[3], Mirsad Sarjlic[4], Christopher Broeg[4], Omar Gabella[5], Michael Lehmitz[6], Wolfgang Gaessler[6], Driss Kouach[7], Jörg Knoche[8], Lea Bonhomme[9], Piotr Maslowski[10], and Alessio Zanutta[11] — [1]Institute for Laser and Optics, University of applied Sciences Emden /Leer — [2]Institute for Astrophysics and Geophysics, Georg-August-University Göttingen — [3]Institute of Photonics and Quantum Sciences, Herriot-Watt-University Edinburgh — [4]Center for Space and Habitability, University of Bern — [5]Laboratoire Univers et Particul de Montpellier — [6]Max-Planck Institut für Astronomie, Heidelberg — [7]Observatoire Midi-Pyrénées, Université de Toulouse — [8]University of Hamburg — [9]Observatoire Midi-Pyrénées — [10]Nicolaus-Copernicus University — [11]Osservatorio Astronomico die Trieste

The ANDES-project entered phase B in January 2022. Among its main scientific goals are the detection of atmospheres of exoplanets and the determination of fundamental physical constants. For this, high radial velocity precision and accuracy are required. Even though the ANDES-spectrograph is designed for maximum intrinsic stability, calibration is mandatory. This talk provides and update of the current baseline design of the spectrograph with special emphasis on the calibration unit(s).

EP 2.10 Tue 17:45 ELP 1: HS 1.22

Atomic oxygen on the dayside and nightside of Venus measured by SOFIA — •Heinz-Wilhelm Hübers[1,2], Heiko Richter[1], Urs Graf[3], Rolf Güsten[4], Bernd Klein[4], Jürgen Stutzki[3], and Helmut Wiesemeyer[4] — [1]DLR, Institut für Optische Sensorsysteme, Berlin, Deutschland — [2]Humboldt-Universität zu Berlin, Deutschland — [3]Universität zu Köln, Deutschland — [4]MPI für Radioastronomie, Bonn, Deutschland

Atomic oxygen is important for the photochemistry in the mesosphere and thermosphere of Venus and can be used as tracer for atmospheric dynamics. It is mainly generated through photolysis of CO2 on the dayside from where it is transported to the nightside. The altitude region in which atomic oxygen predominantly occurs is above the retrograde super-rotating zonal flow between 90 km and 130 km. We have detected atomic oxygen on the dayside as well as on the nightside of Venus by measuring its ground-state transition at 4.74 THz with the upGREAT heterodyne spectrometer on board SOFIA [1]. This is a direct detection in contrast to most of past and current detection methods, which are indirect and rely on photochemical models. We have determined the concentration and temperature of atomic oxygen as well as the brightness temperature of Venus between 15:00 and 21:00 hours local time. The measurements indicate a maximum concentration around 100 km and provide insight into the atmospheric dynamics. The new method will support detailed investigations of the Venusian atmosphere and support of future space missions.

[1] H.-W. Hübers et al., Nature Communications, 14:6812 (2023)

EP 2.11 Tue 18:00 ELP 1: HS 1.22

Atmospheric Modelling Studies of Venus as an Exoplanet — •John Lee Grenfell[1], Jörn Helbert[1], Gabriele Arnold[1], Konstantin Herbst[2], Miriam Sinnhuber[3], Juan Cabrera[1], and Heike Rauer[1,4] — [1]Institute for Planetary Research, German Aerospace Centre (DLR), Berlin, Germany — [2]Christian-Albrechts-Universltät (CAU), Kiel, Germany — [3]Karlsruher Institut für Technologie (KIT), Karlsruhe, Germany — [4]Freie Universität Berlin (FUB), Germany

The recently selected Venus missions EnVISION and VERITAS offer new opportunities for studying Venus but will also contribute to furthering our knowledge of Venus as an exoplanet. Hot rocky planets are favored targets due to generally more frequent transits than cooler Earth-like objects. In this work we simulate Venus as an exoplanet varying stellar, orbital, planetary and atmospheric parameters and study the effect upon atmospheric composition, climate and spectral detectability with the LIFE (Large Interferometer For Exoplanets) telescope.

EP 2.12 Tue 18:15 ELP 1: HS 1.22

Investigation of the Influence of Stellar Energetic Particles (SEPs) on the Atmosphere of TRAPPIST-1e — •Andreas Bartenschlager[1], Miriam Sinnhuber[1], John Lee Grenfell[2], Nicolas Iro[2], Benjamin Taysum[2], and Konstantin Herbst[3] — [1]KIT Karlsruhe — [2]DLR Berlin — [3]CAU Kiel

New instruments (JWST) open up the possibility of studying the composition of exoplanetary atmospheres in habitable zones. On explanets around very active M-stars like TRAPPIST-1, the impact of SEPs on the atmosphere plays an important role and is investigated with the ion chemistry model ExoTIC (Herbst et al., 2022). Within the INCREASE project, we perform model experiments with different N_2 or CO_2 dominated atmospheres, depending on the initial CO_2 partial pressure, as well as humid and dry conditions (Wunderlich et al., 2020). A further specification is the distinction between dead and alive atmospheres, whose composition is characterized by initial lower/higher O_2 fractions. Further model development gives the possibility to simulate the ion chemistry's impact on the atmospheric composition of multiple ionization events with different strengths and frequencies, based on the observed flaring frequency of TRAPPIST-1. Preliminary results show a significant impact of SEP events on the chemical composition of the atmosphere, including biosignatures such as O_3, especially in the recovery of the ozone layer after multiple SEP events. These changes have an impact on the observed transmission spectra. The strength and structure of these

impacts depend on the initial composition, in particular on the availability of O_2, N_2 and H_2O.

EP 2.13 Tue 18:30 ELP 1: HS 1.22

On the Comprehensive 3D Modelling of the Radiation Environment of Proxima Centauri b: a New Constraint on Habitability? — •Klaus Scherer[1], Konstantin Herbst[2], Eugene Engelbrecht[3], Juandre Light[3], DuToit Strauss[3], and Juandre Light[3] — [1]RUB — [2]CAU — [3]NWU

The combined influence of stellar energetic particles (StEPS) and galactic cosmic rays (GCRs) on the radiation environment, and hence potential habitability, of Earth-like exoplanets is relatively unknown. The present study, for the first time, comprehensively models the transport of these particles in a physics-first manner, using a unique suite of numerical models applied to the astrosphere of Proxima Centauri. The astrospheric plasma environment is modelled magnetohydrodynamically, while particle transport is modelled using a 3D *ab initio* GCR modulation code, as opposed to previous 1D approaches to this problem. StEP intensities are also calculated using observed stellar event profiles for Proxima Centauri as inputs. Computed intensities are then used to calculate possible atmospheric ionization effects and dose rates. We demonstrate the significant contribution of GCRs to these quantities and propose a novel constraint on exoplanetary habitability based on the unique 3D modelling approach presented here.

EP 3: Sun and Heliosphere I with Arne-Richter Lecture

Time: Wednesday 11:00–12:30 Location: ELP 1: HS 1.22

Invited Talk EP 3.1 Wed 11:00 ELP 1: HS 1.22

Arne Richter, Rekonnexion und das ebenso wechselhafte Schicksal der AEF — •Jörg Büchner — Max-Planck für Sonnensystemforschung, Göttingen — Zentrum für Astronomie und Astrophysik, TU Berlin

Eigentlich würde ich gern nur über Rekonnexion sprechen. Doch Arne Richter war ja mehr ein Mann der Stoßwellen. Aber auch jemand, dem die extraterrestrische Physik viel zu verdanken hat. Nicht nur durch seine Originalbeiträge, als er noch Wissenschaftler am MPAe war (wer weiß noch, was so hieß?), sondern später auch als aktiver Gestalter der Wissenschaftslandschaft. Einer der wesentlich dazu beitrug, die EGS als EGU zum europäischen Pendant der AGU zu etablieren, auf dass die AGU inzwischen nicht mehr allein die ganze große weite Welt der Extraterrestrik betagen muss. Als erfolgreicher Mitgestalter von Wissenschaftsorganisationen war Arne dann auch wesentlich beteiligt an der Rettung des der Arbeitsgemeinschaft Extraterrestrischen Physik/ Forschung vor ihren Liquidatoren.

Und nun der Bogen zur Rekonnexion, die inzwischen neben den Stoßwellen nicht mehr wegzudenken ist aus der plasmaphysikalischen Weltraumforschung: Wie die Extraterrestrik erlebte die Rekonnexion Jahrzehnte des Auf und Ab: Von ignoriert und gescholten durch die etablierten Krösusse bis zur glücklichen Rettung. Bei beiden zum Besten der Wissenschaft. Von Tiefen und Höhen ist also zu berichten. In der Hoffnung auf Ermutigung der Wissenschaftler nächster Generation, wenn es mal nicht so rund läuft.

Invited Talk EP 3.2 Wed 11:30 ELP 1: HS 1.22

The Sun in Focus: Current Findings and Challenges in Solar Physics — •Markus Roth — Thüringer Landessternwarte Tautenburg

We are living with the Sun in our solar system – a star which has served as a paradigm for astrophysics for many decades. Even though this star is the closest to us it still holds a multitude of secrets, and fascinates astronomers and physicists alike. With dedicated instruments in space and on the ground the various aspects of these secrets are revealed, ranging from the structure and dynamics of the outer solar atmosphere to the deep solar interior. Current research projects and technological advances aim to study the Sun with unprecedented precision. Hence solar physics plays a crucial role in astrophysics and in understanding the origins of space weather. This talk will offer exciting new insights into the fascinating world of solar research and its growing relevance for astrophysics and beyond.

Invited Talk EP 3.3 Wed 12:00 ELP 1: HS 1.22

Vortical motions in the solar atmosphere: observations, physics, cause and effect — •Oskar Steiner[1,2], José Roberto Canivete Cuissa[2], Fabio Riva[2], and Gangadharan Vigeesh[1] — [1]Kiepenheuer-Institut für Sonnenphysik, Freiburg, Germany — [2]IRSOL–Istituto ricerche solari Aldo e Cele Daccó, Locarno, Switzerland

A relatively recent addition to the solar zoo are vortical motions or swirls on very small scales in the photospheric and chromospheric layers of the solar atmosphere. Because of their very small size, their ubiquitousness has only recently been fully recognised. Often, swirls in the deep photosphere and surface layers of the convection zone harbour magnetic fields, which leads to a twist in the magnetic lines of force that propagates with Alfvén speed into the outer layers of the atmosphere. From numerical simulations, we have so far only rough estimates of the energy flux carried by these swirls and got only very recently hints on their dissipation from observations and simulations. Also from numerical simulations we have hints that coronal loops may harbour swirling motions too, which may have their origin in the surface layers of the convection zone or in the chromosphere. This talk briefly summarizes what we know from observations before diving into the physics of magnetic tornadoes and a discussion of the physical quantities used for their characterisation and detection. Finally, we speculate on their effect on the chromosphere and the outer solar atmosphere including coronal loops.

EP 4: Members' Assembly / Mitgliederversammlung

Time: Wednesday 12:45–13:45 Location: ELP 1: HS 1.22

Mitgliederversammlung

EP 5: Astrophysics

Time: Wednesday 14:15–15:45 Location: ELP 1: HS 1.22

EP 5.1 Wed 14:15 ELP 1: HS 1.22

Astrophysical test of the equality of active and passive gravitational mass — •Claus Lämmerzahl and Eva Hackmann — ZARM, University of Bremen, Gemany

Each body possesses three types of a mass: the inertial mass, the passive gravitational mass (or weight), and the active gravitational mass (or gravitating mass). The equivalence of inertial and passive gravitational mass, also known as the Weak Equivalence Principle, has been confirmed at the level of 10^{-15} by the recent space mission MICROSCOPE.

The precision of tests of the equivalence of the active and passive gravitational mass scales with the strength of the gravitational field created by the participating masses. This makes laboratory tests very difficult yielding an estimate of the order 10^{-6}, only. On the other hand, one can show that gravitationally bound astrophysical masses with their strong gravitational fields are not suited for corresponding tests. The only viable situation for an astrophysical test is a solid body composed of different masses of different composition moving in a gravitational field of another body. Our Moon with non-concentric iron and aluminum dominated parts provides such an example.

In the presentation we will provide the theoretical background and describe our data analysis of more than 50 years of Lunar Laser Ranging. As a consequence, with Lunar Laser Ranging, any non-equivalence of the active and passive gravitational mass is now bound by $4 \cdot 10^{-14}$. In addition, new planned laboratory tests will be shortly described.

EP 5.2 Wed 14:30 ELP 1: HS 1.22

Lévy flight model for the superdiffusive transport and acceleration of particles at shocks* — •Sophie Aerdker[1,2], Lukas Merten[1,2], Frederic Effenberger[1,2], and Horst Fichtner[1,2] — [1]Theoretical Physics IV, Faculty of Physics and Astronomy, Ruhr University Bochum — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany

In the heliosphere, power laws in space and time profiles of energetic particles at shock fronts are observed. It has been proposed that they result from superdiffusive transport, which can be modelled by Lévy flights. Such anomalous, non-

Gaussian, transport regimes may arise as a consequence of intermittent magnetic field structures.

Superdiffusive particle transport can be described by a space-fractional Fokker-Planck equation. Numerical solutions can be obtained by solving the corresponding Stochastic Differential Equations (SDEs). In contrast to Gaussian diffusion, where the SDE is driven by a normal distribution, for superdiffusion random numbers are drawn from a symmetric alpha-stable Lévy distribution.

We investigate particle transport and acceleration at a shock front and use the SDE approach to solve the space-fractional Fokker-Planck equation. With a modified version of CRPropa3.2 the time-dependent solutions of the number density and energy spectrum at the shock are obtained. Our simulations lead to results that are compatible with the expected power-law particle distribution upstream of a shock. We also find slightly flatter energy spectra at the shock, analogously to previous work on Lévy walks. *Supported by DFG (SFB1491)

EP 5.3 Wed 14:45 ELP 1: HS 1.22

MHD simulations of turbulent galactic outflows — •Jens Kleimann and Horst Fichtner — Theoretische Physik IV, Ruhr-Universität Bochum, Germany

Simulations of the wind-filled halos of starburst galaxies are performed in the framework of magnetohydrodynamics (MHD), suitably extended to track additional turbulence-related quantities. These quantities comprise the turbulent energy density, the cross-helicity, and the turbulent lengthscale. After a brief discussion of these extended equations and the employed numerical approach, I will present first simulation results, both for non-magnetized benchmark runs as well as for tests using the full system of equations. The dominant and unexpected feature of the former is a macroscopic flow instability near the rotational axis that prevents the outflow from reaching a steady state. Methods to determine the cause and nature of this instability are presented. The talk concludes with an analysis of the resulting turbulent properties, comparing them to the solutions found from similar work targeting the outer heliosphere.

EP 5.4 Wed 15:00 ELP 1: HS 1.22

ComPol - A Compton polarimeter in a Nanosat — •Matthias Meier[1,2], Ion Cojocari[3], Carlo Fiorini[4], Peter Hindenberger[1,2], Philippe Laurent[3], Martin Losekamm[1,2], Susanne Mertens[1,2], Jonas Schlegel[1,2], Lorenzo Toscano[4], and Michael Willers[1,2] — [1]Excellence Cluster ORIGINS, Garching, Germany — [2]Technical University of Munich, Munich, Germany — [3]Alternative Energies and Atomic Energy Commission, Paris, France — [4]Polytechnic University of Milan, Milan, Italy

It is hardly possible to resolve the geometry of astrophysical compact objects due to their small size. One way to indirectly learn about their structure are polarization measurements. Especially in the hard X-ray range polarization data is still partially missing. Therefore, the aim of the CubeSat mission ComPol is to fill this gap and to improve the physical model of the black hole binary system Cygnus X-1.

The detector system is composed of a Silicon drift detector (SDD) used as a scatterer and a CeBr3 calorimeter to capture the full Compton kinematics. From the measured interaction points and energies it is possible to perform an event-wise reconstruction and infer the polarization of the initial radiation.

The talk will give an overview of the scientific motivation, the underlying physics and the detector setup.

This research is supported by the Excellence Cluster ORIGINS which is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy - EXC-2094-390783311

EP 5.5 Wed 15:15 ELP 1: HS 1.22

Angular dependence of the muon neutrino flux — •Leonora Kardum, Karolin Hymon, Mirco Hünnefeld, Pascal Gutjahr, and Jean-Marco Alameddine — Technische Universität Dortmund

The IceCube Neutrino Observatory, a cubic kilometer detector nestled in the ice at the geographic South Pole, exhibits the capability to detect particles across a broad energy range, spanning from several GeV up to PeV. This enables precise measurements of the diffuse neutrino spectrum made from three components: astrophysical (originating from extraterrestrial sources), conventional (resulting from pion and kaon decays in atmospheric Cosmic Ray cascades), and the as-yet-undetected prompt component from the decay of charmed hadrons.

This work reveals the angular dependence and the all-component flux. The unfolding method, a composite model-independent technique, is employed to derive values from related quantities, eliminating the impact of assumptions made in the process. Specifically, we unfold the muon neutrino energy spectrum, incorporating a novel technique for rebinning the observable space to ensure adequate event numbers in the low statistic region at the highest energies.

Our presentation includes the unfolded energy and zenith angle spectrum reconstructed from IceCube data compared to model expectations and previous measurements, providing valuable insights into the accuracy of predicted angular dependencies in the atmospheric neutrino flux.

EP 5.6 Wed 15:30 ELP 1: HS 1.22

Trajectory-Dependent Photo Emission and Detection of Scintillation Light in a Bismut Germanium Oxide Scintillator Crystal — •Tom Ruge, Stephan Böttcher, and Ava Pohley — Christian-Albrechts-Universität zu Kiel IEAP - Extraterrestrische Physik

The Earth is continuously exposed to high-energy charged particles, so-called Galactic Cosmic Rays (GCRs). When these particles hit the Earth's atmosphere, they create a cascade of secondary particles. CHAOS (CHerenkov Atmospheric Observation System) is a particle telescope that is developed at the Department of Extraterrestrial Physics at Kiel University by a team of students to measure the different particle species of the primary GCRs. It consists of multiple solid-state detectors, a Cherenkov aerogel scintillator and a BGO scintillation calorimeter. The hexagonal BGO crystal with a side length of 52 mm and a thickness of 20 mm is one of the largest BGO crystals ever used for particle detection, which is why geometric effects within the BGO are more interesting than ever. When a charged particle interacts with the crystal, isotropic light is emitted that is measured by attached photodiodes. As part of my bachelor thesis, I am investigating in an experiment how much light is measured by the individual photodiodes, depending on where the particle has flown through the crystal. CHAOS is supposed to fly on a stratospheric balloon as part of the BEXUS (Balloon Experiments for University Students) program in fall 2024. This is why it is essential to investigate the properties of the used BGO. I will present my experiment and the findings.

EP 6: Postersession

Time: Wednesday 16:30–18:30 Location: ELP 6: Foyer

EP 6.1 Wed 16:30 ELP 6: Foyer

The Exo-Restart project — •Elena Vchkova Bebekovska[1], Vladimir Bozhilov[2], Desislava Antonova[2], Denitza Stoeva[2], Evelina Zaharieva[2], and Trifon Trifonov[2,3] — [1]Ss. Cyril and Methodius University in Skopje, Faculty of Natural Sciences and Mathematics-Skopje, Institute of Physics, Arhimedova 3, 1000 Skopje, North Macedonia — [2]Department of Astronomy, Sofia University "St Kliment Ohridski", 5 James Bourchier Blvd, BG-1164 Sofia, Bulgaria — [3]Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany

We present the aims of the "EXOplanetary dynamics and stability: Reverse Engineering of STable multi-planetary ARchitecTures" (EXO-RESTART) project, grant KP-06-DV/5. The existing exoplanet-detection techniques often neglect planetary dynamics, leading to a notable bias in their characterization. For deeper insights into planet formation, it is essential to focus on the dynamical properties of these systems, particularly the osculating orbital parameters, as opposed to relying solely on the Keplerian best-fit parameters reported in the literature. Our primary goal is to conduct the first homogeneous dynamical modeling effort of high-precision Doppler and transit photometry data for multiple-planet systems and complement them with an extensive long-term stability analysis, unveiling the current dynamic architecture of exoplanet systems. The comprehensive analysis of statistical, dynamical, and physical properties within EXO-RESTART is anticipated to reveal the primordial planet-disk conditions essential for constructing the observed planetary architectures.

EP 6.2 Wed 16:30 ELP 6: Foyer

Magnetosphärische Induktion beim Planeten Merkur — •Daniel Heyner und Kristin Pump — TU Braunschweig

Merkur besitzt ein schwaches Dipolfeld und ist einem intensiven Sonnenwind ausgesetzt. Dies führt zur Ausbildung einer kleinen Magnetosphäre. Es gibt periodische Änderungen im Sonnenwind wie der 88 Tage-Rotation auf dem elliptischen Orbit um die Sonne, die zu Änderungen in der Magnetosphäre führen. Eine weitere Periodizität stammt von der Eigenrotation des Planeten. Diese Änderungen des externen Magnetfeldes induzieren Ströme im Planeteninneren und rufen damit ein induziertes, internes Magnetfeld (sekundär) hervor. Durch ein empirisches Modell der Magnetosphäre und einem 1D-Modell der elektrischen Leitfähigkeit lässt sich diese Situation modellieren und die zu erwartenden sekundären Magnetfelder darstellen.

EP 6.3 Wed 16:30 ELP 6: Foyer

Solar Flare-Induced Changes in the Ionospheric D-Region Plasmas: A Machine Learning Perspective — •Filip Arnaut, Aleksandra Kolarski, and Vladimir Srećković — Institute of physics Belgrade, University of Belgrade, Pregrevica 118, 11080, Belgrade, Republic of Serbia

We explored the feasibility of utilizing a multi-output machine learning algorithm to estimate ionospheric plasma parameters (sharpness and reflection height). The ionospheric plasma parameters are crucial for determining the properties of ionospheric plasma, such as electron density, rate coefficients, and cross sections for ionization/recombination processes. We examined the feasibility of employing two single-output algorithms, such as a combination of Random Forest (RF) and XGB, for the target variables. The findings revealed that during the in-sample testing phase, the multi-output model (XGB-XGB) consistently yielded the most favorable outcomes in terms of the RMSE. However, a close alternative was observed in the combination of RF and XGB models, where RF was employed for the sharpness parameter and the XGB algorithm was utilized for the reflection height parameter. During the out-of-sample validation, there was minimal variation observed among the four algorithm combinations. The most significant difference was observed between the RF-XGB and RF-RF combinations (7.6% decrease in RMSE). The utilization of different algorithms and combinations of algorithms may yield marginal improvements, suggesting that the most significant improvement can be achieved through the expansion of the database.

EP 6.4 Wed 16:30 ELP 6: Foyer

European Space Weather Activities on ISWI — •Daniela Banyś[1] and national ISWI coordinators[2] — [1]German Aerospace Center (DLR), Neustrelitz, Germany — [2]various institutions

The International Space Weather Initiative (ISWI) is an international space weather program inspired by the activities of the International Heliophysical Year 2007. Each country is invited to assign a national coordinator to strengthen international coordination and cooperation on space weather activities. Special emphasis is placed on the deployment of instruments and the exchange of data. It serves as a platform for developing operational analysis, modelling and forecasting methods, which are sought by communication and navigation industries and government agencies. Through annual workshops and schools, ISWI establishes scientific insight into space weather related topics and communicates these results to the public. This poster presents highlights on European space weather activities.

EP 6.5 Wed 16:30 ELP 6: Foyer

Mechanical Design of the CHerenkov Atmospheric Observation System (CHAOS) — •Jasper Mess, Hannes Ebeling, Ava Pohley, Pierre Bornfleth, Hannah Sophie Grimm, Janna Martens, Justus Mickausch, Clara Pittschellis, Nicolas Rohrbeck, and Tom Ruge — Christian-Albrechts-Universität, Kiel, Germany

The Earth is continuously exposed to high-energy charged particles, so-called Galactic Cosmic Rays (GCRs). When these particles hit the Earth's atmosphere, they create a cascade of secondary particles. CHAOS (CHerenkov Atmospheric Observation System) is a particle telescope that is developed at the Department of Extraterrestrial Physics at Kiel University by a team of students (CHAOS collaboration) to measure the different particle species of the primary GCRs. It consists of multiple solid-state detectors, a Cherenkov aerogel scintillator and a BGO scintillation calorimeter. It has been accepted to the BEXUS program (Balloon EXperiment for Univerity Students), so it will fly on a stratospheric balloon above the Regener-Pfotzer maximum in fall 2024. Through the nature of this experiment there are a few mechanical challenges that need to be met, like the g-forces after the cutoff from the balloon as well as the impact upon landing. A pressure housing is needed to avoid possible corona discharges due to the use of high voltages. On this poster we want to present how CHAOS faces the challenges through its design. More information on `www.bexus.org`.

EP 6.6 Wed 16:30 ELP 6: Foyer

Measurements of cosmic rays by a mini neutron monitor aboard the German research vessel Polarstern — •B. Heber[1], S. Burmeister[1], H. Giese[1], K. Herbst[1], L. Romaneehsen[1], C. Gnebner[2], R.D. Strauss[3], and M. Walter[2] — [1]Christian Albrechts Universität, Kiel, Germany — [2]Deutsches Elektronen-Synchrotron DESY in Zeuthen, Germany — [3]Center for Space Research, North-West University, Potchefstroom 2520, South Africa

Neutron monitors are ground-based devices that measure the secondary particle population, i.e., neutrons produced by, e.g., galactic cosmic rays (GCRs). Due to their functionality, they are integral counters whose flux is proportional to the variation of the input spectrum. However, the measured flux also depends on the geomagnetic position and the static pressure at the monitor's location. To better understand the instrument response, the Christian-Albrechts-Universität zu Kiel, DESY Zeuthen, and the North-West University in Potchefstroom, South Africa, agreed on regular monitoring of the GCR intensity as a function of latitude, by installing a portable device aboard the German research vessel Polarstern in 2012. The vessel is ideally suited for this research campaign because it covers extensive geomagnetic latitudes at least once per year. In this contribution we give an update of our measurements over a full 11 year solar cycle.

The Kiel team received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 870405. The team would like to thank the crew of the Polarstern and the AWI for supporting our research campaign.

EP 6.7 Wed 16:30 ELP 6: Foyer

Detection of protons and helium >50 MeV/nuc on Chandra/EPHIN — •Janna Martens — Christian-Albrechts-Universität zu Kiel

This study presents an in-depth examination of cosmic rays, focusing on protons and helium nuclei, utilizing data from the Electron Proton Helium INstrument (EPHIN) aboard the Chandra X-ray Observatory. The research delves into the energy spectra of these particles, paying particular attention to the influence of solar modulation on their behavior.

The analysis process includes various techniques employed to enhance data resolution. The study also addresses the challenges encountered, such as interference from satellite transits through Earth's radiation belts and issues related to instrument malfunctions, which significantly impact the volume of data suitable for analysis.

In exploring the energy spectra of cosmic rays, the study critically evaluates the force field approach, a prevalent method in cosmic ray propagation research, discussing its limitations. Additionally, the cosmic ray spectrum for the year 2005 is computed, and the integral channel of Chandra/EPHIN is analyzed. This serves as a bridge between its channels for stopping particles and the data collected by the Payload for Antimatter Matter Exploration and Light nuclei Astrophysics detector (PAMELA).

The findings of this research offer valuable insights into the nature of cosmic rays and the functionality of EPHIN, laying a solid foundation for future investigations in this domain.

EP 6.8 Wed 16:30 ELP 6: Foyer

Time-Domain Spectroscopy for Space Exploration — •Yookyung Ha[1,2], Jonas Woeste[2,1], Dominic Azih[2,1], Oliver Gueckstock[3], Georgios Kourkafas[4], Jovana Petrovic[6], Mihailo Rabasovic[5], Aleksandar Krmpot[5], Tom S. Seifert[3,7], Andrea Denker[4], Tobias Kampfrath[3,7], Nikola Stojanovic[1], and Michael Gensch[1,2] — [1]DLR Institute of Optical Sensor Systems, Berlin, Germany — [2]Technical University of Berlin, Berlin, Germany — [3]Free University of Berlin, Berlin, Germany — [4]Helmholtz-Zentrum Berlin, Berlin, Germany — [5]Institute of Physics Belgrade, University of Belgrade, Belgrade, Serbia — [6]Vinca Institute of Nuclear Sciences, National Institute of the Republic of Serbia, University of Belgrade, Belgrade, Serbia — [7]TeraSpinTec GmbH, Berlin Germany

Recently, space-qualified femtosecond laser systems have become available [1,2]. Time-domain spectroscopy techniques, which revolutionised spectroscopy in laboratory environments, are now hence becoming true alternatives as modern spectroscopic sensors for space exploration. Bulky opto-mechanical components can thereby be replaced with compact electro-optic photonic components. Here, we show our progress enroute to time-domain spectroscopy instrumentation that is able to detect Raman- or infrared-active resonances in matter with a bandwidth of 30THz (1000 cm-1) and a resolution of 100GHz (3.3 cm-1). [1]. J. Lee, K. Lee, Y. Jang, et al. Scientific Reports, vol. 4, pp. 5134, (2014). [2]. M. Lezius, T. Wilken, C. Deutsch, et al., Optica 3, 1381 (2016).

EP 6.9 Wed 16:30 ELP 6: Foyer

The Liquid Metallic Hydrogen Model of the Sun — •Alexander Unzicker — Pestalozzi-Gymnasium München

Instead of being interpreted within the paradigm of the standard solar model based on a gaseous plasma, a considerable amount of experimental evidence may also be explained by assuming a real, liquid surface of the sun, as proposed by Robitaille (Progress in physics vol.3, 2011). The differences and respective problems of both models are discussed.

EP 7: Sun and Heliosphere II

Time: Thursday 14:00–17:45 Location: ELP 6: HS 2

EP 7.1 Thu 14:00 ELP 6: HS 2

New results on solar energetic electron events obtained from combined in-situ and remote-sensing observations from Solar Orbiter — •Alexander Warmuth and Frederic Schuller — Leibniz-Institut für Astrophysik Potsdam (AIP)

We present the first statistical results on energetic electron events obtained by joint observations of remote-sensing and in-situ instruments on Solar Orbiter. We use the Energetic Particle Detector (EPD) to measure the properties of the electrons (time profile, anisotropy, inferred injection time at the source, etc.), as well as to determine the composition of the associated energetic ions. X-ray observations from the Spectrometer/Telescope for Imaging X-rays (STIX) constrain the energetic electrons in the solar flare in terms of timing, spectrum, and location. Type III radio bursts detected by the Radio and Plasma Waves (RPW) instrument are used to link the nonthermal X-ray peaks to the interplanetary electron beams. Finally, the Extreme Ultraviolet Imager (EUI) provides context on the flare evolution. We have compiled a large sample of 330 events obtained during the first 2.5 years of the Solar Orbiter mission, which covers a wide range of radial distances ranging from as close as 0.3 au to 1 au. For the first time, this allows us to study the relationship between energetic electron events and associated flares as a function of heliocentric distance. This is crucial to constrain particle propagation effects.

EP 7.2 Thu 14:15 ELP 6: HS 2

Separating fundamental and harmonic emission in LOFAR solar type III radio burst images — •Christian Vocks[1], Mario Bisi[2], Bartosz Dabrowski[3], Diana Morosan[4], Peter Gallagher[5], Andrzej Krankowski[3], Jasmina Magdalenic[6], Gottfried Mann[1], Christophe Marque[6], Barbara Matyjasiak[7], Hanna Rothkaehl[7], and Pietro Zucca[8] — [1]Leibniz-Institute for Astrophysics Potsdam (AIP), Germany — [2]RAL Space, United Kingdom — [3]University of Warmia and Mazury, Olsztyn, Poland — [4]University of Helsinki, Finland — [5]DIAS, Dublin, Ireland — [6]Royal Observatory of Belgium, Brussels, Belgium — [7]Polish Academy of Sciences, Warsaw, Poland — [8]ASTRON, Dwingeloo, Netherlands

LOFAR spectroscopic imaging observations of solar type III radio bursts during an M class flare show distinct compact sources with variations in their positions and intermittent dual structures. These are interpreted as fundamental and harmonic emission, with the one or other being dominant at times. Sources of fundamental emission at one observed frequency, and harmonic emission from a coronal region with plasma frequency of half the observed frequency, can be clearly separated. Thus, it is possible to yield separate lightcurves, and to compare the flux evolution of fundamental - harmonic pairs, e.g. 35 MHz and 70 MHz. Both fundamental and harmonic emission should originate simultaneously from the same coronal source region. Variations in burst onset times and apparent source position then provide information on transport effects, like scattering and refraction, of radio waves in the solar corona.

EP 7.3 Thu 14:30 ELP 6: HS 2

The alignment of STEREO-A and Earth: A unique opportunity to improve solar energetic proton forecasting capabilities — •B. Heber[1], D. Banys[2], J. Berdermann[2], H. Dröge[1], M. Hörlöck[1], A. Kollhoff[1], P. Kühl[1], O. Malandraki[3], J. Martens[1,2], A. Posner[4], and H. Sierks[5] — [1]Christian Albrechts Universität, Kiel, Germany — [2]German Aerospace Center, Institute for Solar-Terrestrial Science — [3]National Observatory of Athens, Greek — [4]NASA, USA — [5]Max-Planck Institute for Solar System Research, Germany

A major impact on human and robotic space exploration activities is the sudden and prompt occurrence of solar energetic ion events. The fact that near relativistic electrons (1 MeV electrons have 95% of the speed of light) travel faster than ions (30 MeV protons have 25% of the speed of light) and are always present in Solar Energetic Particle (SEP) events can be used to forecast the arrival of protons from SEP events with real-time measurements of near relativistic electrons. The Relativistic Electron Alert System for Exploration (REleASE) forecasting scheme uses this effect to predict the proton flux. In 2023 and 2024, STEREO is approaching the Earth from a behind position, soon passing Earth inside its orbit and thereafter moving ahead of Earth. STEREO thus offers several unique opportunities during this passage to test the accuracy and extent of the REleASE system as is, and to enhance REleASE beyond its current capabilities.

EP 7.4 Thu 14:45 ELP 6: HS 2

Solar Energetic Proton forecasting with REleASE during STEREO-A's flyby of Earth — •Henrik Dröge[1], Bernd Heber[1], Alexander Kollhoff[1], Patrick Kühl[1], Olga Malandraki[3], and Arik Posner[2] — [1]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Germany — [2]NASA/HQ, Washington, DC 20546, USA — [3]National Observatory of Athens, Athens, Greece

Solar Energetic Particle (SEP) events can pose a significant radiation hazard for human and robotic space exploration acivities. Therefore SEP forecasting systems are needed to support operations. The REleASE system (A. Posner, 2007) utilizes the fact that near relativistic electrons (1 MeV electrons have 94% of the speed of light) travel faster than ions (30 MeV protons have 25% of the speed of light) and are always present in hazardous SEP events. Their early arrival can be used to forecast the expected proton flux. Originally REleASE uses realtime data from SOHO/EPHIN near Earth. Since the instrument is aging we recently adapted the method to STEREO-A/HET and used the period from June to November, 2023 when STEREO-A passed the Earth to compare the REleASE forecasts from the different instruments.

EP 7.5 Thu 15:00 ELP 6: HS 2

Measurements of ultra-relativistic electrons during solar energetic particle events - Results from the Ulysses Kiel Electron Telescope — •Carlotta Jöhnk, Bernd Heber, and Marlon Köberle — Christian-Albrechts-Universität zu Kiel, Germany

Solar energetic particle (SEP) events are increases of ions and electrons caused by solar activity namely flares and coronal mass ejections. While the most energetic ion population is well studied, SEP events accelerating electrons above 20 MeV have only been reported from measurements by ISEE III in the 1980s and the Kiel Electron Telescope (KET).

The KET aboard Ulysses launched in 1990 and measured the electron flux in the energy range from 4 MeV to above 6 GeV. Here we report on observations of ultra-relativistic electrons and show spectra of electron events during solar cycle 22 and 23 until the end of 2008. The maximum electron energy exceeded 100 MeV during the August 16, 2001 SEP event.

EP 7.6 Thu 15:15 ELP 6: HS 2

Charge sign dependence of recurrent Forbush Decreases in 2016 — •Lisa Romaneehsen, Johannes Marquardt, and Bernd Heber — Christian-Albrechts-Universität zu Kiel, Germany

This study investigates the periodicities of cosmic rays attributed to corotating interaction regions (CIRs) using AMS-02 data from late 2016 to early 2017. These data enable the first-time examination of recurrent Forbush decrease amplitudes induced by CIRs, considering rigidity and charge sign dependence. The findings from the Lomb-Scargle algorithm and Superposed Epoch Analysis were compared. Results reveal that the rigidity dependence of proton decreases attributed to the northern coronal hole aligns with existing literature, while that of the southern coronal hole does not. The amplitude of the Helium modulation exceeds that of protons, in line with previous observations. For positrons statistical limitation prevent definitive conclusions. In comparison to the positively charged ions the modulation behavior of electrons can not be understood in the current paradigma of modulation by diffusion barriers.

EP 7.7 Thu 15:30 ELP 6: HS 2

Quasi-Discontinuous Solar Wind Models — •Lukas Westrich[1,2], Horst Fichtner[1], and Bidzina Shergelashvili[1,2] — [1]Ruhr-Universität Bochum, Institute for theoretical physics IV — [2]Ilia State University, Faculty of Natural Sciences and Medicine, Tbilisi, Georgia

In this talk the heating of the solar wind above the Heliobase will be examined. Based on the discontinuous solar wind solutions from Shergelashvili et al. (2020) we developed new quasi-discontinuous solar wind models. First we will present the basic concept of discontinuous solar wind solutions and the quasi-discontinuous solar wind models, which is basically the assumption of a localized heating source above the Heliobase in a case of 1D quasi- adiabatic radial expansion of the solar wind. Furthermore, we will discuss the differences and the similarities of these. These models contain high gradients in the physical properties. Therefore, after an discussions of the characteristics of these solutions we will examine, how heat conduction could weaken those. It will be shown, that heat conduction is not strong enough to flatten the basic flow structure. As a result, the idea behind these models, that a damping of plasma waves near the trans-sonic point could produce such solar wind structures, is still reasonable.

EP 7.8 Thu 15:45 ELP 6: HS 2

Impact of diffusion models on the spectra obtained by diffusive shock acceleration — •Dominik Walter, Horst Fichtner, Yuri Litvinenko, and Frederic Effenberger — Ruhr-Universität-Bochum

The process of shock acceleration has long been a topic in astrophysics. A very prominent point of discussion is the shock spectrum, which has prooved quite universal over the last decades. In recent years, however, there have been modifications made to the diffusive behaviour of the acceleration process, some of which seem to alter said shock spectrum. Mentioned modifications are based on e.g. fractional or nonlinear diffusion approaches. This presentation will give a few examples and discuss, when a change of the spectral behaviour is to be expected and why.

30 min break

EP 7.9 Thu 16:30 ELP 6: HS 2

Energetic particle transport modelling with PARADISE — •Edin Husidic[1,2], Nicolas Wijsen[1], Stefaan Poedts[1,3], and Rami Vainio[2] — [1]Centre for mathematical Plasma Astrophysics, KU Leuven, Leuven, Belgium — [2]Department of Physics and Astronomy, University of Turku, Turku, Finland — [3]Institute of Physics, University of Maria Curie-Skłodowska, Lublin, Poland

Solar energetic particles (SEPs) constitute high-energy charged particles originating from solar eruptive phenomena. In particular, protons with energies ranging from tens of MeV to a few GeV per nucleon, pose a significant threat to satellites and astronauts. The intensities of SEPs are substantially influenced by the large-scale solar wind configuration, incorporating structures like coronal mass ejections (CMEs) or stream interaction regions (SIRs), which perturb the interplanetary (IP) magnetic field and ultimately affect the transport of SEPs. Despite decades of research, the precise acceleration mechanisms remain not fully known. Numerical models capable of simulating SEP events have proven to be valuable tools in the study of the transport and acceleration of SEPs. Here, we share recent findings derived with the energetic particle transport code PARADISE. The code utilises realistic background solar wind configurations as input, derived from magnetohydrodynamic (MHD) models such as EUHFORIA or the Icarus test case of the MPI-AMRVAC framework. By employing a stochastic approach to solve the focused transport equation, PARADISE obtains SEP intensities in the inner heliosphere. The presented studies focus on particle acceleration at IP shocks associated with CMEs and SIRs.

EP 7.10 Thu 16:45 ELP 6: HS 2

Solar energetic particle transport, gamma ray flares and intermittent turbulence — •Frederic Effenberger, Jeremiah Lübke, Julien Dörner, Horst Fichtner, and Rainer Grauer — Theoretische Physik, Ruhr-Universität Bochum, Germany

The detailed understanding and ultimately the ability to forecast solar energetic particle (SEP) events is critical in our efforts to mitigate space weather risks. I will discuss current issues in SEP modelling and observations with a particular focus on non-thermal particle sources in solar flares and CME shocks, and cross-field transport effects due to solar wind structures and field line random walk. Of particular interest are coherent features in the solar wind turbulence that can influence particle transport behaviour. Synthetic fields to study particle transport are typically generated from superpositions of Fourier modes with a prescribed power spectrum and uncorrelated random phases, bringing the advantage of covering a wide range of turbulence scales at manageable computational effort. However, almost all of these models to date only account for second-order Gaussian statistics and thus fail to include intermittent features. We have developed a novel method to account for this shortcoming based on a minimal Lagrangian map approach. We investigate the particle transport properties by solving a large number of particle orbits in these synthetic turbulence realisations and specifically look for non-diffusive regimes and non-standard energy dependences resulting from the intermittency of the generated fields. Applications to SEP transport and the production of gamma rays from solar events will be discussed.

EP 7.11 Thu 17:00 ELP 6: HS 2

Structured Synthetic Turbulence and Solar Energetic Particle Transport — •Jeremiah Lübke[1], Frederic Effenberger[2], Mike Wilbert[1], Horst Fichtner[2], and Rainer Grauer[1] — [1]Institute for Theoretical Physics I, Ruhr-University Bochum, Universitätsstr. 150, 44801 Bochum — [2]Institute for Theoretical Physics IV, Ruhr-University Bochum, Universitätsstr. 150, 44801 Bochum

Turbulence is ubiquitous in the solar wind, however its impact on the transport of solar energetic particles is poorly understood, since global simulations of the heliosphere are not able to resolve the turbulent length scales properly. This issue can be mitigated by employing synthetic turbulence, which is usually modelled as scale-invariant "smart noise" via sums of waves with a prescribed power spectrum and random uncorrelated phases. We present a novel model for synthetic turbulence, which is more faithful to the complex intermittent character of realistic turbulence, which is dominated by low-curvature coherent structures and high-curvature intense scattering sites. The model is a combination of a log-normal cascade and the multiscale minimal Lagrangian mapping approach. We investigate the resulting vector fields with regard to structure function scaling, fieldline geometry and energetic particle transport properties. Magnetohydrodynamic simulations of turbulence are consulted for comparison. We find that energetic particle diffusion is significantly enhanced by a combination of extended coherent structures and intense high-curvature scattering sites. Finally, applications to specific phenomena in the heliosphere, such as CME sheath turbulence, are discussed.

EP 7.12 Thu 17:15 ELP 6: HS 2

Linear theory of oblique plasma instabilities for reguarlized Kappa-distributions — •Dustin Lee Schröder[1], Horst Fichtner[1], and Marian Lazar[1,2] — [1]Ruhr-Universität Bochum, Bochum, Deutschland — [2]KU Leuven, Löwen, Belgien

A linear plasma solver is employed to investigate proton firehose and electron firehose instabilities for oblique propagation directions in the context of regularized Kappa-distributions.

EP 7.13 Thu 17:30 ELP 6: HS 2

Flux rope formation prior to CME onset by confined precursor flares—a statistical study — •Bernhard Kliem — University of Potsdam, Institute of Physics and Astronomy

I present a statistical study of flare ribbons in confined eruptions which precede a major ejective eruption (coronal mass ejection, CME), using the complete sample of CMEs associated with > M5.0 flares in 2011–2015 and source distance from Sun center of < 50 deg (32 events, from Baumgartner et al. 2018). Ribbons of precursor events within 12 hr from the onset of the CME-associated (eruptive) flare are compared with the ribbons of the main event to assess a potential contribution of the precursor events to the buildup of a flux rope prior to CME onset. It is found that 26 CMEs (81%) have one or several precursors with bright ribbons that cover a part of the ribbons in the main event, hence, clearly contribute to the buildup of the flux rope that later erupts and drives the CME. Two further events (6%) develop such ribbons during an enhancement that is part of the event's slow-rise phase, i.e., also prior to CME onset. Two CMEs only possess precursors with weak, very short, or very transient ribbons, indicating at least a minor contribution to the buildup of the flux rope erupting in the CME, and the final two events do not show any such indication. Of the last four events, however, three are characterized by a large ribbon separation from their onset, suggesting a high-lying flux rope that may have formed at earlier times. Overall, a significant role of flare reconnection for the buildup of a flux rope prior to CME onset is indicated for the great majority (88%) of the considered CME sample.

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Physics and the Environment in Historical Perspectives

Environmental issues are among the most relevant subjects of current scientific research. Addressing these concerns requires multidisciplinary approaches and the ability to integrate physics with other scientific disciplines, like biology, earth sciences or chemistry, and with approaches from the humanities such as transformation studies or economics. To understand the diversity of environmental structures and dynamics, a wide range of physical methods must be combined tailored to the specific objectives at hand.

Throughout history, we witness a variety of developments that sought to exclude or at least to control 'the environment' (which is not a timeless concept) from the production, communication, and adaptation of physical knowledge. The development and standardization of laboratories along with its related practices and instruments, but also approaches such as simulations (not necessarily only mathematical) and modelling can be seen as attempts to stabilize knowledge production against the disorder and unpredictability of the environment.

Many modern topics in environmental science can be seen as responses to the limits of human activity that are set by the environment, that these limits can no longer be ignored, and that we need to draw consequences from these boundaries and act within them. Additionally, for field scientists and particularly their instruments, dealing with unfamiliar environments has brought and still brings exposure to dangers and threats such as temperatures and temperature fluctuations, humidity or dryness, instabilities, etc. However, these environments provide not only challenges but also opportunities for new and different research. Gaining a better understanding of the world as a complex system required that large amounts of data needed to be taken and combined. At the same time, the interaction with representatives of different knowledge systems who, however, had a profound understanding of their own specific environment, led to conflicts that helped to charter the rules as well as the limits of scientific knowledge production.

Overview of Invited Talks and Sessions

Plenary Talk of the History of Physics Division

PV III	Tue	9:00– 9:45	ELP 6: HS 3+4	**Physics as an environmental science: The case of climate history** — •Richard Staley

Invited Talks

GP 1.1	Mon	16:30–17:30	ELP 3: HS 2.33	**Competition, Cooperation, Representation. The Many Faces of the International Geophysical Year from the German Perspective** — •Beate Ceranski
GP 4.1	Tue	16:30–17:30	ELP 3: HS 2.33	**Infusoria, Cress, and Tulips: Physical Experiments with Living Organisms** — •Caterina Schürch

Invited Talks of the joint Symposium How to Cope with Apocalyptic Narratives? (SYAN)

See SYAN for the full program of the symposium.

SYAN 1.1	Mon	14:00–14:40	ELP 6: HS 4	**The Apocalyptic Moment Is Over - And It Won't Come Back Anytime Soon** — •Frank Uekoetter
SYAN 1.2	Mon	14:40–15:20	ELP 6: HS 4	**Shaping Cold War Futures through the Nuclear Winter Study: Narratives, Imaginaries and Legitimacy** — •Egle Rindzeviciute
SYAN 1.3	Mon	15:20–16:00	ELP 6: HS 4	**The Role of Storytelling in Climate Communication** — •Denise Müller-Dum

Sessions

GP 1.1–1.3	Mon	16:30–18:30	ELP 3: HS 2.33	**Understanding the Environment**
GP 2	Mon	19:00–20:00	ELP 3: HS 2.33	**Meeting of Early Career Scholars**
GP 3.1–3.3	Tue	14:00–15:30	ELP 3: HS 2.33	**Dirty Physics**
GP 4.1–4.3	Tue	16:30–18:30	ELP 3: HS 2.33	**Exploring the experimental approach**
GP 5	Tue	18:30–20:00	ELP 3: HS 2.33	**Members' Assembly**
GP 6.1–6.3	Wed	11:00–12:30	ELP 3: HS 2.33	**Crossing Disciplinary and Institutional Boundaries**
GP 7.1–7.4	Wed	14:00–16:00	ELP 3: HS 2.33	**Instruments and Exhibitions**
GP 8.1–8.3	Wed	16:30–18:00	ELP 3: HS 2.33	**Closing Session**

Meeting of Early Career Scholars

Monday 19:00–20:00 ELP 3: HS 2.33
Contact: Michelle Mercier (michelle.mercier@uni-flensburg.de)

Members' Assembly of the History of Physics Division

Tuesday 18:30–20:00 ELP 3: HS 2.33

Sessions

– Invited Talks, Discussions, and Contributed Talks –

GP 1: Understanding the Environment

Time: Monday 16:30–18:30 Location: ELP 3: HS 2.33

Invited Talk GP 1.1 Mon 16:30 ELP 3: HS 2.33

Competition, Cooperation, Representation. The Many Faces of the International Geophysical Year from the German Perspective — •Beate Ceranski — Universität Stuttgart

Since the 18th century at least, research for understanding the environment has been intrinsically global, especially with regard to data acquisition. It has thus been deeply entangled with both infrastructural and political developments.

In my talk I will follow such entanglements with regard to one of the most prominent undertakings in the history of environmental research, the International Geophysical Year (IGY) 1957/58. IGY's carefully equilibrated innovative data management as well as the negotiation and competitive exploration of new research frontiers in antarctica and space have been analyzed as hallmarks of science during the Cold War. The IGY provides an excellent case study for both scientific cooperation and competition and their relationship with one another. My paper deals with the IGY from the German point of view which until now has not been much studied. Whereas in the FRG/BRD the IGY participation evolved quietly within the national research infastructure, there was an interesting debate in the GDR/DDR who was to represent the country in the national IGY committee.

GP 1.2 Mon 17:30 ELP 3: HS 2.33

Air, Ice and Smoke: the Discourse Sourrounding an Experimental Model in Meteorology circa 1850 — •Johannes-Geert Hagmann — Deutsches Museum, Munich

Simulations play a crucial role in contemporary climate research. The exploration of describing and, ideally, predicting global weather phenomena through modeling has been a subject of inquiry since the 19th century. Around 1850, Friedrich Vettin (1820-1905), a physician and amateur researcher, investigated air flow using a simplified model. His laboratory experiments visualized the interaction between cold and warm zones on a rotating disk through the use of smoke. This case study revisits the discussion surrounding the unconventional use of experimental models in an emerging discipline. We argue that, despite slow acceptance, Vettin's approach made a lasting methodological contribution to meteorology.

GP 1.3 Mon 18:00 ELP 3: HS 2.33

Ringing and shooting. Thunderstorm defence practices in the 18th century — •Julia Bloemer — Europa-Universität, Flensburg, Deutschland

The lightning rod is regarded as a prime product of the Enlightenment in the eighteenth century: It materialised the benefits of natural science and marked a liberation from superstition. However, this obscures the fact that older protective practices already existed and continued to be discussed and used even after the lightning rod became widespread. In the foothills of the Alps, these were the so-called thunderstorm ringing and thunderstorm shooting. Using the example of two prize questions of the Bavarian Academy of Sciences, this paper shows how the discussion of these practices contributed significantly to the understanding of meteorological relationships. The change from the original pious practices to physical phenomena and their investigation via electrical experiments shows how broad the discussion was alongside the lightning rod and that it was anything but mono-directional.

GP 2: Meeting of Early Career Scholars

Time: Monday 19:00–20:00 Location: ELP 3: HS 2.33

Contact: Michelle Mercier (michelle.mercier@uni-flensburg.de)

GP 3: Dirty Physics

This session consists of two speakers and a commentary by Richard Staley.

Time: Tuesday 14:00–15:30 Location: ELP 3: HS 2.33

GP 3.1 Tue 14:00 ELP 3: HS 2.33

Cleaning a Dark Matter Detector: Contamination and the Limits of High Energy Physics, 1980-2020 — •Jaco de Swart — Massachusetts Institute of Technology, Cambridge, MA, United States of America

In dark matter detection experiments, Xenon tanks are being used to find traces of dark matter particles that are hypothesised to crisscross the universe. For such detection to succeed, the Xenon in the tanks has to be clean. But what is clean? In this context, it means that no background mimics the signs of dark matter particles. In practice, such cleanliness is difficult to achieve – as soaps may be radioactive, steel may spread electronegativity, and humans are altogether dangerously filthy. In this talk, I discuss the idiosyncratic cleaning practices of the XENONnT experiment, and I place them in the context of the history of dark matter research. What does ensuring a detector's cleanliness entail? And how does one know whether the detector is, in fact, adequately clean? I particularly address how the XENONnT experiment, while cleaning their detector, also had to ensure that it did not interfere with environmental cleanliness.

GP 3.2 Tue 14:30 ELP 3: HS 2.33

'Dirty' spillovers: (geo)physical spillovers between the oil industry and early nuclear projects — •Michiel Bron — Maastricht University, Maastricht, The Netherlands

The development of nuclear physics and the geophysical understanding of uranium deposits during the Twentieth Century has pulled together many environmental actors from both the physical sciences and the oil industry. More than other subfields of the history of science, historians of scientific instrumentation have paid close attention to the commercial and industrial dimensions of scientific knowledge-making. A few industries have figured repeatedly in histories of instrumentation: e.g., telecommunications; agriculture and food production; armaments and defence. One industry in particular, however, has played an outsize, but often under-appreciated, role in the development of scientific instruments during the Twentieth Century: the oil industry. This article shows how specific scientific instruments - crucial to both the development of nuclear (geo)physics, and the commercial applications of uranium enrichment and exploration - were applied, scaled up, and developed during the Manhattan Project in close collaboration with the oil sector based on the (geo)scientific knowledge fostered within the petrochemical industry. The same knowledge and technologies that would later set up new collaborations during the environmental and scarcity debates of the long 1970s between oil companies as Exxon and well-known physicists like Hans Bethe.

Discussion GP 3.3 Tue 15:00 ELP 3: HS 2.33

Commentary to Panel — •Richard Staley — University of Cambridge, United Kingdom

Modern physics is built on dreams of purity. Historians have meticulously analysed the attempts of physicists to obtain orderly theories and uncluttered experimental data. But if conceptual order and messiness have received a lot of interest in the history of physics, material dirt and cleanliness remained in the background. In this panel, we explore different ways in which physicists have realized, affected, and impinged upon realities of pollution, contamination, waste, and otherwise. We explore institutional, intellectual, and material aspects in the history of twentieth century physics and geophysics as they relate to questions of dirt and cleanliness. How were polluting industries entangled in the development of physics theories? What kinds of cleaning practices have laboratories depended on? And how have physics experiments dealt with contamination and waste? Our cases range from the entanglement of the oil industry in the development of nuclear physics and environmental debates in the 1970s, to the construction of extremely clean experiments to detect hypothetical particles starting in the 1990s. With three panelists and one commentator, the panel aims to further explore how physics relates to its earthly surroundings.

GP 4: Exploring the experimental approach

Time: Tuesday 16:30–18:30 Location: ELP 3: HS 2.33

Invited Talk GP 4.1 Tue 16:30 ELP 3: HS 2.33

Infusoria, Cress, and Tulips: Physical Experiments with Living Organisms — •Caterina Schürch — TU Berlin

This talk examines examples – from the mid-eighteenth century to the early twentieth century – of physicists using living organisms in their experiments. Not surprisingly, the decision to work with biological material required different justifications at different times. In the mid-eighteenth century, experimental physicists moved quite naturally from experiments with non-living material to experiments with organized bodies, whereas in the early twentieth century, working with biological systems was considered highly problematic. While prominent biologists suggested that there should be a biologist in every physics laboratory and a physicist in every biology laboratory, there was little interest among physicists in working with complex organisms that were difficult to control. Only in exceptional cases did it make sense for them to use living objects in their experiments. In the early decades of the nineteenth century, however, living animals and plants were still part of the physicist's repertoire. Analyzing the debates about living organisms in physics experiments offers us a promising angle for exploring the changing methodological standards of experimental research in the physical sciences and beyond.

GP 4.2 Tue 17:30 ELP 3: HS 2.33

Trapping single particles - excluding the enviroment in experimental quantum optics, 1979 — •Eckhard Wallis — Deutsches Museum, Munich

The trapping of single ions can be seen as one of the most ambitious attempts of excluding "the environment" from the study of atomic structure. The first observation of single trapped ions was achieved in 1979 by the group of Peter Toschek (1933-2020) in Heidelberg, in close collaboration with the later Nobel laureate Hans Dehmelt (1922-2017) at University of Washington, Seattle. Techniques from particle trapping and laser cooling allowed them to control not only the number of atoms inside their trap but also the motion of the ion. This talk will study the motives behind the pursuit of single trapped ions: A "fundamental" line of argumentation linked the experiments to Ernst Mach's opposition to atomism. However, unperturbed ions also promised useful applications in frequency metrology. The Deutsches Museum will present several artefacts related to this story in the new exhibition "Light and matter".

GP 4.3 Tue 18:00 ELP 3: HS 2.33

Thomas Young's Eriometer: a useful instrument and tool for Young, a failed instrument for everyone else — •Michelle Mercier — Europa-Universität Flensburg

Thomas Young (1773-1829) is best known today for his double-slit experiment. Almost unknown - even today - is an instrument that can be regarded as the first practical application of the results of his earlier investigations on diffraction and interference: the Eriometer. Young, a physician and physicist, claimed to be able to determine the diameter of homogenous samples of small particles and fibers with this instrument. In London, I was able to trace two Eriometers made by Young. One was part of a letter to Joseph Banks (1810). The other one is in the collection of the Royal Institution. Although experimental studies with a reconstruction of the instrument showed that measurements with a high degree of accuracy could be achieved, the instrument and the principle could not establish itself in England at the beginning of the 19th century. In this talk I will analyze the instrument from different perspectives and discuss possible factors for the rejection of the instrument in England at the beginning of the 19th century.

GP 5: Members' Assembly

Time: Tuesday 18:30–20:00 Location: ELP 3: HS 2.33

Invitation and agenda will be sent out separately

GP 6: Crossing Disciplinary and Institutional Boundaries

Time: Wednesday 11:00–12:30 Location: ELP 3: HS 2.33

GP 6.1 Wed 11:00 ELP 3: HS 2.33

Interplay of physics and chemistry at the University of Padua in the 18th century: a case of cross-fertilization among scientific disciplines — •Valentina Roberti — valentina.roberti@unipd.it

Established in 1222, the University of Padua experienced a vibrant scientific era during the 18th century. The scientific disciplines that emerged within the context of the scientific revolution found a place in academic yearbooks. Concurrently, the Republic of Venice promoted the establishment of the first scientific institutions for educational and research purposes. This contribution explores case studies of cross-fertilization between physics and chemistry, which significantly contributed to the advancement of scientific knowledge, shaping the history of the University of Padua. Particular emphasis will be placed on the role played by Giovanni Poleni, appointed in 1739 to the chair of experimental philosophy, and Marco Carburi, professor of chemistry since 1759, in facilitating and promoting knowledge exchange using scientific instruments. Giovanni Antonio Dalla Bella and Nicolò da Rio, keen experimenters and students of Poleni and Carburi, respectively, were directly involved in the creation of a secret society, the so-called Società dei filochimici, with the aim of reproducing the pioneering experiments conducted in France by Antoine-Laurent de Lavoisier. An analysis of the interplay between physics and chemistry will reveal connections between local scientists and the national and international scientific community.

GP 6.2 Wed 11:30 ELP 3: HS 2.33

Anpassungsstrategien unter Umweltstress: Das Zentralinstitut für Astrophysik der DDR im Einigungsprozess — •Henrik Rose — Institut für Philosophie, Literatur-, Wissenschafts- & Technikgeschichte, Technische Universität Berlin — Institut für Physik und Astronomie, Universität Potsdam

Darstellungen der Umgestaltung des Forschungssystems in Ostdeutschland nach 1990 orientieren sich häufig an polarisierenden Deutungen, die entweder eine westdeutsche Kolonisierung beklagen oder aber eine erfolgreiche und notwendige Erneuerung begrüßen. Gemein ist ihnen die Annahme einer disruptiven Veränderung, die vorrangig aus dem Westen getragen wurde. Der Vortrag stellt dem eine alternative Betrachtung über das Fortbestehen von Forschungslinien in inhaltlicher, institutioneller und personeller Hinsicht entgegen. Als Beispiel schildere ich die Umgründung des Zentralinstituts für Astrophysik in Potsdam als Ergebnis einer sich beständig entwickelnden Behauptungsstrategie, die trotz größerer Personaleinbußen die Fortführung von seit den 1980er Jahren entwickelten Forschungslinien erreichte. Ich zeige, dass der Erfolg vorrangig auf der Mobilisierung verschiedener außerwissenschaftlicher Ressourcen beruhte, was teils bereits in Aushandlungssituationen im Forschungssystem der DDR eingeübt, teils adaptiv unter den neuen Bedingungen erprobt wurde.

GP 6.3 Wed 12:00 ELP 3: HS 2.33

Developing an understanding of the impact of the first stereoscope on the model of Wheatstone — •Andreas Junk — Europa-Universität Flensburg

The design of the stereoscope on the model of Charles Wheatstone was introduced to the scientific community by an 1838 article in the Philosophical Transactions of the Royal Society. The apparatus is canonised today as the first of its kind to demonstrate, that two two-dimensional images or drawings are enough to evoke a spatial impression in an observer. In my paper I will present our experiences in the replication of the apparatus as on display at the King's College London and experiences from our reenactment process. While the stereoscopic effect mentioned above could be reproduced with our replica, the use of Wheatstone's drawings from the 1838 article generated more questions about the contemporary status of research on the physiology of vision and the demands on the images to be used with the instrument.

GP 7: Instruments and Exhibitions

Time: Wednesday 14:00–16:00 Location: ELP 3: HS 2.33

GP 7.1 Wed 14:00 ELP 3: HS 2.33

On a 17th Century Telescope Lens Grinding Machine — •Wolfgang Engels — HistEx GmbH, Germany, Marie-Curie-Str. 1, 26129 Oldenburg

Some years ago, a telescope was discovered during excavations in Delft that could originate from the first half of the 17th century. The instrument is suggested to represent a surviving sample of one of the oldest in the Netherlands. The principle of these terrestrial telescopes is the use of a planoconvex objective lens and a planoconcave eyepiece. Surprisingly, the very unusual shape of the planoconvex objective lens of the find corresponds nicely to a grinding method that was suggested by the Capuchin monk Anton Maria Schyrleus of Rheita in 1645 (Oculus Enoch et Eliae...). The polished curvature of the actual objective lens is centred on a piece of flat glass from which it was cut, leaving the surrounding edge rough and unpolished. Rheita claimed that his apparatus was designed to machine both spherical and hyperbolic planoconvex lenses. Based upon Rheita's publication, the machine has been replicated and some lenses have been produced. To date, no finds of early aspherical lenses are known, but further finds of spherical lenses with the typical shape now indicate that Rheita's processing method could have been used on a large scale.

GP 7.2 Wed 14:30 ELP 3: HS 2.33

's Gravesande's parabola - when motion becomes tangible — •Linnéa Bergsträsser — Institute of physics, its didactics and its history, Flensburg, Germany

In the 18th century, Willem Jacob 's Gravesande mentioned an apparatus that was supposed to visualise the flight path of a heavy body. A marble rolls down a ramp and exits in a horizontal direction. The interaction of this horizontal movement with the accelerating force of gravity creates the motion curve of the marble: The parabola. As this flight motion is far too fast for the human eye, 's Gravesande came up with an idea: first with steps, later with rings, he was able to visualise the marble's flight. This apparatus was a typical mechanical demonstration experiment from the 18th century.

At this time Galileis and Newtons mechanics were very popular and I will show the link between Galileis and Newtons mechanics and 's Gravesandes demonstration of motion.

At the Europa-Universität Flensburg, we have a reconstruction of the respective apparatus kept at the Museum Boerhaave. As part of my PhD project, I am working with this device and I analyse the accuracy of this demonstration experiment.

In working with this device, the key function of the instrument is that the ball moves through the rings. To ensure this, I had to learn to work with all my senses and not just trust my eyes. This was also the challenge for demonstrators in the 18th century. They needed to develop a certain way of dealing with demonstration experiments before they showing them to the students in the lectures.

GP 7.3 Wed 15:00 ELP 3: HS 2.33

Light and Matter - Insights into exhibiting quantum optics at the Deutsches Museum — •Katharina Stuhrberg — Deutsches Museum, Munich

For the year 2024, the Deutsches Museum is developing an exhibition on quantum optics with the title "Light and Matter". The new exhibit covers the subjects of quantum physics, lasers and spectroscopy in their historical context. A variety of hands-on demonstrations, objects, as well as "Szenoramas" - a new form of artistic storytelling - are deployed in our exhibition to make quantum physics, optics and their history accessible for all visitors of various backgrounds that come to the Deutsches Museum. This talk will outline the exhibition's concept and discuss how quantum optics and its historical background will be introduced to the public.

GP 7.4 Wed 15:30 ELP 3: HS 2.33

Two Astrolabic Quadrants from 14th Century Damascus and 17th Century London — •Enes Tepe — Europa Universität Flensburg. Institute for Physics, its Didactics and its History. Auf dem Campus 1, 24943 Flensburg, Germany

In the previous (virtual) history of physics DPG conference in Heidelberg, I presented my study about different portable quadrant traditions in the Islamic World and the Western Europe. One of the conclusions of that study was that the astrolabic quadrants from astronomers and instrument-makers of Mamluk and Stuart dynasties can be considered among the most well-founded timekeeping instruments of their respective cultures. In my PhD project, I am researching the practices with two astrolabic quadrants from these periods according to the replication method. One of the instruments is an almucantars / trigonometric quadrant that was made by Muhammad ibn Ahmad al-Mizzi in 1329, Damascus, and now exhibited in David Collection, Copenhagen. The other one is a large quadrant of inverse projection that was made by Henry Sutton in 1658, London, and now kept in the History of Science Museum, Oxford. At the current phase of the project, I am reconstructing these two instruments with the necessary adaptations to 2024 and Flensburg in order to be able to analyze the practices based on their re-enactments. In this talk, I am going to introduce the two astrolabic quadrants and make a comparison of their general features.

GP 8: Closing Session

Time: Wednesday 16:30–18:00 Location: ELP 3: HS 2.33

GP 8.1 Wed 16:30 ELP 3: HS 2.33

Die andere Geschichte der Physik — •Grit Kalies[1] und Duong D. Do[2] — [1]HTW University of Applied Sciences, Dresden, Germany — [2]The University of Queensland, Brisbane, Australia

Die Entwicklung der modernen Physik wird nicht selten als Erfolgsgeschichte präsentiert, von der Mechanik, der kinetischen Gastheorie und der Elektrodynamik über die Relativitätstheorien, die Kopenhagener Deutung und die Higgs-Theorie bis hin zu den heutigen Standardmodellen der Teilchenphysik und Kosmologie und der Geometrodynamics, in der das Verhalten der Materie vollständig auf Geometrie reduziert wird. Es ist eine Geschichte physikalischer Theorien, die man auch "mathematische Phänomenologie" [1] nennen könnte. Zugleich gibt es eine Geschichte von physikalischen Größen, die geprägt ist durch unscharfe Begriffe und Mehrdeutigkeit, eine Vermischung von Kinematik und Dynamik und das Fehlen von Prozessgleichungen. Diese andere Geschichte wird erzählt anhand von Größen wie Kraft, Masse, Impuls, potentielle Energie, Ruheenergie, Entropie, Enthalpie und freie Enthalpie [2]. 1. E. Schatzman: Quantenphysik und Realität. Dtsch. Z. Philos. 2 (1954), 621-641; 2. G. Kalies, D. D. Do, AIP Adv. 13 (2023), 065121, 055317, 095322, 095126.

GP 8.2 Wed 17:00 ELP 3: HS 2.33

Albert Einstein, Alfred North Whitehead — •Christian Thomas Kohl — Freie Universität Berlin, Germany

Modern physics consists not only of new discoveries and inventions through relativity and through quantum physics. Modern physics has also produced new foundations and new ways of thinking, pointed out especially by Albert Einstein and Alfred North Whitehead. Modern physics has abandoned the cliché of black-and-white thinking, for which there are only separate things, without smooth transitions. Since Faraday and Maxwell, there has been a shift in the objects of study: since about 1850, the thought models of modern physics no longer revolve around separate, isolated bodies or building blocks floating in nothingness, but around the flexible webs of relationships between things and around the networks that surround things. Important clues to the modern ways of thinking about physics came from Albert Einstein (1879-1955) when he wrote about Faraday and Maxwell and the newness of physics in the last years of his life: *A courageous scientific imagination was needed to realize fully that not the behaviour of bodies, but the behaviour of something between them, that is, the field, may be essential for ordering and understanding events*.

GP 8.3 Wed 17:30 ELP 3: HS 2.33

Unclear crystals: 18th century projections of crystal formation — •Peter Heering — Europa-Universität Flensburg

"Which is beyond doubt one of the most pleasant observations that can be made with a solar microscope." With these words Wilhelm Friedrich Freiherr von Gleichen genannt von Rußwurm characterized the demonstration of crystallizations with a solar microscope. These projection microscopes were particularly popular in the second half of the 18th century. As I have already discussed, this popularity can be related to a significant degree to the instrument's ability of meeting the cultural standards of the Enlightenment. This understanding benefitted significantly from the practice with two original instruments at the Deutsches Museum. In the meantime, I had the opportunity of continuing to work with a reconstructed solar microscope - this enabled me to work on projecting the above mentioned crystallizations. In this talk I am going to present some of the experiences made in observing crystallisations, In doing so, I am facing a challenge that was already made explicit by the 18th century demonstrators: the projections with a solar microscope go 'beyond the expectation of those who have not seen it'.

Short Time-scale Physics and Applied Laser Physics Division
Fachverband Kurzzeit- und angewandte Laserphysik (K)

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Overview of Invited Talks and Sessions

(Lecture hall ELP 6: HS 1; Poster ELP Foyer)

Invited Talks

K 1.1	Mon	11:00–11:35	ELP 6: HS 1	**Zufall, Struktur und Gesetze in physikalischer Information** — •Rudolf Germer
K 1.2	Mon	11:35–12:10	ELP 6: HS 1	**Wellenfunktion und Realität** — •Alfred Eichhorn

Invited Talks of the joint Symposium Lasers and Photonic Technologies for Environmental Challenges (SYEC)

See SYEC for the full program of the symposium.

SYEC 1.1	Tue	11:10–11:40	ELP 6: HS 1	**Nanostructured optical waveguides inside YAG crystals as a crucial step towards the development of microlasers for advanced sensing applications** — •Omar de Varona, Franzette Paz-Buclatin, Paul Santos, Pablo Molina, Leopoldo Martín, Airán Ródenas
SYEC 1.2	Tue	11:40–12:10	ELP 6: HS 1	**Laser surface modification of graphite anodes for lithium-ion batteries with improved fast-charging capability** — •Max-Jonathan Kleefoot, Jens Sandherr, Jiri Martan, Volker Knoblauch, Harald Riegel
SYEC 2.1	Tue	14:00–14:30	ELP 6: HS 4	**Development of soft glass optical fibers based on 3D printed preforms** — •Ryszard Buczynski, Pawel Wiencław, Przemyslaw Golebiewski, Dariusz Pysz, Adam Filipkowski, Grzegorz Stepniewski, Olga Czerwinska, Andrzej Burgs
SYEC 2.2	Tue	14:30–15:00	ELP 6: HS 4	**Three-dimensional Ultrashort-Pulse Laser Nanolithography of Optical Materials** — •Airán Ródenas, Omar de Varona, Franzette Paz-Buclatin
SYEC 2.3	Tue	15:00–15:30	ELP 6: HS 4	**Fibre-based plasmonic micro reactor CO2 reduction** — •Devin O'Neill, Patrick Spath, Wiebke Albrecht
SYEC 5.1	Tue	17:15–17:45	ELP 6: HS 4	**Studying atmospheric dynamics with lasers in remote places** — •Bernd Kaifler

Sessions

K 1.1–1.2	Mon	11:00–12:10	ELP 6: HS 1	**New Methods**
K 2.1–2.4	Mon	14:00–15:20	ELP 6: HS 1	**Gas dynamics – Laser Systems and Laser Applications**
K 3	Mon	15:20–16:00	ELP 6: HS 1	**Members' Assembly**
K 4.1–4.3	Mon	16:30–18:30	ELP 6: Foyer	**Poster**

Members' Assembly of the Short Time-scale Physics and Applied Laser Physics Division

Monday 15:20–16:00 ELP 6: HS 1

Sessions

– Invited Talks, Contributed Talks, and Posters –

K 1: New Methods

Time: Monday 11:00–12:10 Location: ELP 6: HS 1

Invited Talk K 1.1 Mon 11:00 ELP 6: HS 1

Zufall, Struktur und Gesetze in physikalischer Information — •Rudolf Germer — ITPe.V. — TU-Berlin

Der Zufall begegnet uns beim Würfeln genauso wie beim exponentiellen Abklingen einer Fluoreszenz. Es gibt eine physikalische Struktur, Einfluß von außen und eine begrenzte Informationsmenge, die in der Ungenauigkeit des Zufalls mündet. Was ist physikalische Information ? Gibt es kleinste Informationseinheiten, kürzeste Zeitintervalle und Längen... ? Physikalische Experimente und Theorien vermitteln uns, dem Beobachter, Information und Erkenntnis. Verstanden sind die Zusammenhänge zwischen den elektromagnetischen Quanten und zahlreichen Naturkonstanten, die sich, wie hier schon gezeigt, mit der Geometrie eines Quaders darstellen lassen. Kleinste Informationseinheiten lassen sich dann mit dem Planck'schen Wirkungsquantum h und einer beteiligten Energie E fassen. Bekannt ist die Abhängigkeit der Auflösung des Mikroskops von der Energie und Wellenlänge der Photonen. Viele Einzelheiten finden Sie im Wikibook "Die abzählbare Physik". Eine grobe Abschätzung läßt erwarten, daß diese Gedankenwelt auf die Gravitation übertragbar ist. Ein Vergleich von Gravitations- und Coulombgesetz ermöglicht die Hypothese, daß die Verteilung von Massen im Universum Basis der "Gravitationskonstante" ist. Es sind dann lokal Abweichungen vom Mittelwert des "Gravitationsfaktors" zu erwarten. germer@physik.tu-berlin.de

Invited Talk K 1.2 Mon 11:35 ELP 6: HS 1

Wellenfunktion und Realität — •Alfred Eichhorn — Weil am Rhein

Häufig wird die Frage aufgeworfen, wann bei einer Messung an einem Quantensystem die Wellenfunktion zu Realität wird. Mit Realität ist dabei die Beschreibung im Rahmen der klassischen Physik gemeint, zu der die Größen gehören, die wir messen oder berechnen wollen. Wenn wir eine solche Größe messen, setzen wir voraus, das diese Größe eine Eigenschaft des Systems ist, an dem wir die Messung durchführen. Im Grunde erzeugen wir dabei eine Projektion der Realität auf die Ebene der klassischen Physik, d.h. auf die Ebene unseres Vorstellungsvermögens. Ebenso erzeugen wir, wenn wir aus einer Wellenfunktion den Erwartungswert für eine klassische Größe bestimmen, eine Projektion der Wellenfunktion auf die Ebene der klassischen Physik, wobei die Observable, die die klassische Größe repräsentiert, die Art der Projektion bestimmt. Es hat sich gezeigt, dass die klassische Physik nicht ausreicht, um die Realität vollständig zu beschreiben. Mit Hilfe der Quantentheorie, d.h. einer Wellenfunktion, lassen sich viele Phänomene vollständiger beschreiben. Das lässt den Schluss zu, dass die Wellenfunktion der Realität näher ist, als die Messung oder Berechnung klassischer Größen. In diesem Vortrag soll diese Überlegung näher ausgeführt werden, wobei auch Gödels Unvollständigkeitstheorem eine Rolle spielt.

K 2: Gas dynamics – Laser Systems and Laser Applications

Time: Monday 14:00–15:20 Location: ELP 6: HS 1

K 2.1 Mon 14:00 ELP 6: HS 1

Experimentelle Untersuchungen zu Stoßwellen in Mikro-Stoßrohren mit idealen und realen Gasen — •Lars Jepsen[1], Walter Garen[1] und Ulrich Teubner[1,2] — [1]Hochschule Emden/Leer, Institut für Laser und Optik — [2]Carl von Ossietzky Universität Oldenburg, Institut für Physik

Stoßwellen spielen in vielen Gebieten der Physik und Technik eine wichtige Rolle. Für sehr dünne Stoßrohre (D_{hyd} < 200μm) wächst die Grenzschichtdicke auf die Größenordnung des Stoßrohrquerschnittes an, wohingegen in Makro-Stoßrohren (D_{hyd} ≈ 50mm) der Grenzschichteinfluss oft vernachlässigbar ist. Theoretische Modelle für Mikro-Stoßrohre erfordern daher zusätzliche Informationen der Strömungsform z.B. von geeigneten Kennzahlen.

Es werden ideale Gase in Mikro-Stoßrohren untersucht. Ein schnelles Mikroventil erzeugt bei voreingestellten Treiber- und Testgasdrücken eine Stoßwelle mit nacheilender Kontaktfläche. Eine interferometrische Messung der zeitlichen Dichteänderung am Messort entlang der Stoßachse liefert Informationen über die zeitliche und lokale Stoß- sowie Kontaktflächenausbreitung unter Reibungseinfluß.

Ein weiteres Experiment beschäftigt sich mit der Ausbreitung von Stoßwellen in realen Gasen mit Grenzschichtkondensation an der Oberfläche des aus Glas bestehenden Stoßwellenrohres. Die zeitliche Entwicklung der Kondensationsschichtdicke auf der Rohrinnenwandung wird mit einem Laserreflexionsinterferometer gemessen und liefert die Kondensationsschichtdicke als Funktion der Zeit, die besonders in Mikro-Stoßrohren wichtige Hinweise auf die Strömungsform gibt.

K 2.2 Mon 14:20 ELP 6: HS 1

Parameter study on single-pulse femtosecond laser irradiation of single-crystalline silicon — •Andy Engel, Theo Pflug, Markus Olbrich, Philipp Lungwitz, and Alexander Horn — Laserinstitut Hochschule Mittweida, Hochschule Mittweida, 09648 Mittweida, Germany

In this study single-pulse irradiation of single-crystalline, <111> -oriented silicon is investigated by varying the fluence of the applied ultrashort pulsed laser radiation (pulse duration 40 fs, wavelength 800 nm). The resulting irreversible material changes due to the laser radiation-matter interaction are presented and discussed. The spatially resolved spectral refractive index was determined by ex situ ellipsometry. Comparative analyses of the topography of the irradiated surfaces were performed using confocal laser scanning microscopy and atomic force microscopy. The combination of the measured data with optical models and simulations allows a more accurate description of the physical processes induced by pulsed laser irradiation, starting with changes in crystallinity up to ablation. Additional information about the depth of the thermally induced material phase changes have been obtained by downstream wet chemical etching.

K 2.3 Mon 14:40 ELP 6: HS 1

17 GHz monolithic self-starting Kerr-lens mode-locked Titanium-Sapphire laser — •Torben Fiehler and Ulrich Wittrock — Photonics Laboratory, FH Münster, Stegerwaldstraße 39, 48565 Steinfurt, Germany

Ultrafast lasers with pulse repetition rates in the multi-GHz regime are of interest for applications in frequency metrology, dual-comb spectroscopy, calibration of astronomical spectrographs, microwave generation, and telecommunication.

We present a monolithic self-starting soft-aperture Kerr-lens mode-locked Titanium-Sapphire (Ti:Sa) laser that generates 204 fs pulses at 812 nm with 900 mW average power and a pulse repetition rate of 16.9 GHz. This is the highest repetition rate for a fundamentally mode-locked Ti:Sa laser. Moreover, our laser is the first monolithic mode-locked Ti:Sa laser. It consists of a 5 mm thick plane-parallel Ti:Sa disk where both surfaces bear dispersive mirror coatings. This plane-plane resonator is stabilized by the thermal lens that is generated by the pump power. Reliable self-starting soft-aperture Kerr-lens mode-locking sets in at an absorbed pump power of 1.8 W which corresponds to 700 mW of average mode-locked laser power. At 900 mW, the frequency comb has a spectral bandwidth of 4 nm and about 300 modes resulting in about 5 mW per mode in average. Mode locking is maintained up to an absorbed pump power of 2.6 W and 1100 mW average laser power. Above this power, mode locking becomes unstable.

K 2.4 Mon 15:00 ELP 6: HS 1

High-precision processing of technical glass using a combination of pulsed laser ablation and plasma jet processing at atmospheric pressure — •Martin Ehrhardt[1], Robert Heinke[1,2], Pierre Lorenz[1], Thomas Arnold[1,2], and Klaus Klaus Zimmer[1] — [1]Leibniz Institute of Surface Engineering, Leipzig, Germany — [2]Technische Universität Dresden, Germany

One ultra-precision surface processing technique is non-thermal atmospheric reactive plasma jet etching (PJE). PJE uses reactive plasma interaction to remove material from substrate surfaces by converting it to volatile or gaseous substances. Technical glass is made from a variety of materials, including metal oxides. These metal oxides form non-volatile compounds during plasma jet etching that leave a residue layer after processing.Residue layers lead to self-masking and create a barrier that prevents further material removal. It has been shown that this problem can be solved by combining PJE and laser ablation. In the current study, the interaction between PJE-treated technical glass surfaces and pulsed laser radiation is investigated in detail. SEM, EDX and XPS will be used to examine the surfaces after PJE and subsequent laser ablation.

K 3: Members' Assembly

Time: Monday 15:20–16:00 Location: ELP 6: HS 1

All members of the Short Time-scale Physics and Applied Laser Physics Division are invited to participate.

K 4: Poster

Time: Monday 16:30–18:30 Location: ELP 6: Foyer

K 4.1 Mon 16:30 ELP 6: Foyer

Enhanced energy harvesting efficiency by Surface modification of PVDF/ZnS Composite Nanofibrous Membranes Using Femtosecond Pulses — •Nehal Ali[1], Elham Mostafa[2], and Amna Faid[2] — [1]Tanta University, Tanta, Egypt — [2]Cairo University, Giza, Egypt

The surface modification competence of ceramic/polymer composite is significant for electronic device applications. We report the successful patterning of a micro-grating array on the surface of an electrospun PVDF/ZnS composite membrane by femtosecond (fs) laser to fabricate efficient energy harvesting devices. The femtosecond laser is considered a versatile, speedy, and flexible tool for surface modification of different materials.

The electrospinning technique was chosen to deliver nanofibers with high β-phase content in one step. The PVDF polymeric membrane was loaded with ZnS nanoparticles to enrich the β-phase content.

The effect of laser input fluence on the morphology of patterning the nanofibers was investigated. The results showed successful patterning of tracks on the surface of the fiber while preserving its nature. The capability of the membrane as an energy harvesting device was confirmed by measuring the maximum open circuit voltage density of 1.98 V*m*2 compared to the untreated membrane of a density of 1.49 V*m-2. This work has demonstrated possible applications in electronic devices, such as sensors and actuators, in biomedical fields, such as tissue engineering.

K 4.2 Mon 16:30 ELP 6: Foyer

Two-particle self-consistent study of bi-layer Hubbard model under a static electric field — •Jiawei Yan — Department of Physics, University of Fribourg, 1700 Fribourg, Switzerland

We develop a nonequilibrium steady-state two-particle self-consistent method for Hubbard model. The theory respects the Mermin-Wagner theorem, incorporating non-local spatial fluctuations through a static vertex. By employing the Schwinger-Keldysh contour, we implement the method in real frequency. As an application, we investigate the magnetic behavior of a bi-layer Hubbard model under the influence of an electric field. We find a transition in the spin correlation between the layers, shifting from anti-ferromagnetism to ferromagnetism as the electric field intensity increases. This phenomenon is attributed to the inversion of the collective excitation spectrum within the spin channel.

K 4.3 Mon 16:30 ELP 6: Foyer

Laser-plasma coupling for etching of Zerodur — •Alexander Anthofer[1], Martin Ehrhardt[1], Pierre Lorenz[1], Thomas Arnold[1,2], and Klaus Zimmer[1] — [1]Leibniz Institute of Surface Engineering (IOM), Leipzig, Germany — [2]Technische Universität Dresden

The ever-increasing demands for high-performance optics, particularly in the areas of extreme ultraviolet and free-form optics, require continuous advances in manufacturing techniques. One such technique, atmospheric pressure plasma etching, is proving valuable in achieving both high etch rates and tooling precision for materials such as SiO2, SiC and silicon. The plasma generates reactive species that form volatile compounds with the substrate material, resulting in effective material removal. The present study investigates the effects of plasma parameters on the formation of the residual layer on Zerodur and explores the ablatability of these layers with different laser systems. The evaluation includes techniques such as white light interferometry, X-ray photoelectron spectroscopy, secondary ion mass spectrometry, and scanning electron microscopy for a comprehensive analysis of the ablation process.

Plasma Physics Division
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Overview of Invited Talks and Sessions

(Lecture halls ELP 6: HS 3, ELP 6: HS 4, and WW 1: HS; Poster ELP 6: Foyer)

Plenary Talks of the Plasma Physics Division

PV II	Mon	9:45–10:30	ELP 6: HS 3+4	**The role of plasma conversion technology in the greening of the chemical industry** — •Richard van de Sanden
PV VIII	Thu	9:45–10:30	ELP 6: HS 3+4	**Achieving target gain > 1 from inertial confinement fusion implosions at the National Ignition Facility*** — •Tilo Döppner

Invited Talks

P 1.1	Mon	11:00–11:30	ELP 6: HS 3	**On the observation of Trapped Electron Modes in W7-X** — •Andreas Krämer-Flecken, Paul Costello, Golo Fuchert, Joachim Geiger, Stèphane Heuraux, Alexander Knieps, Josefine Proll, Kian Rahbarnia, Roland Sabot, Luigui Salazar, Gavin Weir, Thomas Windisch, Haoming Xiang
P 2.1	Mon	11:00–11:30	WW 1: HS	**Interaction of reactive components of non-equilibrium atmospheric plasmas with liquids and surfaces** — •Kerstin Sgonina, Alexander Quack, Christian Schulze, Jan Benedikt
P 3.1	Mon	14:00–14:30	ELP 6: HS 3	**Influence of Nanosecond Pulsed Plasmas in Liquids on Copper Surfaces** — •Pia-Victoria Pottkämper, Oliver Krettek, Katharina Laake, Achim von Keudell
P 4.1	Mon	14:00–14:30	WW 1: HS	**Ab initio calculations of conductivities under planetary interior conditions** — •Martin Preising, Martin French, Maximilian Schörner, Mandy Bethkenhagen, Argha Roy, Uwe Kleinschmidt, Ronald Redmer
P 7.1	Tue	11:00–11:30	ELP 6: HS 3	**Physics of Electrical Currents and Fields in the Scrape-off Layer of Tokamak Plasmas** — •D. Brida, G. D. Conway, J. Adamek, J. Cavalier, H. Bergstroem, G. Grenfell, U. Plank, the ASDEX Upgrade Team
P 8.1	Tue	11:00–11:30	WW 1: HS	**Pulsed Complex Plasma In Microgravity** — •Christina A. Knapek, Daniel P. Mohr, Peter Huber
P 10.1	Tue	14:00–14:30	WW 1: HS	**Filament interaction in dielectric barrier discharges** — •Hans Höft, Ronny Brandenburg, Markus M. Becker, Torsten Gerling
P 11.1	Tue	16:30–17:00	ELP 6: HS 3	**Collaboration on RDM in low-temperature plasma physics** — •Marina Prenzel, Kerstin Sgonina, Markus Becker
P 14.1	Wed	11:00–11:30	WW 1: HS	**Insights into the Non-Thermal Character of Molecular Plasmas from Optical Frequency Comb Spectroscopy** — •Ibrahim Sadiek, Norbert Lang, Jean-Pierre H. van Helden
P 15.1	Wed	14:00–14:30	ELP 6: HS 3	**Particle fueling, profiles and transport in neutral beam heated plasmas at Wendelstein 7-X** — •Sebastian Bannmann, Oliver Ford, Peter Poloskei, Jakob Svensson, Samuel Lazerson, Hakan Smith, Robert Wolf
P 16.1	Wed	14:00–14:30	WW 1: HS	**CO_2 dissociation by microwave plasmas: experimental studies on interfaces in view of industrial applications** — •Rodrigo Antunes, Christian K. Kiefer, Ante Hecimovic, Katharina Wiegers, Arne Meindl, Andreas Schulz, Ursel Fantz
P 17.1	Wed	16:30–17:00	ELP 6: HS 3	**Finite Element Method to Describe Magnetic Measurements of Tearing Modes in ASDEX Upgrade** — •Magdalena Bauer, Hartmut Zohm, Marc Maraschek, Anja Gude, Wolfgang Suttrop, Felix Klossek, Bernhard Sieglin, Louis Giannone

P 18.1	Wed	16:30–17:00	WW 1: HS	**Diffusion of reactive species in aqueous solutions treated by a humid atmospheric pressure plasma jet** — •Steffen Schüttler, Emanuel Jess, Judith Golda
P 20.1	Thu	11:00–11:30	ELP 6: HS 3	**Modelling of tungsten erosion and deposition in fusion devices** — •Andreas Kirschner, Sebastijan Brezinsek, Juri Romazanov
P 20.2	Thu	11:30–12:00	ELP 6: HS 3	**Drift flows in the island divertor of W7-X** — •Carsten Killer, Sean Ballinger, Seung-Gyou Baek, Dario Cipciar, Olaf Grulke, Adrian von Stechow, Jim Terry
P 21.1	Thu	14:00–14:30	ELP 6: HS 3	**The collisionally modified Bohm criterion: Insight or illusion?** — •Ralf Peter Brinkmann
P 22.1	Thu	14:00–14:30	ELP 6: HS 4	**First Results of Laser-Induced Desorption - Quadrupole Mass Spectrometry (LID-QMS) at JET** — •Miroslaw Zlobinski, Gennady Sergienko, Ionut Jepu, et al
P 22.2	Thu	14:30–15:00	ELP 6: HS 4	**Deuterium retention analysis in pre-damaged tungsten using laser-induced breakdown spectroscopy** — •Erik Wüst, Christoph Kawan, Sebastijan Brezinsek, Thomas Schwarz-Selinger
P 23.1	Thu	16:30–17:00	ELP 6: HS 3	**Characterizing electron depleted, nanodusty plasmas recent developments and future outlooks** — •Andreas Petersen, Franko Greiner
P 24.1	Thu	16:30–17:00	ELP 6: HS 4	**Electron surface scattering kernel for plasma simulations** — •Franz Xaver Bronold, Felix Willert

Invited Talks of the joint Symposium Plasmas in the Solar System (SYPS)

See SYPS for the full program of the symposium.

SYPS 1.1	Thu	11:00–11:30	ELP 6: HS 4	**Energetic Particles in the Turbulent Heliosphere** — •Horst Fichtner
SYPS 1.2	Thu	11:30–12:00	ELP 6: HS 4	**Persistent solar wind forcing of the F2-region ionosphere observed at Tromsø** — •Claudia Borries, Pelin Iochem
SYPS 1.3	Thu	12:00–12:30	ELP 6: HS 4	**In-orbit diagnostics for artificial plasmas created by electric propulsion systems: The Heinrich Hertz Satellite Mission** — •Thomas Trottenberg
SYPS 1.4	Thu	12:30–13:00	ELP 6: HS 4	**Plasma-based space propulsion: status and scientific challenges** — •Kristof Holste

Sessions

P 1.1–1.4	Mon	11:00–12:35	ELP 6: HS 3	**Magnetic Confinement I/HEPP I**
P 2.1–2.5	Mon	11:00–12:30	WW 1: HS	**Atmospheric Pressure Plasmas and their Applications I**
P 3.1–3.7	Mon	14:00–16:00	ELP 6: HS 3	**Plasma Wall Interaction I**
P 4.1–4.7	Mon	14:00–16:00	WW 1: HS	**Astrophysical Plasmas/Laser Plasmas**
P 5.1–5.5	Mon	16:30–18:15	ELP 6: HS 3	**Magnetic Confinement II/HEPP II**
P 6.1–6.30	Mon	16:30–18:30	ELP 6: Foyer	**Poster I**
P 7.1–7.5	Tue	11:00–12:30	ELP 6: HS 3	**Magnetic Confinement III**
P 8.1–8.5	Tue	11:00–12:30	WW 1: HS	**Complex Plasmas and Dusty Plasmas I**
P 9.1–9.5	Tue	14:00–16:05	ELP 6: HS 3	**HEPP III**
P 10.1–10.7	Tue	14:00–16:00	WW 1: HS	**Atmospheric Pressure Plasmas and their Applications II**
P 11.1–11.3	Tue	16:30–17:40	ELP 6: HS 3	**Codes and Modeling I**
P 12.1–12.31	Tue	16:30–18:30	ELP 6: Foyer	**Poster II**
P 13.1–13.4	Wed	11:00–12:20	ELP 6: HS 3	**Magnetic Confinement IV/HEPP IV**
P 14.1–14.5	Wed	11:00–12:30	WW 1: HS	**Low Pressure Plasmas and their Application I**
P 15.1–15.5	Wed	14:00–16:10	ELP 6: HS 3	**HEPP V**
P 16.1–16.7	Wed	14:00–16:00	WW 1: HS	**Atmospheric Pressure Plasmas and their Applications III**
P 17.1–17.6	Wed	16:30–18:35	ELP 6: HS 3	**Magnetic Confinement V/HEPP VI**
P 18.1–18.7	Wed	16:30–18:30	WW 1: HS	**Atmospheric Pressure Plasmas and their Applications IV**
P 19	Wed	18:45–19:45	ELP 6: HS 3	**Members' Assembly**
P 20.1–20.5	Thu	11:00–12:45	ELP 6: HS 3	**Magnetic Confinement VI**
P 21.1–21.5	Thu	14:00–15:30	ELP 6: HS 3	**Low Pressure Plasmas and their Application II**
P 22.1–22.4	Thu	14:00–15:50	ELP 6: HS 4	**Plasma Wall Interaction II/HEPP VII**
P 23.1–23.5	Thu	16:30–18:00	ELP 6: HS 3	**Complex Plasmas and Dusty Plasmas II**
P 24.1–24.4	Thu	16:30–17:45	ELP 6: HS 4	**Codes and Modeling II**
P 25.1–25.31	Thu	16:30–18:30	ELP 6: Foyer	**Poster III**

Members' Assembly of the Plasma Physics Division

Wednesday 18:45–19:45 ELP 6: HS 3

Sessions

– Invited Talks, Contributed Talks, and Posters –

P 1: Magnetic Confinement I/HEPP I

Time: Monday 11:00–12:35 Location: ELP 6: HS 3

Invited Talk P 1.1 Mon 11:00 ELP 6: HS 3

On the observation of Trapped Electron Modes in W7-X — •Andreas Krämer-Flecken[1], Paul Costello[2], Golo Fuchert[2], Joachim Geiger[2], Stèphane Heuraux[3], Alexander Knieps[1], Josefine Proll[4], Kian Rahbarnia[2], Roland Sabot[5], Luigui Salazar[3], Gavin Weir[2], Thomas Windisch[2], and Haoming Xiang[6] — [1]Forschungszentrum Jülich GmbH, Jülich, Germany — [2]Max Planck Institut für Plasmaphysik, Greifswald, Germany — [3]Institut Jean Lamour; Université de Lorraine, Nancy, France — [4]Eindhoven Uni- versity of Technology, Eindhoven, The Netherlands — [5]CEA, IRFM, Saint-Paul-Les-Durance, France — [6]Advanced Energy Research Center, Shenzhen University, Shenzhen, PRC

In fusion devices Trapped Electron Modes (TEM) are responsible for particle transport in general. An indication for TEMs are the so called Quasi Coherent (QC)-modes, density fluctuations visible in different diagnostics e.g. Poloidal Correlation Reflectometry (PCR) and ob- served in a frequency range of 50 kHz to 250 kHz. In case of TEM origin, these QC-modes propagate in electron diamagnetic drift direction and have a poloidal structure size of 20 mm to 30 mm and $k_\perp \rho^* \geq 1$. This presentation reports on the first observation of TEMs and related QC-modes at the stellarator W7-X, as observed by PCR. They show up in low collisionallity ECRH heated plasmas, within a broad frequency range, depending on magnetic configuration and heating power. From the observed frequency of the QC-modes and there poloidal velocity a scaling is developed. Linear gyrokinetic calculation confirm the existence of TEMs within the parameters obtained for these discharges.

P 1.2 Mon 11:30 ELP 6: HS 3

GPU offloading strategies for gyrokinetic edge turbulence simulations with GENE-X via OpenMP and OpenACC — •Jordy Trilaksono[1], Carl-Martin Pfeiler[1], Philipp Ulbl[1], and Frank Jenko[1,2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]University of Texas at Austin, Austin, TX 78712, USA

The GENE-X code simulates plasma turbulence by solving the gyrokinetic equation using a grid-based/Eulerian discretization. The flux-coordinate independent approach allows GENE-X to simulate plasma turbulence anywhere within magnetic confinement fusion (MCF) devices, from the plasma core to the wall. GENE-X is mainly written in object-oriented modern Fortran 2008 fully utilizing MPI+OpenMP parallelization. Here, we present our development strategies and experiences to further accelerate GENE-X on GPU, which is essential for simulations towards larger, reactor-relevant fusion devices. The GPU offloading features are written on an auxiliary C++ layer interoperated by the main Fortran layer. The C++ layer provides broader selections of GPU offloading tools. MPI+OpenMP and MPI+OpenACC parallelizations are chosen to future-proof our solution against the evolution and diversification of modern GPU architectures. We present performance benchmarks and convergence analysis of our OpenMP and OpenACC implementations on GPU. The computational hotspot in GENE-X achieves a significant performance increase on GPU compared to its CPU-equivalent. The readiness of GENE-X compute capability for large-scale production runs on GPU is further investigated.

P 1.3 Mon 11:55 ELP 6: HS 3

Verification of the gyrokinetic code GENE-X for the edge and scrape-off layer of stellarators — •Marion Smedberg[1], Philipp Ulbl[1], Andreas Stegmeir[1], and Frank Jenko[1,2] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]University of Texas at Austin, Austin, TX, USA

A key open question in magnetic confinement fusion research regards plasma turbulence, particularly in the edge and scrape-off layer (SOL). This is especially true for stellarators, since optimization for low neoclassical transport has only recently been proven; the remaining transport is determined to be turbulent [1]. Numerical codes which simulate the plasma turbulence in such devices are critically important to understand the experiments and predict future reactor performance. Here we present `GENE-X`, a full-f, electromagnetic, Eulerian gyrokinetic code designed for the edge and SOL [2], and its generalization to stellarator geometries. We describe the 3D generalization, including the implementation of non-axisymmetric magnetic fields, development of an approximate flux surface label, and the newly generalized data structure. We also discuss the ongoing verification of the 3D-capable code. This includes convergence testing via the method of manufactured solutions, and could include recreating neoclassical transport predictions and a benchmark against the gyrokinetic code `GENE-3D`.

[1] T. S. Pedersen et al, Nucl. Fusion 62 042022 (2022)

[2] D. Michels, et al, Comput. Phys. Commun. 264 (2021)

P 1.4 Mon 12:20 ELP 6: HS 3

Creating a power balance database study on turbulence at Wendelstein 7-X — •Markus Wappl, Marc Beurskens, Sergey Bozhenkov, Tamara Andreeva, Sebastian Bannmann, and Håkan Smith — Max Planck Instiute for Plasma Physics, Greifswald, Germany

Power balance analysis is used to compile a comprehensive database of anomalous transport in various plasma scenarios at the stellarator Wendelstein 7-X. The anomalous transport is attributed to turbulence. As a figure of merit, an effective turbulent transport coefficient χ_{eff} is defined. The database spans a broad parameter range covering different fueling schemes, heating power values and methods as well as different magnetic configurations of W7-X.

Experiments with neutral beam or hydrogen pellet injection allow to increase the central density and ion temperature while creating steep gradients. The database unveils a characteristic dependence of χ_{eff} on the gradient lengths of density and ion temperature, a/Ln and a/LT. This hints at the prevalence of ion temperature gradient (ITG) modes. The critical parameters governing ITG stability, a/Ln_{cr} and a/LT_{cr}, are identified from the database. Based on power and density scan experiments, the scaling behaviour of the effective turbulent transport coefficient is explored. χ_{eff} positively correlates with electron cyclotron heating power, predominantly in the electron channel of turbulent transport.

The benefits of the turbulence database results in a future extrapolation to a stellarator reactor based on W7-X are discussed.

P 2: Atmospheric Pressure Plasmas and their Applications I

Time: Monday 11:00–12:30 Location: WW 1: HS

Invited Talk P 2.1 Mon 11:00 WW 1: HS

Interaction of reactive components of non-equilibrium atmospheric plasmas with liquids and surfaces — •Kerstin Sgonina[1], Alexander Quack[1], Christian Schulze[1], and Jan Benedikt[1,2] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]KiNSIS, Kiel University

Cold atmospheric pressure plasmas (CAP) are a source of reactive species, such as electrons, ions, radicals, excited species, and photons. Typical application fields are surface or liquid treatments, which are based on additive or synergistic effects of these species at solid surfaces or in liquids. However, knowledge about the isolated effect of each plasma component is rare. The isolated interaction of two different reactive components, positive ions and atomic oxygen, with solid surfaces or liquids, respectively, will be presented.

To study the isolated effect of positive ions on substrates at atmospheric pressure, the so-called Vacuum-ultraviolet(VUV)-photoionization chamber has been developed. It uses a helium driven CAP to generate VUV-radiation to photoionize given precursor. With this, an ion-based thin film deposition at atmospheric pressure can be realized.

For atomic oxygen, its effective reaction with organic compounds in liquids is known. However, it was unknown whether these reactions are liquid-surface or volume dominated. Phenol solutions were used as a chemical probe to be treated by the effluent of the COST-Jet as a source of atomic oxygen. The comparison of experimental and modeling results revealed the predominance of reactions of atomic oxygen at the liquid surface.

P 2.2 Mon 11:30 WW 1: HS

Investigation of atmospheric-pressure DBD for thin film deposition in Ar-HMDS mixture — •Marjan Stankov[1], Markus M. Becker[1], Lars Bröcker[2], Claus-Peter Klages[2], and Detlef Loffhagen[1] — [1]Leibniz Insti-

tute for Plasma Science and Technology, Greifswald, Germany — [2]Institute for Surface Technology, Technische Universität Braunschweig, Braunschweig, Germany

Although atmospheric-pressure plasma-enhanced chemical vapour deposition processes employing dielectric-barrier discharges (DBDs) as a plasma source are widely explored for diverse surface modifications, a thorough understanding of main aspects of this process is still lacking. This particularly pertains to identify key particle species responsible for the formation of thin films. Here, a study based on modelling and experimental analysis of DBDs in Ar with the addition of hexamethyldisilane (HMDS) as precursor is reported. A single-filament discharge driven by a 19 kHz sinusoidal voltage is investigated using a time-dependent, spatially one-dimensional fluid-Poisson model including an extensive reaction kinetics related to HMDS. The analysis of surface fluxes of particle species indicates that silicon-containing cations play an important role in the film formation process. The contribution of specific cations is investigated and related to the measured average mass of deposited ions. Furthermore, the influence of different chemical processes on the formation of the cations is discussed.

Funded by the Deutsche Forschungsgemeinschaft (DFG) - project number 504701852.

P 2.3 Mon 11:45 WW 1: HS

Atmospheric plasma as a source of VUV radiation for particle-free thin film deposition — •Tristan Winzer, Christina Reiser, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

Thin-film deposition using plasma to remotely produce VUV photons for photochemistry is an alternative to direct injection of precursor molecules into a plasma, which often results in generation of particles or strong deposition in the source, compromising the properties of the deposited films and the jet operation. This is especially the case at atmospheric pressure, due to high collision rates. At this pressure, noble gas plasmas are efficient sources of VUV radiation down to 60 nm (helium plasma), which can be utilized to initiate photochemistry with subsequent film deposition in precursor gases.

We present here a study on the photochemistry and ionic thin-film deposition from common precursors using a novel source designed for separation of plasma species, radiation and photochemistry products at atmospheric pressure. Precursors were studied for their use in photochemical vapor deposition by analyzing ionic species formed during VUV-treatment of the precursor with ion mass spectrometry and deposited films with Fourier-transform infrared spectroscopy. Particle formation was checked down to 1 nm diameter using a scanning mobility particle sizer.

P 2.4 Mon 12:00 WW 1: HS

Setup and Investigation of a Plasma Window for Heavy Particle Beam Transmission to High Pressurized Targets — •Andre Michel, Fateme Ghaznavi, Michael Händler, Adem Ates, Bernhard Bohlender, Marcus Iberler, and Joachim Jacoby — Goethe University Frankfurt

With an ever-growing enhancement of particle beam intensities and energies in accelerators around the world, a reliable vacuum to high-pressure-target separation technique is strongly needed where common separation techniques such as differential pumping stages or solid membranes might fail. A plasma window, first introduced by A. Hershcovitch [1], offers the advantage of a membraneless particle beam transmission from low- to high pressurized target areas.

At the plasma physics department of Goethe University Frankfurt, a plasma window was developed and successfully tested during the 2022 GSI UNILAC beamtime, utilizing an 48Ca10+ ion beam at 4.8MeV/u - therefore being the first plasma window setup proving its applicability on the transmission of heavy ion beams.

This talk presents the underlying working mechanisms of the plasma window, its plasma physical properties, electrical parameters, its pressure separating properties as well as the characteristics of the transmitted ion beam.

[1] Hershcovitch, A., J. Appl. Phys., AIP Publishing, 1995, 78, 5283

P 2.5 Mon 12:15 WW 1: HS

Spatio-temporal analysis of plasma electrolytic polishing: Insights from optical and electrical diagnostics — •Sehoon An[1], Luka Hansen[2], Thorben Wolff[1], Rüdiger Foest[1], Maik Fröhlich[3], and Holger Kersten[2] — [1]INP Greifswald, Greifswald, Germany — [2]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [3]Leupold Institute of Applied Sciences, University of Applied Sciences Zwickau, Zwickau, Germany

Plasma electrolytic polishing (PEP) has recently gained much attention for its ecological benefits and its ability to enhance the surface quality of intricate metallic components. Understanding the dynamics of the gaseous layer around the workpiece, accompanied with electrical discharges, is crucial for optimal outcomes, as it significantly influences the surface modification effect. Here, we investigate the PEP process using optical and electrical monitoring, utilizing a high-speed camera synchronized with electrical waveform measurements. The temporal development of the temperatures of the workpiece and the surrounding electrolyte is measured and discussed in relation to the discharge characteristics. The experiment involves a WC-Co workpiece immersed in a 10 wt% Na2CO3 solution, anodically polarized at 120 V for 30 s. By high-speed video (1000 fps) a temporally resolved development of the gas layer involving numerous discharges on the workpiece surface is visualized which is correlated to the current signal. We report observations on oscillating discharge currents and characteristic frequencies, analyzed using FFT, in relation to process parameters and the workpiece temperature evolution.

P 3: Plasma Wall Interaction I

Time: Monday 14:00–16:00 Location: ELP 6: HS 3

Invited Talk P 3.1 Mon 14:00 ELP 6: HS 3

Influence of Nanosecond Pulsed Plasmas in Liquids on Copper Surfaces — •Pia-Victoria Pottkämper, Oliver Krettek, Katharina Laake, and Achim von Keudell — Ruhr-Universität Bochum

One application of plasmas in liquids is the modification of metal surfaces. In this project a plasma is ignited in water at an electrode using high voltages, nanosecond pulses and fast rise times. The plasma is then used to modify a coppper surface in contact with the plasma-activated liquid. The plasma causes a dissociation of the water molecules, leading to the creation of many different reactive species with varying lifetimes such as molecular oxygen and hydrogen, solvated electrons and hydrogen peroxyde. The created electric field with a short rise time leads to a fast pressure increase at the ignition site and an expansion of a shock wave which transports the reactive species to the surface. Here different reactions may occur that lead to the modification of the copper. It is possible to reduce the surface or to initiate growth of nanostructures depending on the experimental conditions. The changes are monitored via FTIR spectroscopy, SEM and XPS. The creation of uniform CuxO nanocubes has been observed under certain conditions. One application of these structures is the catalysis of the electrochemical reduction of CO2. During this reaction the activity of these catalysts decreases over time. The in-liquid plasma can cause a re-oxidation and therefore the formation of new CuxO nanocubes. It is postulated that by an in-situ in-liquid plasma treatment the lifetime of the catalytic surfaces can be extended.

P 3.2 Mon 14:30 ELP 6: HS 3

Characterization of boron layers on tungsten substrates by picosecond and nanosecond laser-induced breakdown spectroscopy — •Huace Wu, Sebastijan Brezinsek, Rongxing Yi, Anne Houben, Gennady Sergienko, and Yunfeng Liang — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung * Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany

Boronization is considered in ITER as wall conditioning method for full-W material option. Boron acts primarily as oxygen getter, but can also reduce intrinsic impurity content such as carbon and nitrogen as well as moderately the hydrogen recycling. However, the boron layer thickness, and therefore the lifetime by plasma-induced erosion, is limited, not necessarily toroidal homogeneous, and repetitively boronization needs to be applied to be effective. LIBS as a versatile tool for the investigation of the element composition and is a potential candidate for in-situ investigations of erosion, deposition and material mixing in nuclear fusion devices. At first, we study LIBS in the laboratory on thin boron films (about 100nm) or boron-tungsten layer systems produced by magnetron sputtering on the polished tungsten substrates. Ps (35ps,355nm) and ns (7ns,1064nm) lasers were used to characterize the ablation rate of boron layers as well as matrix effects in the layer system. The ps laser provides a better depth resolution due to the smaller ablation rate. Comparison studies with boron layers (about 10nm) obtained on W substrates in the midplane manipulator of W7-X from boronization will be presented.

P 3.3 Mon 14:45 ELP 6: HS 3

Experimental studies of Hydrogen plasma produced in Pulsed Plasma Accelerator source — •Azmirah Ahmed, Sumit Singha, Pradipta P Kalita, Pallabi Baruah, Nirod K Neog, and Tridip K Borthakur — Centre of Plasma Physics-Institute for Plasma Research (CPP-IPR)

Hydrogen plasma is produced in a Pulsed Plasma Accelerator (PPA) source to simulate the heat loading phenomena of an ELM transient event of fusion devices. A 200 kJ Pulsed Power System (PPS) powers the PPA by delivering a discharge current pulse of 100 kA of half-time period ~ 0.5 ms. An accelerated

plasma stream is produced which has a relatively high density and high velocity. An external longitudinal magnetic field of ~ 0.1 T in the observation region is generated using an electromagnet to study its effect on the plasma stream. Calorimetric study, high-speed imaging and OES is carried out for proper optimization of the plasma. The calorimetric study gives the measure of optimized energy density ~ 0.22 MJ/m2 of the hydrogen plasma. The imaging done using a high speed video camera shows the confinement, shape, uniformity and intensity distribution of plasma. The spectroscopic observations shows the emission from Hα and Hβ transitions of hydrogen and also the transitions of different impurity species generated during the plasma production. The interaction of this hydrogen plasma with a fusion relevant tungsten material is then studied by exposing the tungsten target. By using XRD and FESEM techniques, the impact on the material is studied and initial testing shows formation of major and micro cracks on tungsten.

P 3.4 Mon 15:00 ELP 6: HS 3

Laser enhanced copper surface oxide generation by plasma generated reactive oxygen species — •Sascha Chur[1], Robin Minke[1], Marc Böke[2], and Judith Golda[1] — [1]Plasma Interface Physics, Ruhr-University Bochum, D-44801 Bochum, Germany — [2]Experimentalphysik II, Ruhr-University Bochum, D-44801 Bochum, Germany

Copper, a promising catalyst for CO_2 electroreduction, faces challenges of poor selectivity and energy efficiency. Copper oxides enhance selectivity, particularly towards C_{2+} products. Surface morphology significantly influences performance, and our study demonstrates that combined laser and plasma treatment fine-tunes these characteristics for effective functionalization. Treatment with a micro atmospheric pressure plasma jet induces Cu(II) oxides on copper by generating reactive oxygen species. Investigation into prevalent reaction partners produced by the plasma jet revealed atomic oxygen density at 10^{21} m^{-3} (two-photon absorption laser-induced fluorescence). Singlet delta oxygen, at 10^{20} m^{-3} (emission spectroscopy) closely aligned with simulation results, while ozone density, calculated at 10^{21} m^{-3} (absorption spectroscopy), was overestimated by the simulation. X-ray Photoelectron Spectroscopy of treated surfaces demonstrated an increasing Cu(II) oxide ratio with extended treatment. This research provides insights into controlled and precise copper surface modification, applicable in diverse fields requiring tailored material properties. Supported by the DFG within CRC 1316, project B2.

P 3.5 Mon 15:15 ELP 6: HS 3

Data-integrated multiphysics simulations of reactive magnetron sputtering — •Tobias Gergs[1], Luca Vialetto[1,2], Christian Stüwe[1], and Jan Trieschmann[1] — [1]Theoretical Electrical Engineering, Kiel University, Kaiserstraße 2, 24143 Kiel, Germany — [2]Department of Aeronautics and Astronautics, Stanford University, 496 Lomita Mall, Stanford, CA 94305, United States of America

Reactive magnetron sputtering is widely used in science and industry. However, the understanding of the physical kinetics remains incomplete, primarily because the intrinsic length and time scales of the plasma and the surface differ by orders of magnitude. Individual scientific disciplines have frequently concentrated on only one of these aspects in detail (i.e., plasma or surface), while the other aspect may have been considered in a simplified manner. In this work, established and novel methods are combined to adequately describe the coupled plasma and surface physics involved in the sputter deposition of silicon oxide in Ar/O_2 discharges. The dynamics of the plasma are described by 2d3v particle-in-cell simulations with a Monte Carlo transport scheme for charged particles, energetic neutrals, and sputtered atoms. The surface evolution is determined by rate equations for the surface coverage, which account for chemisorption, physisorption, diffusion of adatoms, and physical sputtering. The energy and angular distributions of sputtered particles are incorporated by an integrated machine learning model, which was trained with Monte Carlo simulation data. The influence of process parameters (e.g., admixtures of O_2) on phenomena such as target poisoning is emphasized.

P 3.6 Mon 15:30 ELP 6: HS 3

Low Pressure Plasma Spraying of Tungsten on Plasma Facing Components for Future Fusion Devices — •Gunnar Schmidtmann[1,2], Andrey Litnovsky[1], Jan Willem Coenen[1], Robert Vassen[2], Sebastijan Brezinsek[1], Christian Linsmeier[1], Olivier Guillon[2], and Georg Mauer[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie und Klimaforschung - Plasmaphysik (IEK-4), 52425 Jülich, Germany — [2]Forschungszentrum Jülich GmbH, Institut für Energie und Klimaforschung - Werkstoffsynthese und Herstellungsverfahren (IEK-1), 52425 Jülich, Germany

Tungsten is currently the baseline plasma-facing material (PFM) for future fusion devices. Despite its advantageous properties, tungsten gets damaged under the extreme plasma conditions, which can lead to a reduced lifetime of the plasma facing components (PFC) or the outage of the whole fusion reactor. As repairing is time and resource intense, Low Pressure Plasma Spraying emerges viable as a fast and affordable solution to restore the PFM and repair damages. Pre-heating of the different substrate materials: Carbon fibre composite, tungsten and Eurofer ($T < 740\ ^{\circ}C$), helped to mitigate residual stresses caused by the thermal mismatch between coating and substrate. Quality parameters such as porosity below 5 % and number of defects were evaluated using digital image analysis. Further characterization was performed to obtain more information on the surface roughness and a coating thickness of at least 100 *m. In future work, selected coatings will be tested under fusion-relevant conditions to obtain a lifetime prediction and to allow to infer further possible improvements.

P 3.7 Mon 15:45 ELP 6: HS 3

Studies of deuterium retention in pre-damaged tungsten with laser-induced ablation quadrupole mass spectrometry — •Christoph Kawan[1,2], Sebastijan Brezinsek[1], Timo Dittmar[1], Thomas Schwarz-Selinger[3], and Erik Wüst[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]Mathematisch-Naturwissenschaftliche Fakultät, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany — [3]Max-Planck-Institut für Plasmaphysik, D-85748 Garching, Germany

Future fusion devices based on magnetically confined plasma will operate with the hydrogen (H) isotopes deuterium (D) and tritium (T) as fuel gases and tungsten (W) as wall material. The extreme conditions inside the fusion device damage the wall surface and change the H retention properties. T accumulating in the W wall is a high risk in terms of radiation safety. Therefore, in-situ methods are needed to quantify the amount of H isotopes. Laser-induced ablation quadrupole mass spectrometry (LIA-QMS) is a promising method which can provide H isotope depth profiles in the wall material, potentially also in-situ. Here, LIA-QMS depth profiles on targets with different amounts of D with established methods such as laser-induced breakdown spectrometry (LIBS) and nuclear reaction analysis (NRA) are compared. LIA-QMS shows a higher sensitivity than LIBS (<0.1 at% with 150 nm depth resolution). The absolute amount differs compared to NRA (6 at% QMS, 1 at% NRA), thus requiring an optimized calibration.

P 4: Astrophysical Plasmas/Laser Plasmas

Time: Monday 14:00–16:00 Location: WW 1: HS

Invited Talk P 4.1 Mon 14:00 WW 1: HS

Ab initio calculations of conductivities under planetary interior conditions — •Martin Preising[1], Martin French[1], Maximilian Schörner[1], Mandy Bethkenhagen[2], Argha Roy[1], Uwe Kleinschmidt[1], and Ronald Redmer[1] — [1]Universität Rostock, Rostock, Germany — [2]École Polytechnique, Palaiseau, France

We summarize our recent efforts to calculate thermal and electrical conductivities under planetary interior conditions with ab initio simulations.

We applied our method to state-of-the-art models [Mankovich and Fortney, Astrophys. J., 889, 51 (2020)] for the gas giant planets Jupiter [French et al., Astrophys. J. Suppl. Ser., 202, 5 (2012)] and Saturn [Preising et al., Astrophys. J. Suppl. Ser., 269, 47 (2023)]. We found a profound impact of the proposed helium-rich layer above Saturn's core on thermal and DC conductivity profiles. The results will affect future magnetohydrodynamic simulations for Saturn's magnetic field.

The ice giant planets Uranus and Neptune are not too well constrained by observational data. We consider different mixtures of hydrogen and methane. Our results show a steady increase in DC conductivity along Uranus' P-T path [Roy et al., submitted (2024)].

A recent study of fcc and hcp iron over a P-T range covering Earth's core-mantle boundary and inner core boundary resulted in fit formulas for the DC and thermal conductivity [Kleinschmidt et al., Phys. Rev. B, 107, 085145 (2023)], applicable to all rocky planets with an iron core.

P 4.2 Mon 14:30 WW 1: HS

Kinetic simulations of strong non-relativistic shocks propagating in a turbulent medium — •Karol Fulat[1], Artem Bohdan[2,3], Michelle Tsirou[4], and Martin Pohl[1,4] — [1]Institute of Physics and Astronomy, University of Potsdam, D-14476 Potsdam, Germany — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, D-85748 Garching, Germany — [3]Excellence Cluster ORIGINS, Boltzmannstr. 2, D-85748 Garching, Germany — [4]Deutsches Elektronen-Synchrotron DESY, Platanenallee 6, D-15738 Zeuthen, Germany

Strong non-relativistic shocks are known to accelerate particles up to relativistic energies. However, for Diffusive Shock Acceleration electrons must have a highly

suprathermal energy, implying a need for very efficient pre-acceleration. Most published studies consider shocks propagating through homogeneous plasma, which is an unrealistic assumption for astrophysical environments. To address this limitation, we have developed a novel simulation technique that provides a framework for studying shocks propagating in turbulent media from first principles. We have performed PIC simulations of non-relativistic high-Mach-number shocks propagating in an electron-ion plasma with a turbulent upstream medium. We have explored the impact of the fluctuations on electron heating and acceleration, the dynamics of upstream electrons, and the driving of plasma instabilities. We will also discuss our recent results from oblique shock simulations.

P 4.3 Mon 14:45 WW 1: HS

First operation of APEX-LD, a levitated dipole trap designed for e+e- plasmas — •Alexander Card — Max-Planck-Institut für Plasmaphysik — Technische Universität München

The mission of the APEX-LD (A Positron-Electron eXperiment - Levitated Dipole) trap is to provide a compact (~10-liter) volume of closed dipole magnetic field lines, to be used for the confinement and study of low-temperature, long-lived e+e- pair plasmas. The requirements for this application posed a number of challenges for experiment design and engineering. (These included, e.g., the need to repeatedly make and break thermal contact with cryogenically cooled components in a vacuum environment; excitation of current in the superconducting "floating coil", followed by long-duration, feedback-stabilized levitation; and a demand for robustness to repeated quenches and possible mechanical shocks). A comparable number of experiment design and engineering solutions have been found and implemented, and APEX-LD has successfully started operation, enabling the first electron experiments to commence in late 2023. This talk will outline the design of the APEX-LD systems, then present the highlights of the experiment commissioning (e.g., efficient current induction to ~0.5 T on axis, levitation times in excess of three hours, and slow/"gentle" quenching of the non-insulated HTS [high-temperature superconducting] coil). Finally, it will describe results from first experiments (i.e., magnetic field line visualizations and e- injection) and next steps for making e- plasmas and later injecting cold, dense pulses of e+.

P 4.4 Mon 15:00 WW 1: HS

Improved Conductivity model for fully ionized hydrogen plasma — •Uwe Kleinschmidt and Ronald Redmer — Universität Rostock, Institut für Physik, Albert-Einstein-Strasse 23-24, D-18059 Rostock, Germany

Electrical and thermal conductivities for matter under extreme conditions are an important input in magnetohydrodynamic simulations to model, e.g., the dynamo action in the deep interior of planets like Jupiter or the Ohmic dissipation rate in the atmosphere of hot Jupiters (see [1]). Such gas giant planets consist mainly of hydrogen and helium so that the calculation of corresponding conductivity data for a wide range of pressures and temperatures is an important task. In addition, the construction of conductivity models, e.g., by solving the Boltzmann equation in relaxation time approximation, as proposed by Lee and More [2] help to keep the computational costs low in such simulations. The Lee-More conductivity model provides reasonable results for weakly coupled high temperature plasmas but deviates strongly from ab initio methods like density functional theory molecular dynamics (DFT-MD) simulations for lower temperatures and stronger coupled plasmas (see [3]). We performed extensive DFT-MD simulations to calculate conductivities for fully ionized hydrogen plasma. We used this data to modify the conductivity model by Lee and More and to provide conductivity data for a wide range of temperature and density.

[1] S. Kumar et al., Phys. Rev. E 103, 063203 (2021)
[2] Y. T. Lee and R. M. More, Phys. Fluids 27, 1273 (1984)
[3] M. French et al., Phys. Rev. E 105, 065204 (2022)

P 4.5 Mon 15:15 WW 1: HS

Chirped plasma density gratings for compression of high-intensity laser pulses — •Götz Lehmann and Karl-Heinz Spatschek — Heinrich-Heine-Universität, Düsseldorf

Modern high-power chirped-pulse (CPA) laser systems are limited in several ways by optical damage thresholds and detrimental nonlinearities. Amplification, compression, and polarization control of intense laser beams is often ultimately limited by the ionization threshold of solid state materials. Hence, plasma-based optical elements, often referred to as damageless optics, are attractive alternatives.

We study the formation and optical properties of plasma density gratings which may act as reflective and transmissive optics for high-power pulses. The plasma gratings themselves are driven via laser pulses to ma- nipulate pulses of higher intensity. Our interest lies in chirped plasma gratings that then can be used for compression of chirped pulses similar to conventional compression gratings in modern high-power CPA systems. We demonstrate via simulations the formation of chirped gratings, discuss their compression capabilities, and outline parameter regimes for applications.

P 4.6 Mon 15:30 WW 1: HS

Nonmetal-to-metal transition in dense fluid nitrogen at high pressure — Armin Bergermann and •Ronald Redmer — Univ. Rostock, Institut für Physik, A.-Einstein-Str. 23, 18059 Rostock

The high-pressure phase diagram of solid nitrogen is extremely rich: 12 molecular phases, two nonmolecular phases, and an amorphous one have been reported so far [1]. Recent molecular dynamics (MD) simulations on dense fluid nitrogen using density functional theory (DFT) predict a first-order liquid-liquid phase transition (LL-PT) at about a megabar, see e.g. [2]. Static experiments using diamond anvil cells as well as dynamic shock-wave experiments have been applied to access the corresponding region.

We calculate the electrical conductivity and the equation of state of dense fluid nitrogen for high pressures up to several megabars by using DFT-MD simulations [3]. We determine the instability region of the first-order LL-PT which results from an abrupt dissociation of nitrogen molecules. This transition is accompanied by a nonmetal-to-metal transition (metallization) of the fluid and corresponding structural changes from a molecular to a polymeric phase. We compare our data with earlier theoretical results and available experiments.

[1] R. Turnbull et al., Nat. Commun. 9, 4717 (2018) [2] B. Boates, S. A. Bonev, Phys. Rev. Lett. 102, 015701 (2009). [3] A. Bergermann, R. Redmer, Phys. Rev. B 108, 085101 (2023)

P 4.7 Mon 15:45 WW 1: HS

Negative Corona, free Electrons and their Role in the Creation of Ball Lightning — •Herbert Boerner — Mainz

Ball lightning (BL) is still an unexplained phenomenon of atmospheric physics. Until recently, all evidence came from reports by accidental observers, but in the last years, additional information became available, mainly from lightning location systems. In order to make progress in defining suitable experiments and in selecting a theory that is consistent with the observations, it is important to choose from the thousands of anecdotal reports those that are reliable and that also contain information on the physics involved. There are indications, that positive cloud-ground lightning (+CG) has a much higher probability to create these objects that negative CG lightning. Together with the fact that BL objects can be produced far away from lightning channels, this allows a definition of the conditions under which BL is created. The importance of negative corona in air, of Trichel pulses, and the role of free electrons is discussed and an experimental setup is proposed.

P 5: Magnetic Confinement II/HEPP II

Time: Monday 16:30–18:15 Location: ELP 6: HS 3

P 5.1 Mon 16:30 ELP 6: HS 3

Searching for SQuIDs:*Stable Quasi-Isodynamic Designs for Stellarators — •Alan Goodman, Pavlos Xanthopoulos, Gabriel Plunk, Sophia Henneberg, Carolin Nuhremburg, Hakan Smith, Craig Beidler, Gareth Roberg-Clark, and Per Helander — Max-Planck-Institut fur Plasmaphysik, D-17491 Greifswald, Germany

Quasi-isodynamic (QI) stellarators are a uniquely attractive fusion reactor candidate due to their low neoclassical transport, excellent confinement of fusion-borne alpha particles, and vanishingly small bootstrap currents [1]. Due to the complexity of their geometries, QI stellarators must generally be designed through numerical optimization, which requires an objective metric that quantifies the degree to which a given design is QI. While once thought impossible, we recently showed that nearly-perfectly QI geometries can be found using an appropriately-designed objective function [2]. We have since built upon this approach, now finding QI geometries with reduced turbulence, improved MHD stability, and lower surface area-to-volume ratios, which are potential candidates for future stellarator experiments and reactors.

References:

[1] P Helander and J Nührenberg. Bootstrap current and neoclassical transport in quasi-isodynamic stellarators. PPCF (2009).

[2] A Goodman et al. Constructing precisely quasi-isodynamic magnetic fields, JPP (2023).

P 5.2 Mon 16:55 ELP 6: HS 3

Equilibrium and stability of plasma with arbitrary non-neutrality in a levitated dipole trap — •Patrick Steinbrunner[1], Thomas O'Neil[2], and Matthew Stoneking[3] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]University of California San Diego, La Jolla, United States — [3]Lawrence University, Appleton, United States

A purely nonneutral plasma can be confined in a global thermal equilibrium state as well as a local thermal equilibrium along magnetic field lines in a magnetic dipole trap. A plasma consisting of a mixture of electrons and positrons, as it is envisioned by the APEX collaboration (A Positron-Electron eXperiment), can only be confined in a local thermal equilibrium state. While global thermal equilibria are maximum entropy states and hence guaranteed to be stable, local thermal equilibria can be unstable.

One of the dominant instabilities, the diocotron mode, was studied to a great extend in the homogeneous magnetic field of a Penning-Malmberg trap. We will focus on the inhomogeneous magnetic field of a z-pinch, which serves as an approximation of the vicinity of a levitated coil. This implies two differences in comparison to a Penning-Malmberg trap. First, grad-B and curvature drifts influence the instability. Second, plasmas of arbitrary nonneutrality can be confined. We found that in the general case of arbitrary nonneutrality, the stability is governed by an interplay between the diocotron and the interchange instability.

P 5.3 Mon 17:20 ELP 6: HS 3

Direct Construction of Large Aspect Ratio Quasi-isodynamic Stellarators — •Katia Camacho Mata, Gabriel G. Plunk, and Alan G. Goodman — Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

Quasi-isodynamic (QI) stellarators are attractive fusion reactor candidates due to their good confinement properties, inherent steady-state operation, low toroidal currents and favourable turbulence properties. However, optimisation methods traditionally used to find QI fields are highly dependent on the initial guess, often result in complicated geometries and do not offer physical insight into the solution space structure. The near-axis expansion (NAE) method, an expansion of the magnetohydrodynamic equations, can be used to construct exact QI equilibria in the vicinity of the magnetic axis, to first or second order. The NAE method is discussed, and it is shown that configurations with low neoclassical transport and simple boundary shapes can be constructed, even far from the axis, by carefully choosing the initial NAE parameters. The QI solution space structure is investigated using these parameters. The role the helicity of the magnetic axis plays in dividing the space into regions with different confinement properties is described and is used to construct NA QI solutions similar to existing optimised stellarators. The strengths of the NAE are discussed, namely its suitability to provide initial points for traditional optimization, and the ability to perform a systematic and exhaustive search of the QI solution space, aiding in the search of the next generation stellarator designs.

P 5.4 Mon 17:45 ELP 6: HS 3

Stochastic Single-Stage Stellarator Optimization for EPOS and Analysis of Coil Perturbations — •Pedro F. Gil, Jason Smoniewski, Paul Huslage, and Eve V. Stenson — Max-Planck-Institute for Plasma Physics, Garching, Germany

The EPOS (Electrons and Positrons in an Optimised Stellarator) project, as part of the APEX (A Positron Electron eXperiment) Collaboration, aims to build a small-scale stellarator for the confinement of pair plasmas. The magnetic field in EPOS will be quasi-axisymmetric, meaning that the magnetic field amplitude is invariant along a toroidal coordinate. This symmetry ensures the good confinement of trapped particle orbits. The device will receive a limited amount of positrons setting a constraint on its size, leading to unmanageable coil manufacturing and assembly tolerances. An analysis of the perturbations that affect the induced magnetic field is performed in order to guide the optimization towards robust configurations.

Stellarator optimization is usually a two-step process: find a target equilibrium, and design coils to match that desired equilibrium. Stochastic optimization of the coils randomly perturbs the shape of the coils N times and averages the magnetic field. This both broadens the width of the minima allowing to find more robust configurations and reduces the likelihood of getting trapped in local minima. Combined with a single-stage approach it smooths the objective function while searching for both coils and plasma. This method is expected to relax the coil construction constraints for EPOS into the ± 0.3 mm range, making it buildable.

P 5.5 Mon 18:00 ELP 6: HS 3

Optimized HTS Coils for the EPOS Stellarator — •Paul Huslage, Pedro Gil, Jason Smoniewski, and E. V. Stenson — Max-Planck Institue for Plasma Physics

The future EPOS (Electrons and Positrons in an Optimized Stellarator) aims to confine an electron positron pair plasma using non-planar high-temperature superconductor (HTS) coils. The non-planar shape combined with the requirement for compactness results in significant mechanical strain imposed on the HTS tapes, which can cause cracks in their functional ceramic layer and requires careful optimization of the coils. With its small size and moderate magnetic field (R=0.2m, B=2T), EPOS provides an attractive platform for advancing stellarator coil design.

En route to an engineering design for the experiment, we built several non-insulated, superconducting prototype coils, both planar and non-planar and operated them under cryogenic conditions. We use 3D-printed metal frames to wind the superconductor into the desired shape.

We present our prototype coils together with critical current measurements and quench tests both in liquid nitrogen and at 20 K inside a vacuum chamber.

P 6: Poster I

Time: Monday 16:30–18:30 Location: ELP 6: Foyer

P 6.1 Mon 16:30 ELP 6: Foyer

Thermo-Field emission from cathodes made of selected materials — •Margarita Baeva[1], Dirk Uhrlandt[1], Dominik Bratek[2], Carsten Uber[2], Bogdan Barbu[3], and Frank Berger[3] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany — [3]Technische Universität Ilmenau, Germany

Electric discharges in a metal vapour released from the cathode during contact opening are observed in various application fields. In explosion protection, the ignition prediction in flammable gas mixtures is concerned with contact break discharges. The latter represent an ignition source for the gas mixture. In low-voltage switching devices, an electric arc in metal vapour occurs during the so called immobility phase, which is essential for the breaking performance of the device.

This contribution is concerned with the emission of electrons from cathodes made of selected materials (Cu, W, Cd, Zn, Ir) that occurs by collective effects (high temperature in the cathode, high electric field on the cathode surface). These effects characterize the arc regime of operation of electric discharges. In order to obtain the electron emission current for operation with cathodes of the aforementioned materials, the transferred matrix method is applied. This method is applicable to arbitrary shapes of the surface potential barrier. The selected materials considered in this work represent both refractory and non-refractory cathodes.

P 6.2 Mon 16:30 ELP 6: Foyer

Deducing line-integrated density, collision frequency and density profile of an atmospheric plasma torch from microwave diagnostics — •Christos Vagkidis, Eberhand Holzhauer, Walter Kasparek, Alf Köhn-Seemann, Stefan Merli, Mirko Ramisch, Andreas Schulz, and Günter Tovar — IGVP, University of Stuttgart, Germany

Microwaves are crucial in plasma applications, either as a heating mechanism or diagnostics tools. In this work we are utilizing high-frequency microwaves to deduce fundamental information of an atmospheric plasma torch. A network analyzer is used in order to measure the phase shift and the attenuation of a microwave that transverses the plasma torch. These measured quantities are directly related to the line-integrated density and the electron-neutral collision frequency of the torch through the plasma index of refraction. Additionally, the microwave is scattered due to the interaction with the plasma and this scattering depends on the plasma density profile. By moving the receiving antenna of the network analyzer, perpendicularly to the plasma torch, the beam scattering profile can be measured. Numerical full-wave simulations in a 3D domain have been carried out, which allow a variation of the density profile over a wide parameter range. Direct comparison of the experimental scattering profile against the simulations enables a precise estimation of a 2D density profile of the plasma torch.

P 6.3 Mon 16:30 ELP 6: Foyer

Kinetic Modeling of the Chemical and Physical Mechanisms in a Rf Plasma Combined with a Catalyst — •Fatma-Nur Seferoglu[1], Dirk Reiser[1], Achim Von Keudell[2], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich Gmbh, Jülich, Germany — [2]Ruhr-Universität Bochum, Bochum, Germany

Plasma driven catalysis is a promising method for addressing environmental challenges, particularly in the removal of volatile organic compounds (VOC), the reduction of nitrogen oxides and the oxidation of hydrocarbons. The oxidation of n-butane is often used as a benchmark for the efficiency of a catalytic system to remove VOC. However, the description of the chemical and physical

mechanisms of plasma catalytic processes can be very challenging due to the high number of possible reaction pathways. On the one hand, the plasma changes the surface coverage of the catalyst and on the other hand, the catalyst influences the variety of the plasma species, i.e. due to desorption of species from the catalytic surface.

This work presents an approach to model the species concentration in a radiofrequency atmospheric pressure plasma combined with a manganese dioxide catalyst and to identify the most effective reaction pathways. In the experiment, the plasma channel is filled with different admixtures of carbon dioxide diluted in helium to investigate the dissociation and recombination of molecules using fourier-transform infrared spectroscopy. For better understanding of the chemical and physical mechanisms in the plasma catalytic system, more gas phase and surface reactions will be tested.

P 6.4 Mon 16:30 ELP 6: Foyer

Silicon nitride membrane as entrance window for plasma-induced VUV radiation — •Görkem Bilgin[1], Luka Hansen[1,2], and Jan Benedikt[1,2] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Kiel Nano, Surface and Interface Science KiNSIS, Kiel University, Kiel, Germany

The measurement of vacuum-ultraviolet (VUV) radiation generated by atmospheric pressure plasmas is restricted by the cutoff-wavelength of typical VUV window materials around 100 nanometers as the VUV radiation has to be transfered into the vacuum to avoid absorption [1]. Silicon nitride membranes originally designed for applications in transmission electron microscopes offer the possibility to be used as entrance windows in monochromators. First measurements show that these membranes are capable of withstanding the forces generated by the pressure gradient while being much thinner (20 nm to 200 nm membrane thickness) than typical VUV window materials.

Two different non-thermal atmospheric pressure plasma sources, based on a capillary jet [2] and a DC microplasma [3], were used to generate He-excimer-radiation in the VUV range. Results of the vacuum resistance as well as the VUV absorption measurements of the silicon nitride membranes are presented for different membrane thicknesses.

[1] J. Golda *et al.*, 2020 *Plasma Process. Polym.* **17** 201900216
[2] T. Winzer *et al.*, 2022 *J. Appl. Phys.* **132** 183301
[3] L. Hansen *et al.*, 2022 *Plasma Sources Sci. Technol.* **31** 035013

P 6.5 Mon 16:30 ELP 6: Foyer

Overcoming He: Towards a more sustainable plasma-driven biocatalysis — •Steffen Schüttler[1], Tim Dirks[2], Sabrina Klopsch[2], Jannis Kaufmann[1], Niklas Eichstaedt[1], Julia E. Bandow[2], and Judith Golda[1] — [1]Plasma Interface Physics, Ruhr-University Bochum, Universitätsstraße 150, 44801 Bochum, Germany — [2]Applied Microbiology, Ruhr-University Bochum, Universitätsstraße 150, 44801 Bochum, Germany

In plasma-driven biocatalysis, an RF atmospheric pressure plasma jet operated with humid He is used to generate and deliver H2O2 into a liquid in which biological enzymes act as catalysts [1]. Promising total turnover numbers were found, showing that this approach is competitive with other approaches presented in literature. However, 99% of the operating costs of the process are due to the use of He as feed gas. Therefore, in order to achieve a more sustainable approach, Ar was used as a feed gas because it can be extracted from air and is less expensive than He. A less stable plasma operation and a lower H2O2 production were found, which counterbalances the lower cost of Ar compared to He. To obtain a more stable plasma with Ar, a kHz plasma jet was also tested, which could also be used well in biocatalysis. N2 or air as feed gas are the most cost-effective gases. Therefore, the operation of the kHz plasma jet in humid N2 has also been tested for plasma-assisted biocatalysis, enabling a wider range of applications.

This work is supported by the DFG within CRC1316 (Subproject B11, project number 327886311).

[1] A. Yayci et al., ChemCatChem 12, 5893-5897 (2020)

P 6.6 Mon 16:30 ELP 6: Foyer

Investigation of the morphology of a pulsed discharge in water using stereoscopic images — •Robert Werberger[1,2], Raphael Rataj[2], and Klaus-Dieter Weltmann[1,2] — [1]Universität Greifswald — [2]Leibniz-Institut für Plasmaforschung und Technologie e. V.

In the past, the morphology of streamer discharges in water was mainly analysed using 2D imaging systems, which resulted in measurement uncertainties due to the loss of depth information on the structure of the discharges. To take the spatial information into account, 3D images of the discharges are required. This study utilised a stereoscopic camera system to determine the disparity between two images resulting from different viewing angles. An automated analysis procedure was used to determine the corresponding points between the images, which was then used to create a 3D reconstruction of the discharges, thereby obtaining spatial information. The streamer discharges were generated at a needle-to-plate electrode with a positive, pulsed voltage signal with an amplitude ranging from 35 to 45 kV and a pulse duration of 100 ns. In the study, effects of voltage amplitude and liquid conductivity on the spatial positions of discharge channel branches and their splitting angles were investigated. Additionally, a comparison between two- and three-dimensional results will be presented.

P 6.7 Mon 16:30 ELP 6: Foyer

Experimental studies on H_2 addition to a CO_2 atmospheric microwave plasma torch — •Marc Bresser, Sophie Wahl, Katharina Wiegers, Andreas Schulz, Matthias Walker, and Günter Tovar — IGVP, University of Stuttgart, Germany

Man-made climate change, caused for example by an increased concentration of carbon dioxide (CO_2) in the atmosphere, is causing a switch from fossil fuels to renewable energy sources. The chemical industry is searching for new renewable ways to synthesize hydrocarbons. One way is to utilize the resulting CO_2 as a reactant and create a cycle process. CO_2 can be activated by a microwave plasma and split into carbon monoxide (CO) and oxygen (O_2). The big advantage is, that this technology enables the use of intermittent energy from wind and sun. The resulting CO can be further processed into hydrocarbons. One idea is to add other gases to the CO_2 plasma in order to utilize the energy and produce higher value products. In this work, the addition of "green" hydrogen (H_2) to a CO_2 plasma is investigated. The CO_2 gas is introduced tangentially in a reverse vortex flow of a microwave plasma torch. On top of the plasma torch a 13 mm restriction nozzle is mounted to quench the plasma and prevent the reverse reaction. The position of the H_2 addition is varied. After cooling to room temperature, the product gas is analyzed using a Fourier transform infrared (FTIR) absorption spectrometer. The influence of microwave power, gas flow and gas composition on the product gas is studied.

P 6.8 Mon 16:30 ELP 6: Foyer

Impact of CO_2 on the metastable atom density in the COST Reference Microplasma Jet — •Alexander Schicke, Sebastian Burhenn, and Judith Golda — Plasma Interface Physics, Ruhr-Universität Bochum, 44801 Bochum, Germany

In the plasma community, the dissociation of CO_2 has become a growing topic over the last years. Many applications include decarbonising the atmosphere and producing carbon for chemicals and fuels. Typical degrees of dissociation of about 45% can be achieved by adding CO_2 to e.g. a helium rf-plasma. The degree of dissociation can be increased by adding argon to the helium discharge gas stream. In previous works, it was assumed that two of the main reaction pathways responsible for the dissociation of CO_2 are electron impact dissociation and dissociation via Penning collisions with metastable atoms.

Therefore, to quantify how big of a role the metastable atoms play in the COST Reference Microplasma Jet, we changed the He/Ar ratio in the feed gas while simultaneously measuring the Ar and He metastable atom densities via tunable diode laser absorption spectroscopy (TDLAS). Additionally, the density profiles were measured as 2D maps, which gives us information about the spatial distribution of the metastable atoms in the discharge channel.

P 6.9 Mon 16:30 ELP 6: Foyer

Construction and test of a (micro-)hollow cathode assembly regarding hydrogen production via methane — •Marcel Margraf — Goethe Universität Frankfurt, IAP

A (Micro-)Hollow cathode assembly was designed with purpose of finding an efficient method to separate Methane into Hydrogen and Carbon. Compared to other discharges a hollow cathode discharge (HCD) allows for higher current densities at same conditions. Due to this higher dissociation degrees can be expected and thus possibly better efficiencies. A cylindrical cathode with a diameter of 0,8mm was used, separated from the anode by a 0,5mm thick MICA isolator. The assembly was powered by a DC high voltage generator and measurements were conducted from 0,2 to 0,9 mA under pressures of 300 to 800 mbar. Discharge voltage and current were measured with an oscilloscope and the conversion rate was measured with a gas analyzer. No correlation between pressure and efficiency was found in this test, however the efficiency went up with higher input currents. The best efficiency of 6,26% +/- 2,62% was achieved with 0,9mA at the highest pressure. This is a promising result for the idea to use such assemblies at atmospheric pressure and a basis for further tests.

P 6.10 Mon 16:30 ELP 6: Foyer

Imaging Spectrography at the Plasma Liquid Interface — •Kai Bröking[1,2], Daniel Tasche[1,2], and Christoph Gerhard[1,3] — [1]HAWK Hochschule für angewandte Wissenschaft und Kunst, Fakultät Ingenieurwissenschaften und Gesundheit, Göttingen — [2]Technische Universität Clausthal, Fakultät für Natur- und Materialwissenschaften, Clausthal-Zellerfeld — [3]Politecnico di Milano, School of Industrial and Information Engineering, Milano, Italy

Imaging spectrographs preserve spatial details imaged onto a spectrograph slit throughout the whole of their optical system. This grants access to spatially resolved spectral information, in our case about both plasma induced processes and, concurrently, to properties of the plasma. We have implemented a fast direct vision spectrograph for imaging in near real time, which allows access to process parameters in near real time as well. This is of marked interest for study-

ing processes near the plasma liquid interface in the plasma induced formation of silver nanoparticles (AgNP). Taking spatially resolved absorption spectra of the AgNP simultaneously with the emission spectra of the plasma permits local process parameters to be observed in real time and investigated with a view to adjusting conditions of the reaction accordingly.

P 6.11 Mon 16:30 ELP 6: Foyer

Investigation of a plasma window arc discharge for particle beam transmission to high pressure targets — •Fateme Ghaznavi — Goethe University, Frankfurt am Main, Germany

A Plasma window [1] is a device which can be used to separate two different pressure levels, allowing for an unperturbed transmission of ion beams from the accelerator vacuum to high pressure targets. This sealing effect is provided by an arc discharge, burning along the ion beam transmission axis. At Goethe University Frankfurt, we constructed a plasma window, featuring an aperture of 5mm, using an 98%Ar-2%H_2 working gas compound and currents between 60-120 A with a flow rate between 1-4 slm. The aim of this study is to investigate the plasma physical characteristics of this arc discharge. A spectroscopic system is adjusted along the discharge axis to allow for a simultaneous estimation of the electron temperature and density at 4 different positions. They were found to range between 1-1.5 eV for the electron temperature and $0.6\text{-}3.8\cdot10^{16}$ cm^3 for the electron density, reaching 30% higher pressures compared to previous measurements utilizing the same aperture with lower currents [2].

[1] Hershcovitch, A. High-pressure arcs as vacuum-atmosphere interface and plasma lens for nonvacuum electron beam welding machines, electron beam melting, and nonvacuum ion material modification J. Appl. Phys., AIP Publishing, 1995, 78, 5283

[2] B. F. Bohlender Characterization of a plasma window as a membrane free transition between vacuum and high pressure Physical review accelerators and beams 23, 2020

P 6.12 Mon 16:30 ELP 6: Foyer

Comparison of the finite element and spectral element methods in modelling of streamer discharges. — •I. L. Semenov, A. P. Jovanovic, and M. M. Becker — Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany

Numerical modelling of streamers at atmospheric pressures is a challenging problem due to the multiscale nature of this discharge type. The current need to simulate streamers in realistic geometries and model the streamer-surface interaction drives the development of novel computational approaches to this problem. One of the key challenges is the development and implementation of efficient methods for solving large-scale electrostatic problems. As it was shown in [I. L. Semenov, K. D. Weltmann, J. Comput. Phys. 465, 111378 (2022)], the use of the hierarchical Poincaré - Steklov (HPS) scheme can be a promising approach to improve the computation efficiency of solving elliptic problems in streamer simulations. The HPS scheme is a multidomain spectral collocation method that has a number of attractive features. In this contribution we compare the streamer simulation scheme based on the HPS method with that based on the conventional finite element method (implemented using FEDM within the FEniCS framework). A number of test problems is considered and the efficiency of both methods is assessed in terms of the required computational time and the number of discrete unknowns being involved.

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – Projektnummern 515939493, 466331904.

P 6.13 Mon 16:30 ELP 6: Foyer

Benefits and perspectives of semantic data acquisition in low-temperature plasma physics — Ihda Chaerony Siffa[1], Hidir Aras[2], Harald Sack[2], Markus Stocker[3], and •Markus M. Becker[1] — [1]Leibniz Institute for Plasma Science and Technology (INP) — [2]FIZ Karlsruhe - Leibniz Institute for Information Infrastructure — [3]TIB - Leibniz Information Centre for Science and Technology

The scientific communities have recognized that structured storage and provision of data and technical information according to the FAIR data principles can represent a tremendous added value for research and development. This is reflected by the establishment of metadata schemas, ontologies, and knowledge graphs within the framework of the National Research Data Infrastructure (NFDI) in Germany and other projects in the field of research data management, where researchers from various fields work closely with computer scientists to develop sustainable infrastructures and tools. In this contribution, we present a basic ontology for low-temperature plasma (LTP) physics and show how a knowledge graph for LTP is created, which allows for easier reuse of data by providing a structured and interconnected representation of information. An application example demonstrates the development of an infrastructure for the simplified search of context-related information in patents, scientific literature and research data. Furthermore, we present how this can also support data-driven research and utilize the benefits of open-access publications.

The work was supported by the DFG (project 496963457) and by the BMBF (projects 16QK03A-B and 16KOA013A-B).

P 6.14 Mon 16:30 ELP 6: Foyer

Research data management with eLabFTW and Adamant — •Markus M. Becker[1], Ihda Chaerony Siffa[1], Robert Wagner[1], Nick Plathe[1], Kerstin Sgonina[2], and Marina Prenzel[3] — [1]Leibniz Institute for Plasma Science and Technology (INP) — [2]Institute of Experimental and Applied Physics, Kiel University (CAU) — [3]Research Department Plasmas with Complex Interactions, Ruhr-University Bochum (RUB)

The practical implementation of present requirements of the funding organizations with regard to the collection of standardized metadata and compliance with the FAIR data principles presents scientists and institutes with new challenges. Research data should be documented in a structured way and provided with identifiers to keep both data and metadata findable, accessible, interoperable and reusable. Electronic laboratory notebook (ELN) systems can support the implementation of these requirements. This contribution introduces the open-source ELN system eLabFTW (https://www.elabftw.net) and demonstrates its practical application in several groups in the field of low-temperature plasma physics. Furthermore, it is shown how the open-source tool Adamant (https://github.com/plasma-mds/adamant) can help to collect and store metadata in structured formats supporting the implementation of automated workflows for metadata acquisition, storage and publication on the basis of eLabFTW.

The work is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under the National Research Data Infrastructure – [NFDI46/1] – 501864659 and project 327886311.

P 6.15 Mon 16:30 ELP 6: Foyer

Characterization of millimeter-sized low-pressure plasmas in multi-scale aeromaterials — •Karin Hansen[1], Julian Held[2], Jonas Lumma[3], Lena Marie Saure[3], Fabian Schütt[3], Rainer Adelung[3], and Franko Greiner[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Department of Mechanical Engineering, University of Minnesota, Minneapolis, USA — [3]Institute for Materials Science, Kiel University, Kiel, Germany

Environmental protection is pivotal in our daily lives, and catalysis, particularly plasma catalysis, stands as a promising avenue to address these challenges. The efficiency of chemical processes hinges on the interplay between the plasma and catalyst surface. Nanodusty plasmas, comprising nanometer-sized particles spaced at micrometer intervals in a low-pressure plasma, exhibit notable attributes - a high surface-to-volume ratio and exceptional plasma permeability with a filling factor $f \approx 10^{-5}$. Multi-scale aeromaterials, micron-sized tetrapodal frameworks with nano-sized walls, share a comparable filling factor. These highly porous and lightweight aeromaterials remain solid and deployable within a plasma environment.

Our investigation centers on probing the interaction between these aeromaterials and low-pressure, radio-frequency argon plasmas. The plasma is ignited in a system of millimeter-sized aeromaterial cylinders with cylindrical cavities, providing a large aeromaterial-surface to plasma-volume ratio. Optical emission spectroscopy and electrostatic double probes as key techniques have been tailored to this millimeter-sized system. Our preliminary studies focus on aeroglass (t-SiO2).

P 6.16 Mon 16:30 ELP 6: Foyer

Langmuir probe measurements in a dual-frequency capacitively coupled rf discharge — •Viktor Schneider[1], Jessica Schleitzer[1], Ihor Korolov[2], Gerrit Hübner[2], Peter Hartmann[3], Julian Schulze[2], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics (IEAP), Kiel University — [2]Chair of Applied Electrodynamics and Plasma Technology, Faculty of Electrical Engineering and Information Sciences, Ruhr University, Bochum, Germany — [3]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Hungary

A dual-frequency capacitively coupled rf argon plasma has been investigated using a passively compensated Langmuir probe. The discharge is driven by two different excitation frequencies (13.56 MHz and 27.12 MHz) simultaneously with variable phase angle θ between them, utilizing the electrical asymmetry effect (EAE). With a passively compensated Langmuir probe the floating potential, plasma potential, electron temperature and electron density are measured for different phase angles in two different geometrically asymmetric discharges. Similar to the dc self-bias, the plasma parameters show a pronounced dependence on the phase. However, the measured profiles of the density and temperature as a function of phase in both experimental setups are not symmetric around $\theta = 90^\circ$, unlike the dc self-bias. This observation is confirmed by PIC/MCC simulations, which reveal asymmetrical electron excitation/ionization dynamics at the corresponding phases. This implies that the observed trends are a property of the 2f discharge in combination with a geometric asymmetry of the discharge.

P 6.17 Mon 16:30 ELP 6: Foyer

Seagull - A compact helicon discharge — •Stefan Knauer, Nils Fahrenkamp, Sebastian Haag, and Peter Manz — Felix-Hausdorff-Str 6, 17489 Greifswald

The Seagull experiment is a radio-frequency powered plasma experiment with a planar double spiral antenna. The plasma forms in a cylindrical high-vacuum,

within a volume of about 1dm^3. It was used to study capacitively (CCP) and inductively (ICP) coupled radio-frequency discharges, e.g. by means of a microwave interferometer, electron detachment and a set of Langmuir probes. Phase transitions and instabilities in electro-negative gases were investigated, as it aims to provide insight in industrial relevant coating processes. We plan to upgrade the experiment with copper coils to add a static magnetic field to the discharge area. A static magnetic field is required for helicon discharges, which are known for their height densities. Since Seagull exhibits unusual small vessel dimensions compared to other helicon experiments (sometimes multiple meters long), a comparatively short wavelength should be sufficient and thus a low magnetic field. This parameter and diagnostic set-up might enable well diagnosed helicon discharge measurements at the size of a table-top experiment.

P 6.18 Mon 16:30 ELP 6: Foyer

Development and application of low energy plasma treatments for steel surfaces — •Gustav Gürtler[1,2], Wolfgang Burgstaller[1], Markus Valtiner[2], and Friedrich Aumayr[2] — [1]voestalpine Stahl Gmbh, voestalpine Straße 3, 4020 Linz, Austria — [2]Institute of Applied Physics, TU Wien, Wiedner Hauptstraße 8-10/E134, 1040 Wien, Austria

Plasma cleaning can be an efficient way of preparing metallic surfaces for subsequent coating procedures by removing oxides and other contaminants and consequently enhancing the adhesion of deposited coating layers [1]. This study investigates the efficiency of low-pressure plasma treatments of steel batch samples. Plasma monitoring via optical emission spectroscopy (OES) is performed on a pulsed-DC argon plasma discharge. A successful removal of sample material is confirmed by Fe atomic emission, while an estimation of electron density Ne and electron temperature Te is attempted by exploiting intensity ratios of neutral argon Ar (I) emission lines via a modified Boltzmann plot and a Te-dependent neutral Ar (I) emission line ratio [2]. A possible correlation of Te and Ne values and the amount of detached material is investigated.

[1] H. C. Barshilia et al, 2012, Vacuum, 86 1165-1173

[2] J. B. Boffard et al, 2012, J. Phys. D: Appl. Phys. 45 045201

P 6.19 Mon 16:30 ELP 6: Foyer

Helicon wave physics for the development of a helicon plasma cell for particle-driven wakefield accelerators — •Alf Köhn-Seemann[1], Luis Herrera[1], Oliver Lass[2], and Peter Manz[2] — [1]IGVP, University of Stuttgart, Germany — [2]Institute of Physics, University of Greifswald, Germany

Plasma wakefield accelerators provide significantly higher gradients in the electric field to accelerate particles than linear particle accelerators, thereby significantly reducing their overall size. High electric fields require high electron plasma densities. Helicon plasma discharges are known to provide the highest electron densities. In this contribution we will give an overview of our newly started DFG-funded project to understand the helicon wave propagation and dissipation in the plasma based on a joint experimental and numerical approach between the University of Stuttgart and the University of Greifswald.

P 6.20 Mon 16:30 ELP 6: Foyer

Investigation of charge exchange collisions in an ion beam — •Philipp Georg Johannes Kropidlowski, Leo Zeidler, Thomas Trottenberg, and Holger Kersten — IEAP, Christian-Albrechts-Universität zu Kiel

Charge exchange collisions (CEX) play an important role in operation of ion beam sources for industrial applications and electric propulsion systems for space travel. CEX collisions convert part of the ions into a beam of fast neutral atoms.

Several diagnostic methods can be used to measure this phenomenon, like a combination of force probe [1] and Faraday cup [2]. In this contribution, we use a Faraday cup to measure the spatial electric current density of the beam ions. In addition, a force probe measures the momentum flux density of all energetic beam particles, including the neutrals generated by charge exchange collisions, which cannot be detected by a Faraday cup.

We present measurements in the beam of an inductively coupled plasma (ICP) gridded ion source.

[1] T. Trottenberg, A. Spethmann, and H. Kersten, EPJ Techn. Instrum. 5, 3 (2018)

[2]J. Benedikt, H. Kersten, and A. Piel, Plasma Sources Sci. Technol. 30, 033001 (2021)

P 6.21 Mon 16:30 ELP 6: Foyer

Transport Across an X-Point in HiPIMS plasmas — •Martha Finke[1], Achim von Keudell[1], Dennis Krüger[2], and Marc Böke[1] — [1]Fakultät für Physik und Astronomie, Bochum, Germany — [2]Fakultät für Elektrotechnik und Informationstechnik, Bochum, Germany

Magnetized low pressure plasmas have a wide range of applications such as sputter deposition of metals and oxides or plasma thrusters for small satellites. In case of High Power Impulse Magnetron Sputtering (HiPIMS) the plasma currents may affect the magnetic fields. By combining two magnetrons with their magnets facing each other one obtains a specific topology of the magnetic field with an X-point, where we seek to find signatures of magnetic recinnection events. We investigate in the time-resolved behaviour of the plasma during the HiPIMS pulse using an ICCD camera and observe that the plasma igniting in front of the driven targen is strongly influenced by the magnetic field of the opposite magnetron.

P 6.22 Mon 16:30 ELP 6: Foyer

Multidimensional effects in low-pressure discharges — •Jonas Thiel, Tsanko V. Tsankov, and Uwe Czarnetzki — Ruhr-University Bochum, Faculty of Physics and Astronomy

The transport in low-pressure discharges, such as the ones commonly used in many industrial applications, is governed by diffusion. Most of the insights on the behavior of these plasmas is obtained through the use of one-dimensional models. Such a treatment forces equality of the ion and electron fluxes and leads to the well-known ambipolar diffusion. However, in realistic systems with metal walls, flux balance has to be satisfied only globally but not locally. This leads to a peculiar behavior, with regions where the ion flux to the walls exceeds the electron flux and vice versa. In this contribution, the effect is investigated experimentally for a large area rectangular discharge chamber, which provides a simple geometry. The plasma is generated by inductive coupling provided by the recently developed INCA configuration. An array of wall-mounted planar probes allows the measurement of the spatial profiles across one of the major walls. The spatial distributions of the electron and ion fluxes, as well as of the plasma potentials, the densities and the electron temperature are measured and analyzed. The results demonstrate the expected deviation from local equality of the fluxes.

P 6.23 Mon 16:30 ELP 6: Foyer

Formation of ammonia in a surfaguide discharge assisted by catalysis — •Vinzenz Wolf[1], Roland Friedl[1], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Ammonia (NH_3) is an important chemical widely used as fertiliser and in the chemical industry. Plasma-catalysis has attracted great interest in the last years as an alternative for the energy intensive thermal-catalytic synthesis of ammonia via the Haber-Bosch process. The plasma generates photons, radicals, excited and metastable states which lead to and additional activation of the precursor hydrogen and nitrogen molecules, thereby lowering the activation energy needed for the generation of NH_3.

In this contribution, the effect of changes in pressure in the range of 3 Pa to 1000 Pa, the hydrogen-nitrogen gas composition, and the presence and position of a commercial Ruthenium catalyst (2 wt% Ru on γ-Al_2O_3 pellets) on ammonia production are investigated in a microwave (2.45 GHz) plasma discharge by means of mass spectrometry. The calibration of the mass spectrometer and the influence of considering the background water are described. Additionally, optical emission spectroscopy is used to determine the vibrational and rotational temperatures of the molecules in the plasma.

P 6.24 Mon 16:30 ELP 6: Foyer

Effect of low-pressure plasma treatment on triboelectric properties of polypropylene (PP) and polylactic acid granules (PLA) — •Alina Bachmann — Hessen, Germany

This study evaluates the effect of low-pressure plasma treatment of approximately spherical polypropylene (PP) and cylindrical polylactic acid granules (PLA) on triboelectric properties. Using low-pressure plasma, various process gases and treatment durations, surfaces of the polymer materials were modified.

Within the experimental procedure these process parameters were varied to achieve saturation charge for PP and PLA. The charge-to-mass ratio and surface charge density serve as crucial parameters for characterising the treated surfaces.

The results of the study find application in the electro-sorting of plastics based on triboelectricity. Since this phenomenon is not scientifically understood to a full extent, the generated data contributes to a more optimised implementation in the technical field.

P 6.25 Mon 16:30 ELP 6: Foyer

Stokes-Einstein Relation for Binary Mixtures — •Yang Liu and Dietmar Block — IEAP, Christian-Albrechts-Universität, D-24098 Kiel, Germany

The Stokes-Einstein (SE) relation connects the diffusion coefficient (D) of Brownian particles in liquids to their temperature (T) and the shear viscosity (η) [1]. Extensive evidence has confirmed the validity of the SE relation in ordinary liquids and dusty plasmas, except for systems near the melting temperature and for the gaseous behavior [2]. However, for binary mixtures, i.e. dusty plasmas consisting of two particle species with different charges, an explicit validation of SE is lacking.

In this paper, a Langevin simulation code is used to generate 2D binary systems whose structural and dynamical properties match the experimental conditions [3]. The obtained η and D in monodisperse and binary systems are analyzed and compared. Finally, the applicability of the SE relation to 2D finite binary mixtures is tested. Our results show that, even in finite systems the SE relation holds. Further, the transport properties of monodisperse and binary

systems can be combined in a generalized SE relation if properly defined coupling strengths and screening parameters are used.

[1] A. Einstein, Investigations on the Theory of the Brownian Movement (Courier Corporation, 1956).

[2] N. Ohtori, et al., Phys. Rev. E 95 (2017) 052122.

[3] F. Wieben, et al., Phys. Plasmas 24 (2017) 033707.

P 6.26 Mon 16:30 ELP 6: Foyer

Plasma processing of Ag nanoparticles for resistive switching applications — •Arthur Fabritz[1], Florian Ziegler[2], Blessing Adejube[2], Alexander Vahl[2,3], Franz Faupel[2,3], and Jan Benedikt[1,3] — [1]Institute of Experimental and Applied Physics, Kiel University — [2]Institute of Materials Science, Kiel University — [3]KiNSIS, Kiel University

Given their negative charge when inserted or formed in plasma, nanoparticles can be stored in the positive plasma potential and can be effectively modified inside a plasma, which allows for applications in various fields such as optoelectronics, sensors, or medicine. A large area of study are their electric characteristics, where especially their utilization in memristive devices is still largely unexplored. Memristic devices allow for the simulation of complex neuronal systems, and could therefore contribute to a vast improvement in the functionality of electrical components.

In this work, silver nanoparticles generated in a gas aggregation source are injected into low pressure plasma and coated with thin films (hydrocarbons, SiOx) to form core-shell nanoparticles. Injection of additional silver nanoparticles and extraction of the trapped particles onto non-conducting substrate can prepare mixed nanoparticle films with the density of uncoated particles on the percolation limit, the condition needed for the successful construction of a device with memristive properties. The experimental setup, in-situ diagnostics with UV-Vis absorption spectroscopy, nanoparticle extraction and measurements of their electrical properties will be discussed.

P 6.27 Mon 16:30 ELP 6: Foyer

On the use of configurational temperature for an ion focus measurement — •Natascha Blosczyk and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

Complex plasmas -especially those using micronsized dust grains- allow to study fundamental physical processes. Due to the particle size they attain a large negative charge and allow to study strongly coupled systems in a fluid and crystalline state. However, in the plasma sheath the negatively charged dust grains perturb the ion flow, resulting in a positive space charge region downstream of each particle which modifies the interparticle interaction force. This positive space charge region is called the ion focus and has a non-negligible effect on interaction strength as its charge is comparable to a significant portion of particle charge and its distance to the particle layer is of the order of interparticle distance. However, to determine the strength and position of the ion focus is a difficult task. In this contribution the configurational temperature method will be used to estimate the focus properties. If the particle charge and the screening length are known, the contribution of ion focus in terms of focus strength and position can be estimated from force equilibrium and a configurational temperature fit. The method is tested for results of MD-simulations as well as experimental data.

P 6.28 Mon 16:30 ELP 6: Foyer

The charging of nonspherical particles in a dusty plasma — •Isabel König, Armin Mengel, and Franko Greiner — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

For the most part, studies focus on the charging of spherical particles in a plasma, and only a few experiments were performed studying the charging of nonspherical particles. Nonspherical particles have a varying surface potential, which complicates the calculation of the equilibrium particle charge and also affects dust dynamics. One ansatz to determine the charge of nonspherical particles is the smallest enclosing sphere approximation [Asnaz, Phys.Plasmas 2018].

To analyze the charging of micrometer-sized nonspherical particles we use a combination of long-distance microscopy and the phase-resolved resonance method. We compare the nonspherical particles with spherical SiO_2 particles which levitate at the same position in the sheath. Measurements for different kinds of nonspherical particles are performed: clustered microparticles (doublets and triplets), cylinders, tetrapods, MgO and sapphire crystals, multiscale aeromaterials and MOFs.

P 6.29 Mon 16:30 ELP 6: Foyer

COMPACT – the future complex plasma facility for the ISS — •Daniel P. Mohr[1], Christina A. Knapek[1], Stefan Schütt[1], Daniel Maier[1], André Melzer[1], and COMPACT Collaboration[2] — [1]University of Greifswald, Institute of Physics, Greifswald, Germany — [2]International: CA, US, SE, DE

Complex, or dusty, plasmas consist of micrometer-sized grains that are injected into a low-temperature noble gas discharge. The grains become charged and interact with each other via a screened Coulomb potential. On ground, gravity compresses the system and prevents the formation of larger, three-dimensional particle clouds.

The future complex plasma facility COMPACT will allow the investigation of large three-dimensional complex plasmas under microgravity conditions aboard the International Space Station (ISS). Its technology is based on preliminary studies (Ekoplasma, PlasmaLab), including a novel plasma chamber with adaptive internal geometry, a four-electrode radio-frequency system for plasma generation, and a stereoscopic particle diagnostic that enables the 3D particle dynamics to be recorded in real time. COMPACT is a project with international scientific contributions, funded by space agencies (DLR, NASA). A phase 0/A study is currently underway in collaboration with the space industry and will be finished until 02/2024.

We will present the scientific objectives of COMPACT, scientific and technological progress and the project status.

This work is funded by DLR/BMWi (FKZ 50WM2161).

P 6.30 Mon 16:30 ELP 6: Foyer

Oxygen dependent size evolution of PMMA particles in the plasma sheath — Franziska Reiser, •Sören Wohlfahrt, and Dietmar Block — Kiel University, Kiel, Germany

Microparticles are the essential component of complex (dusty) plasmas. The forces affecting the particles, as well as their accumulated charge, depend prominently on their size. However, dependent on the particle material, the size and surface morphology of the particle will change when exposed to the plasma. Polymethymethacrylat (PMMA) particles show a strong plasma-particle interaction, resulting in a significant size reduction, or etching of the particle. In addition, a heavily modified surface structure with crests and trenches that has a reduced mass density of up to 50 % was reported. Compared to melamine formaldehyde (MF) particles, which show only a moderate response to the surrounding plasma, PMMA particles are an excellent research object to investigate the material dependent plasma-particle interaction itself, as well as the possible influence of the surface morphology on charging processes. An enhanced light scattering diagnostic based on Lorentz-Mie-theory is used to determine and track size and optical properties of the particle and thus the evolution of the plasma-particle interaction. The time resolved evolution of size and the optical properties of single PMMA particles for a systematic variation of oxygen admixture to the argon plasma are presented in this contribution. The results are compared to MF particles and complimented with levitation height measurements, which act as an indicator for particle charge.

P 7: Magnetic Confinement III

Time: Tuesday 11:00–12:30 Location: ELP 6: HS 3

Invited Talk P 7.1 Tue 11:00 ELP 6: HS 3

Physics of Electrical Currents and Fields in the Scrape-off Layer of Tokamak Plasmas — •D. Brida[1], G. D. Conway[1], J. Adamek[2], J. Cavalier[2], H. Bergstroem[1], G. Grenfell[1], U. Plank[1], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching/Greifswald, Germany — [2]Institute of Plasma Physics of the CAS, Prague, Czech Republic

The outermost layer of tokamak plasmas, the so-called Scrape-Off Layer (SOL), exhibits strong electric fields and currents, which affect the plasma transport in the SOL and possibly also the confinement of the overall plasma. Understanding the physics governing SOL electric fields and currents and having accurate models describing them is therefore potentially crucial to operate and design future fusion devices. The validation and improvement of these models requires detailed comparisons to measurements obtained in present-day tokamaks, such as ASDEX Upgrade in Garching.

This contribution provides an introduction to the physics of SOL electric fields and currents and presents recent experimental studies conducted at ASDEX Upgrade and other tokamaks. The dependence of the electric field on the divertor conditions, measured by Langmuir probes, is analyzed for different plasma states. Using an analytical model, based on Ohm's law, it is shown how the divertor conditions are related to the electric field further upstream. The studies highlight the pivotal role of the divertor state in determining the electric field and show how currents can lead to substantial heat fluxes onto the divertor target.

P 7.2 Tue 11:30 ELP 6: HS 3

Edge current density distributions in the island divertor configurations on the J-TEXT tokamak — •Jiankun Hua[1,2], Yunfeng Liang[1,2,3], Qinghu Yang[2], Jie Yang[2], Song Zhou[2], and Yutong Yang[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung Plasmaphysik, 52425

Jülich, Germany — [2]International Joint Research Laboratory of Magnetic Confinement Fusion and Plasma Physics, Huazhong University of Science and Technology, Wuhan, 430074, China — [3]Institute of Plasma Physics, Chinese Academy of Sciences, 23003 Hefei, China

The island divertor configuration was recently operated on the J-TEXT tokamak, and the magnetic field structure can vary with the edge safe factor (qa), amplitude and phase of the island divertor coil current. A set of probes called the Directional Electron Probe (DEP) was developed to measure edge plasma current density distributions in different configurations. The qa scan was performed by increasing the total plasma current from 80kA to 110kA with a fixed toroidal magnetic field (1.6T) and island divertor coil current (+5kA or -5kA). At the same time, the m/n=3/1 magnetic island will move from the inside of the last closed flux surface (LCFS) to the outside. In this experiment, the DEP remains at the same position in the plasma, and the dynamic of plasma current density distribution can be measured as the m/n=3/1 magnetic island moves. Preliminary experimental results show that the edge current density distribution has a strong correlation with the length of the magnetic field lines and the edge magnetic configuration (such as magnetic island).

P 7.3 Tue 11:45 ELP 6: HS 3

Machine learning based fast optimization of free parameters in W7-X edge plasma modeling with EMC3-EIRENE — •Y. Luo[1,3], S. Xu[1], Y. Liang[1,3], E. Wang[1], J. Cai[1], Y. Feng[2], D. Deiter[3], A. Knieps[1], S. Brezinsek[1,3], D. Harting[1], M. Krychowiak[2], D. Gradic[2], E. Flom[2], F. Henke[2], Y. Gao[2], R. König[2], A. Pandey[2], M. Vecsei[2], and A. Dinklage[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany — [2]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [3]Faculty of Mathematics and Natural Science, Heinrich Heine University Düsseldorf, 40225 Düsseldorf, Germany

EMC3-EIRENE is a powerful tool for simulating edge plasma transport, capable of providing insights into transport parameters based on limited local experimental measurements. However, achieving a closer match between simulations and actual experiments often requires extensive scanning of input-free parameters. To address this challenge, we have developed a machine learning model that, by learning from a simulation database, can predict optimal edge cross-field transport coefficients, based on multiple edge measurements. To quantify the performance of the trained model, we calculate mean squared error in the test set, resulting in an error magnitude of 0.024. Moving forward, our plan is to expand the range of learned parameters and significantly enhance the simulation database, thus trying to employ the machine learning technique for directly forecasting plasma information of all EMC3-EIRENE cells based on local experimental measurements.

P 7.4 Tue 12:00 ELP 6: HS 3

Fast 2D n_e and T_e profile measurements with the divertor helium beam at ASDEX Upgrade — •Sebastian Hörmann[1,2], Marco Cavedon[3], Michael Griener[1], Daniel Wendler[1,2], Ulrich Stroth[1,2], and The ASDEX Upgrade team[4] — [1]Max-Planck-Institut für Plasmaphysik, Garching — [2]Physik-Department E28, Technische Universität München, 85747 Garching, Germany — [3]Dipartimento di Fisica "G. Occhialini", Università di Milano-Bicocca, Milano, Italy — [4]See author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

The divertor is an important element to achieve magnetic confinement fusion, reducing the impurity content of the core plasma and increasing the pumping efficiency. Too high heat loads on the target plates of the divertor can be mitigated by a layer of neutral gas which forms in front of the target plates, such a state is called detachment. To study the condition of the divertor and the detachment process, a new thermal helium beam diagnostic with high spatiotemporal resolution has been installed in the outer divertor of ASDEX Upgrade. It is capable to measure two-dimensional electron density, temperature and hence pressure profiles by means of a collisional radiative model. This makes it possible for the first time to observe the change in these profiles from an attached to a partially detached divertor state on a fast time scale and therefore contribute to the understanding of the dynamics during this transition. In particular, the movement of the detachment front and divertor plasma oscillations during the transition to detachment are presented within this contribution.

P 7.5 Tue 12:15 ELP 6: HS 3

Electromagnetic particle-in-cell simulation of the tokamak scrape-off layer — •Annika Stier[1], Alberto Bottino[1], David Coster[1], Thomas Hayward-Schneider[1], Andreas Bergmann[1], Frank Jenko[1], and Laurent Villard[2] — [1]Max-Planck Institute for Plasma Physics, Boltzmannstrasse 2, Garching, 85748, Bavaria, Germany — [2]Ecole Polytechnique Federale de Lausanne (EPFL) Swiss Plasma Center (SPC), Rte Cantonale, Lausanne, CH-1015, State Two, Switzerland

The particle-in-cell code PICLS is a full-f finite element tool intended to simulate turbulence in the tokamak scrape-off layer using gyrokinetic ions and drift-kinetic electrons. Up until now however, PICLS has been a purely electrostatic code with a prescribed background magnetic field. This approach is not perfectly suited to represent unstable regimes occurring in the scrape-off layer, since although $\beta = 2\mu_0 p/B^2$ can be small, turbulence there is still dominated by electromagnetic effects [1]. In order to capture those effects, an Ampère-solver is added to the code and the evolving magnetic field is taken into account in the particle pusher stage. In order to combat the Ampère-cancellation problem that arises from the Hamiltonian canonical Lagrangian formulation that PICLS is based on, we combine the newly added Ampère-solver with a pullback scheme akin to the one used in ORB5 [2]. This improved version of PICLS opens up possibilities in simulating β-dependent ITG-KBM transitions like illustrated in ref. [3] for the codes GENE, GKW, EUTERPE and ORB5, shear Alfvén waves, microtearing modes and more.

P 8: Complex Plasmas and Dusty Plasmas I

Time: Tuesday 11:00–12:30 Location: WW 1: HS

Invited Talk P 8.1 Tue 11:00 WW 1: HS

Pulsed Complex Plasma In Microgravity — •Christina A. Knapek[1,2], Daniel P. Mohr[1,2], and Peter Huber[2] — [1]Institute of Physics, University of Greifswald, 17489 Greifswald, Germany — [2]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt, 51147 Köln, Germany

A new experimental method for creating void-free complex plasmas under microgravity conditions is presented. The method is based on a pulsed operation mode of a four-channel radio-frequency generator for plasma generation. A dust cloud of micrometer-sized particles can be immersed in the bulk of a low temperature plasma under microgravity conditions. It typically contains a central volume depleted of particles – the void – that prevents the generation of large, continuous clouds. Experiments performed at different neutral gas pressures and discharge volumes during the microgravity phase of a parabolic flight show that the central void is closed completely once the pulsed operation mode is applied. The particle cloud shape, and the density distribution within the cloud, are practically independent on the pulse period within the investigated parameter range. The proposed method has great potential for future application in experimental facilities dedicated to fundamental studies of large three-dimensional, homogeneous complex plasma systems in microgravity. Prospective ongoing studies are outlined that are dedicated to investigate the underlying physical processes for the observed void closure.

This work is funded by DLR/BMWi (FKZ 50WP0700, 50WM1441, 50WM2161) and StMWi.

P 8.2 Tue 11:30 WW 1: HS

A full Stokes imaging polarimeter for nanodusty plasma applications — •Alexander Schmitz, Andreas Petersen, and Franko Greiner — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

Full Stokes imaging Mie polarimeters are required to study the detailed dynamic of particle growth in reactive plasmas. Various concepts exist, which often rely on the rotation or switching of optical components. Our setup, constructed from two divisions of focal plane CMOS cameras, presents a new imaging polarimeter with high spatial resolution that does not require moving optics.

The accuracy of the polarimeter has been carefully investigated. The performance of the new polarimeter is demonstrated by visualizing two-generation layered particle growth in a reactive Argon-Acetylene plasma.

P 8.3 Tue 11:45 WW 1: HS

Three-dimensional investigation of dust flows around obstacles under microgravity — •Stefan Schütt, Christina Knapek, Daniel Maier, Daniel Mohr, and André Melzer — University of Greifswald, Greifswald, Germany

Dust flows around a tungsten wire in three-dimensionally extended dusty plasmas have been investigated on parabolic flights. A fixed wire has been installed in the midplane between the electrodes of a parallel plate rf discharge. The dust particles were captured three-dimensionally with a stereoscopic four-camera system. The dust flow around the wire was investigated during the pull-out phase at the end of each parabola, when gravity sets in and the dust cloud moves downward past the wire. Additionally, a periodic dust motion was generated by superimposing a low-frequency ($f \approx 1\,\mathrm{Hz}$) modulation on the electrodes. The repetitive nature of the dust motion in the latter case allows to stroboscopically

overlay dust trajectories from multiple modulation periods and to accurately obtain fluid properties in three dimensions.

This work was supported by DLR grants 50WM1962 and 50WM2161.

P 8.4 Tue 12:00 WW 1: HS

Electrostatic probes in high Havnes nanodusty plasmas — •Franko Greiner[1] and Julian Held[2] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Department of Mechanical Engineering, University of Minnesota, Minneapolis, USA

Invasive diagnostics, such as Langmuir probes, pose challenges when employed in nanodusty plasmas with high dust density. When a floating probe is utilized, it establishes a dust-free 'probe void' around itself. Applying a more negative probe voltage expands this void, while a more positive probe voltage results in a significant dust flow toward the probe upon reaching the plasma potential. Since the plasma potential is unknown, probe contamination and the disruption of the nanodusty plasma become inevitable.

Double probes, which inherently float below the plasma potential at zero voltage bias, appear to be the preferred choice for probes. This choice helps in avoiding probe contamination, and the impact on dust density is minimal across all probe voltages. In our study, we present measurements of ion density and electron temperature in a nanodusty, strongly electron-depleted argon plasma.

P 8.5 Tue 12:15 WW 1: HS

Surface modification and core-shell structure of MF particles in the plasma sheath — •Sören Wohlfahrt, Franziska Reiser, and Dietmar Block — Kiel University, Kiel, Germany

Complex (dusty) plasmas consist if micrometer sized particles in addition to the typical plasma species of ions, electrons and neutrals. Dependent on the particle material, they show a distinct plasma-particle interaction that leads to a modification of the particles surface and even a decrease of the particle size in a process commonly referred to as 'etching'. In case of the widely used melamine formaldehyde (MF) particles, there is a strong connection between the surface reactivity and the etch process itself, which can be explained in the framework of an increasingly roughened surface shell and an unmodified particle core. We use a polarization resolved light scattering technique based on Lorentz-Mie theory to investigate the size and size evolution of single MF-particles in the plasma sheath. Our scattering-model assumes a coated sphere, which is analogous to a core-shell structure. Thus, the optical properties of the particle surface become directly accessible in the experiment. We will present time resolved measurements of single MF particles whose core is unaffected by the etch process, while the shell shows a steep increase in the imaginary part of the refractive index. Although the shell is only 100 nm thick (< 5% of particle size), this increase has a significant influence on the overall scattering- and absorption cross section of the particle and affects the particle dynamics as well.

P 9: HEPP III

Time: Tuesday 14:00–16:05 Location: ELP 6: HS 3

P 9.1 Tue 14:00 ELP 6: HS 3

Integrated modelling of impurity transport in ASDEX Upgrade — •Daniel Fajardo[1], Clemente Angioni[1], Ralph Dux[1], Emiliano Fable[1], Giovanni Tardini[1], and the ASDEX Upgrade Team[2] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]see author list of Stroth *et al* 2022 *Nucl. Fusion* **62** 042006

Impurities play crucial roles in fusion devices, from the deleterious fuel dilution and radiative cooling of the core to the beneficial edge cooling for safe power exhaust. Predicting their behavior and effects becomes essential as tokamaks approach reactor operation. We present an integrated framework that demonstrates multi-species, multi-channel modelling capabilities for the prediction of impurity density profiles and their feedback on the main plasma through radiation and dilution. It combines all presently known theoretical elements in the local description of quasi-linear turbulent and collisional transport.

The workflow reproduces ASDEX Upgrade experimental results in L-mode and H-mode, with full-radius and core simulations, respectively. In particular, predictions of a radiative L-mode with one seeded (Ar) and two intrinsic (B, W) impurities match its measured radiated power and H-mode-like confinement. Likewise, the control of W accumulation with ECRH and ICRH in NBI-heated H-mode plasmas is studied in dynamical simulations of experiments featuring wave heating power steps, finding good agreement with the measured W peaking.

P 9.2 Tue 14:25 ELP 6: HS 3

Shattered pellet injection experiments performed at ASDEX Upgrade — •Paul Heinrich[1], G. Papp[1], M. Bernert[1], P. de Marné[1], M. Dibon[2], S. Jachmich[2], M. Lehnen[2], T. Peherstorfer[3], N. Schwarz[1], U. Sheikh[4], B. Sieglin[1], J. Svoboda[5], and the ASDEX Upgrade team[6] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]ITER, St. Paul-lez-Durance, France — [3]TU Wien, Wien, Austria — [4]EPFL, Lausanne, Switzerland — [5]IPP CAS, Prague, Czech Republic — [6]See author list of U. Stroth et al. 2022 NF 62 042006

Future fusion devices like ITER, which are based on the tokamak concept, require a disruption mitigation system (DMS) to ensure machine protection. While the fusion reactions will naturally come to a hold within a fraction of a second in an unforeseen event causing a disruption, this can cause large forces and heat loads on the structure which might damage the device. In order to support the design of the ITER disruption mitigation system, a highly flexible shattered pellet injection (SPI) system was installed at the tokamak ASDEX Upgrade. Hereby, frozen pellets of deuterium, neon or a mixture thereof, are injected into the plasma to isotropically radiate the confined energy. Optimized mitigation is investigated by variation of the pellet parameters (e.g. size, velocity) or shatter geometry. The injection parameters are found to have a stronger impact on material assimilation, while the radiation characteristics are dominated by the pellet composition. A system overview as well as first analysis results for the experimental campaign – with focus on the radiation characteristics – are presented.

P 9.3 Tue 14:50 ELP 6: HS 3

Exploring the influence of plasma triangularity on pedestal stability and structure in ASDEX Upgrade — •Lidija Radovanovic[1], Elisabeth Wolfrum[2], Mike Dunne[2], Tobias Görler[2], Georg Harrer[1], Facundo Sheffield Heit[2], Friedrich Aumayr[1], and The ASDEX Upgrade Team[3] — [1]Institute of Applied Physics, TU Wien, 1040 Vienna, Austria — [2]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [3]See author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

The confinement and the performance of a tokamak plasma in the high confinement regime are closely related to the structure of the pedestal. One possible factor limiting the pedestal width is the onset of instabilities, kinetic ballooning modes (KBMs), at the top of the pedestal, which we approximate by local ideal ballooning modes (IBMs). The stability of these modes can be altered by varying the plasma shape. To determine the role of local IBMs at the pedestal top, other possible instabilities present in the pedestal top are analysed with the local linear version of the gyro kinetic code GENE and compared with the shearing rate. The results show that different physical mechanisms influence the pedestal width of the electrons and ions with respect to their density and temperature. Particularly, the electron pressure pedestal top strongly correlates with the minimum in ballooning stability. The objective of this study is to link physical processes in frameworks of MHD, transport and gyro kinetics with the experimentally observed pedestal structure.

P 9.4 Tue 15:15 ELP 6: HS 3

Properties of Tungsten Particles Produced by Arcing — •Albertto Castillo Castillo[1,2], Martin Balden[2], Volker Rohde[2], Peter Siemroth[3], Michael Laux[3], Heinz Pursch[3], Juergen Sachtleben[3], and Rudolf Neu[1,2] — [1]Technische Universität München, 85748 Garching, Germany — [2]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [3]retired, was with Arc-Precision GmbH, 15711 Königs Wusterhausen, Germany

Metal droplet emission by arcing is one of the mechanisms generating dust in a magnetic confinement fusion device. Tungsten droplet production is of particular interest for full tungsten wall devices. The potential of a droplet to introduce impurities in the plasma depends on its velocity, diameter, and angle. The distributions of these parameters has been measured in a dedicated device with multiple independent methods in order to provide useful data to evaluate their effect on plasma operation.

In a addition to a time-of-flight detection system based on light scattering by droplets to measure their size, velocity and angle, a high-speed camera was added to record videos of the flying droplets. Dedicated software was developed to track the trajectories in the video, and fitting the thermal radiation curves to a model of the cooling of particles allows measurement of diameter and initial temperature. This first measurement of initial temperatures reveals that a significant fraction of particles are ejected in a solid state. This is supported by microscopy analysis of the particle deposition showing non-spherical particles.

P 9.5 Tue 15:40 ELP 6: HS 3

Spectroscopy based inference of impurity transport at the plasma edge in different tokamak confinement regimes — •Tabea Gleiter[1,2], Ralph Dux[1], Francesco Sciortino[3], Tomáš Odstrčil[4], Thomas Hayward-Schneider[1], Daniel Fajardo[1], Ulrich Stroth[1,2], and the ASDEX Upgrade Team[5] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Physik-Department E28, Technische Universität München, Garching, Germany — [3]Proxima Fusion GmbH — [4]General Atomics, San Diego, USA — [5]Authors of U. Stroth et al. 2022 Nucl. Fusion 62 042006

We present the inference of radial impurity diffusion and convection profiles in steady state discharges. The experimental basis are customized charge exchange recombination spectroscopy (CXRS) measurements, yielding line radiances from multiple impurity charge states. A forward model based on the impurity transport solver Aurora is able to generate synthetic CXRS-data for given transport coefficients. It requires additional inputs, such as neutral beam and thermal deuterium densities, kinetic profiles and atomic rate data. This model is used for a Bayesian inverse inference of transport coefficent probabilities. Due to the complexity, the selection of suitable free parameter sets, prior distributions and data likelihoods is important.

The framework is mostly suitable for the plasma edge, i.e. where impurities are not fully ionized. Since the pedestal impurity transport in tokamaks is crucial for energy confinement and radiative power exhaust, we compare various confinement regimes at ASDEX Upgrade, including promising reactor scenarios without large ELMs.

P 10: Atmospheric Pressure Plasmas and their Applications II

Time: Tuesday 14:00–16:00 Location: WW 1: HS

Invited Talk P 10.1 Tue 14:00 WW 1: HS

Filament interaction in dielectric barrier discharges — •Hans Höft[1], Ronny Brandenburg[1], Markus M. Becker[1], and Torsten Gerling[1,2] — [1]Leibniz Institute for Plasma Science and Technology (INP), Felix-Hausdorff-Str. 2, 17489 Greifswald, Germany — [2]Competency centre for diabetes (KDK), Greifswalder Str. 11, 17495 Karlsburg, Germany

The formation and interaction of individual filaments in dielectric barrier discharges (DBDs) are essential for the efficiency and efficacy of DBD reactors. In most DBD arrangements, multiple filaments are formed, since the power input per filament is limited. Therefore, the impact of O_2 concentration and high-voltage operation (pulsed vs. sinusoidal) on the number of filaments per period and their ignition pattern is studied. The spatially 1D multi-filament arrangement had a length of about 10 mm while the gap distance was set to 1.0 mm. The working gas was a binary mixture ranging from 0.1 to 20 vol% O_2 in N_2 at 1 bar. The DBDs were characterised by iCCD camera imaging determining the filament number and the discharge development by a streak camera to obtain the filament positions during different phases of one HV period. Simultaneously, electrical measurements using fast probes were performed. The results clearly show the different effects of the performed parameter variations on pulsed and sine-driven discharges, particularly regarding the spatial stability and number of filaments. Finally, the findings for the multi-filament arrangement are linked to single-filament DBDs under the same experimental conditions.

Funded by the DFG – project number 466331904.

P 10.2 Tue 14:30 WW 1: HS

Electric field components within a micro scaled dielectric barrier discharge measured by Stark shift and splitting of helium lines — •Henrik van Impel, David Steuer, Robin Labenski, Volker Schulz-von der Gathen, Marc Böke, and Judith Golda — PIP & EP2, Ruhr-University Bochum, D-44801 Bochum

Atmospheric pressure dielectric barrier discharges (DBDs), such as the micro cavity plasma array (MCPA) [1], have emerged as promising technologies for the conversion of volatile gases. These conversion processes' effectiveness can be enhanced by integrating catalytically active surfaces. To deepen the understanding of the plasma-catalyst interaction, it is crucial to investigate the transport dynamics of reactive species to the catalytic surface. The transport is in particular affected by the electric field perpendicular to the catalytic surface. However, experimental data on the component-wise electric field strength within DBDs are rare. To address this issue, we performed polarized optical emission spectroscopy on the shifting and splitting of the allowed 492.19 nm ($^1D \rightarrow {}^1P^0$) and forbidden 492.06 nm ($^1F^0 \rightarrow {}^1P^0$) helium line pair. This diagnostic approach requires a non-radially symmetric geometry, which leads to an adapted reactor design of the MCPA allowing the side-on observation of the discharge. The discharge operates in pure helium at atmospheric pressure, utilizing a triangular excitation voltage with a frequency of 15 kHz and an amplitude of 600 V. Field components reveal differences of approximately 5 kV cm^{-1} or 20 %. The project is funded within project A6 of the SFB 1316.

[1] Dzikowski et al 2020 Plasma Sources Sci. Technol. 29 035028

P 10.3 Tue 14:45 WW 1: HS

Time-resolved ion mass spectrometry to investigate the ion chemistry of a dielectric barrier discharge — Nils Dose[1], •Luka Hansen[1,2], Tristan Winzer[1], Christian Schulze[1], and Jan Benedikt[1,2] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Kiel Nano, Surface and Interface Science KiNSIS, Kiel University, Kiel, Germany

The ion chemistry plays a crucial role for many plasma chemical processes ranging from particle or thin film growth to the production of biomedical relevant species [1]. Ion mass spectrometry allows a direct measurement of the formed ions with the drawback of a limited temporal resolution due to the flight time of ions from the plasma through the filtering optics of the mass spectrometer to the detector [2].

To overcome this issue the ion mass spectrometer was equipped with a multi channel scaler which allows to measure the incoming ions with up to 10 ns resolution. The mass dependent ion flight times were determined using a (pulsed) dielectric barrier discharge usually utilized for deposition processes [3] and compared with SIMION simulations. The derived connection between flight times and mass can be used to correct the time-resolved ion measurements, therefore allowing to gain inside into the production and conversion of ions.

The diagnostic will be presented and its potential demonstrated on first measurements with N_2 and O_2 admixtures.

[1] P. Tosi *et al.*, 2009 *Plasma Sources Sci. Technol.* **18** 034005
[2] J. Benedikt *et al.*, 2012 *J. Phys. D: Appl. Phys.* **45** 403001
[3] L. Bröcker *et al.*, 2023 *Plasma Process. Polym.* e2300177

P 10.4 Tue 15:00 WW 1: HS

Tunable laser absorption spectroscopy of all four Ar*($3p^5 4s$) states in a pulsed-driven dielectric barrier discharge with short gas-residence times — •Levin Krös, Hans Höft, Andy Nave, Jean-Pierre van Helden, and Ronny Brandenburg — Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany

Dielectric Barrier Discharges (DBDs) can be applied for plasma enhanced chemical vapour deposition processes, i.e. for the deposition of thin functional films. In case of short gas-residence times realised by e.g. high working gas flows, ions play an important role in the deposition process. A significant production channel for ionic species is provided by excited argon species, especially the metastable states, via Penning ionisation. Therefore, tunable laser absorption spectroscopy is utilized to measure absolute number density of the four lowest energetic excited states of argon. The ability to determine the number density all four Ar*($3p^5 4s$) states as a function of the operation parameters, like gas flow and characteristics of the applied high-voltage pulse, is especially valuable for a comparison with numerical models. As a starting point, the number densities of these states will be measured in a pulsed-driven DBD with 3 mm gas gap flushed with pure argon at atmospheric pressure.

P 10.5 Tue 15:15 WW 1: HS

Fluid Simulation of Streamer Dynamics in Nanosecond Pulsed Surface Dielectric Barrier Discharges — •Dominik Filla, Gerrit Hübner, Nils Schoeneweihs, Ihor Korolov, Thomas Mussenbrock, and Sebastian Wilczek — Department of Electrical Engineering and Information Science, Ruhr-University Bochum

The efficient conversion of airborne pollutants, such as volatile organic compounds (VOCs) and nitrogen oxides, is not only crucial for environmental protection but also holds great scientific interest. Within this scope, surface dielectric barrier discharges (sDBD) driven by nanosecond pulses emerge as promising tools for energy-efficient gas conversion. This study delves into the streamer dynamics in sDBD systems, utilizing the 2D plasma simulation code nonPDPSIM. We demonstrate how key process parameters – such as pressure, voltage pulse amplitude, and pulse rise time – significantly influence streamer behavior, affecting its length, propagation speed, and direction. Our numerical results show a qualitative alignment with experimental data obtained from time-resolved optical emission spectroscopy. This correlation underscores the practical relevance of our simulations in advancing the understanding of plasma-based pollutant conversion.

**The authors thank a) Mark Kushner (University of Michigan) for providing nonPDPSIM and b) the DFG for financial support via SFB 1316.

P 10.6 Tue 15:30 WW 1: HS

Electrical Characterization and Imaging of the Discharge Morphology in a Small Scale Coaxial Packed Bed Dielectric Barrier Discharge — •Rezvan Hosseini Rad[1], Volker Brüser[1], and Ronny Brandenburg[1,2] — [1]Leibniz Institute for Plasma Science and Technology, Felix-HausdorffStraße 2, 17489 Greifswald, Germany — [2]University of Rostock, Institute of Physics, Albert-Einstein-Str. 23-24, 18059 Rostock, Germany

Packed Bed Dielectric Barrier Discharges (PB-DBDs) are gaining widespread attention due to direct interaction between plasma and catalyst, resulting in enhanced product selectivity in gas processing. In this contribution, a small scale coaxial DBD reactor, enabling the end-on view observation of the discharge gap, has been constructed. The primary objective is to correlate electrical measurements such as voltage-charge (V-Q) plots with the plasma morphology in PB-DBD for different pressures, gas compositions, packing materials and applied voltage amplitudes. Simultaneous imaging and V-Q plot analysis, with special attention to parasitic capacitances, result in the revision of equivalent circuit for PB-DBDs and a more accurate experimental determination of the key capacitance values, namely the cell capacity (Ccell), and effective dielectric capacity (ζdiel). Additionally, the analysis includes the role of parasitic discharges, which can lead to the overestimation of input power. We aim to enhance the understanding of PB- DBDs, to provide sound knowledge about the power input and penetration of the flowing gas by active plasma.

P 10.7 Tue 15:45 WW 1: HS

Novel methods for determination and manipulation of surface charges in an atmospheric DBD microplasma — •Robin Labenski[1], David Steuer[1], Henrik van Impel[1], Marc Böke[2], Volker Schulz-von der Gathen[2], and Judith Golda[1] — [1]Plasma Interface Physics, Ruhr-University Bochum — [2]Experimental Physics II, Ruhr-University Bochum

In photo- and electrocatalysis it is already well-established that surface charges can alter the chemical adsorption and reaction paths of the catalyst. However, the novel realm of plasma catalysis lacks experimental exploration regarding the impact of plasma-induced surface charges on catalysis. We pave that way by introducing a straightforward method for precisely charging the dielectric (catalyst) using a microplasma at atmospheric pressure, while also monitoring the level of deposited surface charge over time. Through pre-charging we examine its effect on re-ignition and forming of equilibria in the discharge. Additionally, a laser assisted technique is introduced to further fine-tune the amount of surface charge on the dielectric and assess the plasma's response to this subtle manipulation of surface charge.

P 11: Codes and Modeling I

Time: Tuesday 16:30–17:40 Location: ELP 6: HS 3

Invited Talk P 11.1 Tue 16:30 ELP 6: HS 3

Collaboration on RDM in low-temperature plasma physics — •Marina Prenzel[1], Kerstin Sgonina[2], and Markus Becker[3] — [1]Research Department Plasmas with Complex Interactions, Ruhr- University Bochum (RUB) — [2]Institute of Experimental and Applied Physics, Kiel University (CAU) — [3]Leibniz Institute for Plasma Sci- ence and Technology (INP)

The dynamic research environments in low-temperature plasma physics, including plasma sources and instrumentation often developed in the course of research, have historically lacked standardized research data management (RDM). The absence of established standards not only complicates the implementation of structured RDM, but also hinders data comparability and reusability, impeding the seamless transfer of research outcomes to new plasma applications. In response to these challenges, research groups at INP, RUB and CAU have started a collaborative initiative to develop common standards and tools for comprehensive data documentation.

This contribution provides an update on the current status of these collaborative efforts, focusing on the practical implementation of data management standards in laboratory settings and presenting real-world examples from different research groups.

The presentation aims to underscore the significance of structured RDM in low-temperature plasma physics and its concrete implications for advancing research outcomes in this field.

The work was supported by grants 16QK03A (BMBF) and 327886311 (DFG).

P 11.2 Tue 17:00 ELP 6: HS 3

Learning physics-based reduced models from data for the Hasegawa-Wakatani equations — •Constantin Gahr[1], Ionuț-Gabriel Farcaș[2], and Frank Jenko[1] — [1]Max-Planck-Institute for Plasma Physics, 85748 Garching, DE — [2]Oden Institute for Computational Engineering & Sciences, Austin, TX 78712, US

This presentation focuses on the construction of non-intrusive Scientific Machine-Learning (SciML) Reduced Order Models (ROMs) for nonlinear, chaotic plasma turbulence simulations. In particular, we propose using Operator Inference (OpInf) to build low-cost physics-based ROMs from data for such simulations. As a representative example, we focus on the Hasegawa-Wakatani (HW) equations used for modeling two-dimensional electrostatic drift-wave plasma turbulence. We first use the data obtained via a direct numerical simulation of the HW equations starting from a specific initial condition and train OpInf ROMs for predictions beyond the training time horizon. In the second, more challenging set of experiments, we train ROMs using the same data set as before but this time perform predictions for six other initial conditions. Our results show that the OpInf ROMs capture the important features of the turbulent dynamics and generalize to new and unseen initial conditions while reducing the evaluation time of the high-fidelity model by up to six orders of magnitude in single-core performance. In the broader context of fusion research, this shows that non-intrusive SciML ROMs have the potential to drastically accelerate numerical studies, which can ultimately enable tasks such as the design and real-time control of optimized fusion devices.

P 11.3 Tue 17:25 ELP 6: HS 3

Solving the Parametric Boltzmann Equation for Electrons Using Physics-Informed Neural Networks — •Ihda Chaerony Siffa[1], Detlef Loffhagen[1], Markus M. Becker[1], and Jan Trieschmann[2] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Kiel University, Kiel, Germany

The coupling of fluid-Poisson models for low-temperature plasma simulations with the Boltzmann equation of electrons is often needed to ensure the reliability of such models. A direct coupling is, however, often too expensive with respect to calculation time. The pre-calculation of look-up tables for the electron transport and rate coefficients as a function of the reduced electric field strength or mean electron energy is therefore a common practice. In this work, we present a way to parametrically solve the electron Boltzmann equation in two-term approximation using the so-called Physics-Informed Neural Networks (PINNs). PINNs are a mesh-free method and provide differentiable solutions with the potential to ultimately predict electron properties more efficiently than traditional Boltzmann solvers. Presently, the artificial neural network surrogate model takes into account two inputs, the kinetic energy of electrons and an additional input parameter, which represents either the reduced electric field or the mean electron energy, and outputs the isotropic component of the electron velocity distribution function. This contribution discusses the advantages and limitations of the present approach, and gives an outlook for future work.

P 12: Poster II

Time: Tuesday 16:30–18:30 Location: ELP 6: Foyer

P 12.1 Tue 16:30 ELP 6: Foyer

Inference of transport coefficients in helium puff modulation studies at W7-X — •Thilo Romba[1], Felix Reimold[1], Oliver Ford[1], Peter Zsolt Poloskei[1], Sebastian Bannmann[1], Tabea Gleiter[2], Erik Flom[3], and Thomas Klinger[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald 17491, Germany — [2]Max-Planck-Institute for Plasma Physics, Garching 85748, Germany — [3]University of Wisconsin-Madison, Madison, WI 53706, USA

The precise monitoring of the impurity content and the understanding of the transport mechanisms is crucial for future fusion reactor operation due to the associated restrictions to the operational parameter space via dilution and increased radiative losses.

This work aims to analyze the transport properties of the fusion ash helium in the confined region of the optimized stellarator Wendelstein 7-X (W7-X) [1]. Spatially and temporally densities of He2+ are measured using charge exchange recombination spectroscopy (CXRS) [2]. To introduce a time variation in the local density response, periodic helium puffs outside the confined region are imposed as the helium source.

Based on the local helium density response measured, local diffusion and con-

vection coefficients of the helium particle transport are inferred with the 1.5D transport code aurora [3]. Experiments over varying magnetic configurations show dominant anomalous transport in all cases, consistent with previous results for higher Z impurities [4].

[1] Erckmann 1997, [2] Fonck RSI 1985, [3] Sciortino PPCF 2021, [4] T Romba PPCF 2023

P 12.2 Tue 16:30 ELP 6: Foyer

Influence of density-potential cross-phase on particle and momentum transport in TJ-K — •Ralph Sarkis, Mirko Ramisch, and Günter Tovar — IGVP, University of Stuttgart, Germany

Transport formation in magnetically confined plasmas is heavily dependent on the coupling between density and potential. Drift-waves can be destabilized when the electron response to a density perturbation is hindered and the positive potential perturbation that arises has a non-zero phase shift with respect to the density perturbation. The momentum transport, also called Reynolds stress, and particle transport have opposite promoting conditions with respect to the density-potential coupling, that is highly coupled and decoupled, respectively. To understand the conflicting occurrence of both transport phenomena peaking at comparable poloidal positions, as observed at the stellarator experiment TJ-K, a spatio-temporal analysis is performed by means of a poloidal Langmuir probe array, which allows for the spectral decomposition in order to determine the transports' interplay on the basis of the coupling/decoupling influence. Conditional sampling reveals a separation of particle and momentum transport peaks in time. Both transports dynamics are related to the evolution of the density-potential cross-phase in time, and differentiated from the amplitude modulation, to establish a time-based relation between the spectral components and the transport events. Scale separation of the components and of the transport phenomena in the time-based analyses provides a deeper insight of the weighted contribution of each scale investigated.

P 12.3 Tue 16:30 ELP 6: Foyer

Hybrid kinetic-MHD simulations of the fishbone instability with JOREK — •Felix Antlitz[1], Xin Wang[1], Matthias Hoelzl[1], and Guido Huijsmans[2,3] — [1]Max Planck Institute for Plasma Physics, Garching b. M., Germany — [2]CEA, Saint-Paul-Lez-durance, France — [3]Eindhoven University of Technology, Eindhoven, Netherlands

Energetic particles (EPs) will play a central role in future burning plasma experiments, as they can strongly interact with the bulk plasma and drive magneto-hydrodynamic (MHD) instabilities. For instance the fishbone instability is the result of an internal kink mode destabilized by EPs in tokamaks. This contribution describes applications and developments of the nonlinear extended MHD code JOREK, whose kinetic module is used to investigate the interaction between EPs and core MHD instabilities both in the linear and the nonlinear regime. The kinetic module uses a particle-in-cell technique and describes the EP distribution function with a full-f formulation. The results will also be compared to gyrokinetic simulations performed with the ORB5 code. Furthermore, the current work on implementing a model in JOREK that describes also the thermal ions kinetically is presented.

P 12.4 Tue 16:30 ELP 6: Foyer

Dynamics of a pellet produced plasmoid in a stellarator — •Carl Wilhelm Rogge[1,3], Ksenia Aleynikova[1], Pavel Aleynikov[1], Rohan Ramasamy[2], Matthias Hoelzl[2], and Per Helander[1,3] — [1]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany — [2]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [3]University of Greifswald

Pellet injection will play a critical role in refueling future tokamak and stellarator reactors. Although pellet plasmoid physics has been extensively studied in tokamak magnetic geometries, understanding in stellarator geometries remains less comprehensive. This gap partially arises due to the lack of numerical tools capable of accurately describing the 3D physics effects with sufficient spatial and temporal resolutions, covering extensive time spans that encompass the various timescales of key physical effects. The non-axisymmetry of the equilibrium field in stellarators increases the complexity of numerical analysis.

However, recent advancements in the stellarator extension of the JOREK nonlinear 3D MHD code, which employs a reduced MHD model for stellarator geometry, show significant promise in addressing this challenge. Consequently, this project aims to leverage JOREK to gain a deeper understanding of pellet plasmoid dynamics in stellarator geometries. This poster offers an overview of pellet physics, employed physics and numerical models, and outlines future research inquiries.

P 12.5 Tue 16:30 ELP 6: Foyer

Investigating density build-up in the W7-X island divertor — •Nassim Maaziz, Felix Reimold, Victoria Winters, David Bold, Frederik Henke, and Yuhe Feng — Max-Planck-Institute for Plasma Physics, Greifswald 17491, Germany

The island divertor has been proposed for power and particle exhaust in stellarators and is investigated as a viable solution for a reactor in the Wendelstein 7-X (W7-X) experiment. The divertor capabilities increase with higher divertor densities. However, significantly lower densities have been measured in the W7-X divertor in comparison to tokamaks. We assess the impact of the island field line pitch on the density build-up with EMC3-EIRENE modeling and comparing to experimental measurements. The modeling shows an increase of field line pitch leads to higher achievable divertor densities. A more fundamental understanding of the density build-up motivated the development of a simplified geometry model for the island divertor, which we study with EMC3-EIRENE. We look at both, the impact of the field line pitch as well as the effect of the divertor geometry. The beneficial effect on the density build-up of increasing the field line pitch has been observed in this simplified case. A close divertor geometry appears to provide significantly higher achievable densities.

P 12.6 Tue 16:30 ELP 6: Foyer

Towards a 3D Full MHD plasma model comprehensive of electromagnetic and halo current coupling with 3D conductive structures — •Raffaele Sparago[1], Javier Artola[2], and Matthias Hoelzl[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]ITER Organization, St. Paul Lez Durance Cedes, France

An adequate modelling of the electromagnetic interaction of the plasma with the surrounding conductors is paramount for the correct reproduction of 3D plasma dynamics. Simulations of the latter provide in turn useful predictions regarding the plasma evolution, the related MHD modes leading to disruptions and the electromagnetic forces acting on the vacuum vessel's components when said disruptions occur. The latest modelling efforts with the 3D FEM non-linear JOREK code have been directed towards the eddy current coupling of a reduced MHD plasma model with thin and volumetric wall codes. In the context of this work, an eddy current coupling between the full MHD model of JOREK and the STARWALL code has been performed; this new coupling scheme relaxes all the degrees of freedom in JOREK's magnetic boundary conditions, allowing for three-dimensional interactions between the magnetic vector potential A and the magnetic field B. Preliminary benchmarks prove the consistency of the Full MHD coupling. Furthermore, this contribution features the recent theoretical development in view of the coupling of halo currents, which flow from the plasma to the wall and viceversa, thus originating additional electromagnetic loads on the vessel that require proper modelling.

P 12.7 Tue 16:30 ELP 6: Foyer

Characterization of electromagnetic instabilities in high-beta plasmas at Wendelstein 7-X — •Charlotte Büschel, Christian Brandt, Henning Thomsen, Kian Rahbarnia, Sara Vaz Mendes, Adrian von Stechow, and Jan-Peter Bähner — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

In the last campaigns of Wendelstein 7-X, comparable high plasma beta core values around $\beta_0 \sim 2.5\,\%$ have been reached in different scenarios, e.g. after the injection of frozen hydrogen pellets or with heating scenarios combining electron cyclotron resonance heating and neutral beam injection. However maintaining the plasma in this state with plasma energies up to 1.2 MJ and densities around $1.4 \times 10^{20}\,\mathrm{m}^{-3}$ has up to date been challenging. With increasing density, strong mode activity in the range of 20-50 kHz has been observed, which might contribute to the decrease of the plasma energy and density after a transient peak. To determine the driving instability, these modes are characterized by analyzing data from Mirnov coils, the phase contrast imaging diagnostic and the soft X-ray tomography system. Furthermore the dependency on local and global plasma parameters is investigated.

P 12.8 Tue 16:30 ELP 6: Foyer

Tomographic localization of turbulent density fluctuations in the Wendelstein 7-X stellarator — •Christian Brandt, Thomas Wegner, Charlotte Büschel, Sara Vaz Mendes, Kian Rahbarnia, Henning Thomsen, and and the W7-X Team — Max-Planck-Institute for Plasma Physics, Greifswald, Germany

The soft X-ray tomography system in the Wendelstein 7-X stellarator is suited to spatially localize turbulence activity by elaborating X-ray radiation fluctuations, which are the results of turbulent density fluctuations. The amplitude of fluctuations investigated in poloidal-radial mappings of temporal evolving tomographic inversions suggests a connection to the flux surface geometry, especially to the flux surface compression. This effect is investigated for different plasma scenarios in terms of heating and density, which enable a variation of turbulent fluctuation levels as generally known from other measurements. The presented diagnostic approach as well as the link to the driving mechanism of turbulence are discussed.

P 12.9 Tue 16:30 ELP 6: Foyer

Modulational instability in isolated dynamics of Geodesic-Acoustic-Mode packets — •David Korger[1,2], Emanuele Poli[1], Alessandro Biancalani[3], Alberto Bottino[1], Omar Maj[1], and Juvert Njeck Sama[4] — [1]Max-Planck-Institut für Plasmaphysik, Garching, 85748, Germany — [2]Ulm University, Ulm, 89081, Germany — [3]École supérieure d'ingenieurs Léonard-de-Vinci (ESILV),

Paris La Défense, F-92916, France — [4]Institut Jean Lamour, Université de Lorraine, Nancy, 54011, France

The geodesic-acoustic-mode (GAM) is a plasma oscillation observed in fusion reactors with toroidal geometry and is recognized to be the nonstationary branch of the zonal flows (ZFs). It was recently shown that the dynamics of the isolated, undamped GAM is well described by a (cubic) nonlinear Schrödinger equation (NLSE). This model equation predicts the susceptibility of GAM packets to the modulational instability (MI).

The necessary conditions for this instability are analyzed analytically and numerically using the NLSE model. The predictions of the NLSE are compared to gyrokinetic simulations performed with the global particle-in-cell code ORB5, where the GAM packets are created from initial perturbations of the axisymmetric radial electric field E_r. An instability of the GAM packets with respect to modulations is observed, in both cases in which an initial perturbation is imposed and when the instability develops spontaneously. However, significant differences in the dynamics of the small scales are discerned between the NLSE and gyrokinetic simulations.

P 12.10 Tue 16:30 ELP 6: Foyer

Real-time vibration monitoring system for the pellet centrifuge at ASDEX Upgrade with empirically derived limit values — •Fin Schmidt[1], Bernhard Ploeckl[2], Martin Prechtl[1], P. T. Lang[2], and ASDEX Upgrade team[3] — [1]Hochschule Coburg — [2]Max-Planck-Institut für Plasmaphysik — [3]see author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

The ASDEX Upgrade centrifuge pellet launcher, utilized to reliably control the particle flux and ELM frequency, is now in operation for more than 30 years. The units age as well as its unique design necessitate a real-time vibration monitoring system, to reliably detect, warn and prevent damage or malfunctions. Due to space restrictions, two sensors were affixed close to the lower ball bearing. This configuration allows for an efficient monitoring of both the overall structure and at least one of the two bearings, providing some insight into the stability of the rotor. In the absence of literature and established standards for vibration control specific to this structure and application, the key to find vibrational limits is to derive them empirically. Setting a baseline for limit values considers the current operational values as optimal and establishes more precise limits based on the observed behavior of the unit during different operational states. Advanced tools, such as envelope analysis, are employed to monitor specific machine components, especially the ball bearings. Beyond enhancing the safety of pellet injection at ASDEX Upgrade, the current state of the system includes a scheme to safely shutting down the centrifuge before reaching threatening vibration magnitudes.

P 12.11 Tue 16:30 ELP 6: Foyer

Parametrisation of target heat flux in W7-X — •Johannes Droste[2], Felix Reimold[1], David Bold[1], and Ralf Schneider[2] — [1]Max-Planck Institute for Plasma Physics, Greifswald, Germany — [2]Universität Greifswald

This poster presents an approach to address the complex behaviour of the W7-X strike line. It introduces a tool for parameterising the heat flux on to the W7-X island divertor. Particularly distinctive at high densities, the strike line profile exhibits multiple, sometimes overlapping features. The developed tool allows for the separation and characterisation of these features. Through a comparative analysis of feature positions and corresponding connection lengths, a link is established to different transport channels within the island. In addition, the methodology allows the localisation of errors in heat flux calculations due to material deposition and damage to the target surface of the divertor. The width and amplitude of the strike line are key parameters, providing valuable insight into transport and diffusion within the scrape-off layer. Accurate measurement of these parameters is essential for improving and validating scrape-off layer modeling. The influence of time dependent parameters like toroidal plasma current and its influence on strike line position is also investigated.

P 12.12 Tue 16:30 ELP 6: Foyer

Parametrisation of target heat flux in W7-X — •Johannes Droste[2], Felix Reimold[1], David Bold[1], and Ralf Schneider[2] — [1]Max-Planck Institute for Plasma Physics, Greifswald, Germany — [2]Universität Greifswald

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P 12.13 Tue 16:30 ELP 6: Foyer

Modelling of shattered pellet injection in ASDEX Upgrade — •Peter Halldestam[1], Paul Heinrich[1], Gergely Papp[1], Mathias Hoppe[2], Oskar Vallhagen[3], Matthias Hoelzl[1], and Frank Jenko[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Royal Institute of Technology, Stockholm, Sweden — [3]Chalmers University of Technology, Göteborg, Sweden

One of the main issues threatening the success of future reactor-scale tokamaks is disruptions. It is the sudden loss of confinement where the plasma rapidly dissipates its energy onto the surrounding structures, exposing the device to excessive mechanical stress and heat loads. In addition, an electric field is induced that can accelerate a significant fraction of the electrons to relativistic energies, giving rise to runaway electrons (REs). Unmitigated disruptions could potentially cause severe damage to the device and thus, modeling such events is crucial for being able to assess the effectiveness of various mitigation techniques.

With the modeling framework DREAM [Hoppe CPC 2021], we self- consistently evolve in time the poloidal flux and parallel current density, ion charge state densities and temperatures, thermal electron temperature (their density follows from quasi-neutrality) as well as the RE density – all in a flux surface-averaged fluid description of the plasma. In this contribution we study the effects shattered pellet injection (SPI) of deuterium and neon has on disrupting plasmas for ASDEX Upgrade. Initial simulations show good agreement with experimentally observed current quench rates and radiated energy fractions.

P 12.14 Tue 16:30 ELP 6: Foyer

An engineering tool for the minimization of leading edges in a tungsten-based divertor for W7-X — •Antara Menzel Barbara[1,2], Joris Fellinger[1], Rudolf Neu[1,2], and Dirk Naujoks[1] — [1]Max Planck Institute for Plasma Physics, Greifswald/Garching, Germany — [2]Technical University of Munich, Munich, Germany

An innovative engineering tool is developed specifically for minimizing leading edges in the design of a future tungsten divertor for the Wendelstein 7-X fusion device. Traditionally, mitigating leading edges involves shadowing techniques such as tilting the divertor target or chamfering the problematic edges. However, as W7-X is capable of operating various magnetic configurations, this can lead to particle fluxes impinging from opposing directions on the same target surface, potentially exposing new leading edges when mitigating one. The tool harnesses an extensive ANSYS dataset to correlate heat flux and incidence angles from EMC3-Lite simulations with maximum temperatures at potential leading edges. It comprehensively evaluates major magnetic configurations across varied plasma pressures and toroidal currents, while considering manufacturing and assembly tolerances. In instances where chamfering is necessary, the tool analyzes possible chamfer geometries and assesses the resulting exposed leading edges on neighboring components under different magnetic configurations. Its computational efficiency, enabling analysis within minutes on a single core, allows seamless integration into broader optimization frameworks.

P 12.15 Tue 16:30 ELP 6: Foyer

In-situ Uptake Measurement of Deuterium Atoms in Self Damaged Tungsten at Different Temperatures — •Abdulrahman Albarodi[1,2], Thomas Schwarz-Selinger[2], and Klaus Schmid[2] — [1]Tech. Univ. München, 85748 Garching, Germany — [2]Max-Planck Institut für Plasmaphysik, 85748 Garching, Germany

Self-damaged tungsten samples (damage dose 0.23 dpa) were exposed to low energy deuterium (D) atoms (< 5 eV) from a microwave plasma source at 400, 500 and 600 K to investigate D uptake and D retention at different temperatures. The time evolution of the D depth profile was observed in-situ with $_3$He nuclear reaction analysis after each uptake increment. Thermal desorption spectroscopy was performed ex-situ to determine the de-trapping energies and the surface adsorption energies in the tungsten samples. The deuterium flux was measured by an independent erosion measurement to be 2.1 x 10^{21} D/m^2/s. The macroscopic rate equation code TESSIM will be used to model the uptake using the measured de-trapping energies, D flux, the surface binding energy and the surface barrier energy in order to determine the incident particle energy. The results are expected to show an increase in the total retention and uptake of deuterium at higher exposure temperatures.

P 12.16 Tue 16:30 ELP 6: Foyer

Build quality benchmark of tungsten powder bed fusion additive manufacturing processes — •Robert Lürbke[1,2], Alexander von Müller[2], Georg Schlick[3], and Rudolf Neu[1,2] — [1]Technical University Munich, 85748 Garching, Germany — [2]Max Planck Institute for Plasma Physics, 85748 Garching — [3]Fraunhofer Institue for Casting, Composite and Processing Technology, 86159 Augsburg, Germany

Plasma-facing components (PFCs) in future magnetic confinement fusion reactors must sustain high heat fluxes and intense neutron irradiation. These extreme conditions might create the need for specially engineered materials. Tungsten (W) is currently considered the preferred plasma-facing material in fusion devices. To create a wall component, it has to be joined to an actively cooled heat sink. Additive manufacturing (AM) of W is a potentially helpful tool to cre-

ate tailored structures to reinforce a high-conductivity copper matrix, forming a composite heat sink with optimized thermomechanical behavior. AM of W is a rapidly developing field, and various processes have been elaborated recently by research institutions and industry. The contribution will give an overview of AM powder bed fusion processes for W and highlight the development of a benchmark part based on which the processes shall be evaluated in view of their capabilities related to PFC production.

P 12.17 Tue 16:30 ELP 6: Foyer

Validation of the GENE - KNOSOS - Tango Framework Using W7-X Discharges — •Don Lawrence Carl Fernando[1], Alejandro Bañon Navarro[1], Daniel Carralero[2], Jose Luis Velasco[2], J. Arturo Alonso[2], Alessandro Di Siena[1], Felix Wilms[1], Frank Jenko[1], and W7-X Team[3] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Laboratorio Nacional de Fusión, CIEMAT, 28040 Madrid, Spain — [3]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

A pre-requisite to carrying out plasma profile predictions using simulation codes are validation studies. Validation ensures the accuracy of the simulated quantities with respect to experimental results. For this reason, a validation study was carried out using four OP1.2b W7-X scenarios that exhibit different turbulence characteristics. The framework of GENE-KNOSOS-Tango, a coupling of gyrokinetic, neoclassical, and transport codes respectively, is used to predict plasma profiles.

The results of this study show the successful validation of this framework for the four scenarios. Additionally, different key effects are also touched upon, such as electron-scale turbulence and the neoclassical radial electric field and its shear. Finally, we looked into simulated turbulence characteristics, such as density fluctuations and heat diffusivity, and compared these with experimental values. Good qualitative agreement is observed as well. This is the first time that such a study has been done for stellarators. The validation of the GENE-KNOSOS-Tango framework enables us to make credible predictions of physical phenomena in stellarators and reactor performance.

P 12.18 Tue 16:30 ELP 6: Foyer

GRILLIX: Turbulence validation efforts and simulations of advanced divertor concepts — •Jan Pfennig, Wladimir Zholobenko, Andreas Stegmeir, Konrad Eder, Christoph Pitzal, Kaiyu Zhang, Garrad Conway, Gustavo Grenfell, Dominik Brida, and Frank Jenko — Max Planck Institute for Plasma Physics, 85748 Garching b. Muenchen, Germany

Predictive turbulence simulations represent a key tool to describing and understanding the anomalous transport of particles and energy across magnetic flux surfaces of tokamak fusion devices, which is commonly believed to be the main factor determining their confinement properties [1], and thus economic viability. In order to test and verify the physics quality of the locally field-aligned but flux coordinate independent edge turbulence code GRILLIX, extensive validation efforts against ASDEX Upgrade (AUG) L-mode have been performed. As a successive step, GRILLIX simulations of future machine advanced divertor concepts (ADCs), such as downscaled DEMO ADCs [2] as well as magnetic configurations of the new upper divertor in AUG [3], are performed and evaluated.

[1] - A. Dimits et al., Physics of Plasmas, Vol. 7, 2000, DOI 10.1063/1.873896

[2] - F. Militello et al., Nuclear Materials and Energy, Vol. 26, 2021, DOI 10.1016/j.nme.2021.100908

[3] - T. Lunt et al., Nuclear Materials and Energy, Vol. 12, 2017, DOI 10.1016/j.nme.2016.12.035

P 12.19 Tue 16:30 ELP 6: Foyer

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[3] - T. Lunt et al., Nuclear Materials and Energy, Vol. 12, 2017, DOI 10.1016/j.nme.2016.12.035

P 12.20 Tue 16:30 ELP 6: Foyer

Hybrid gyrokinetics: Electromagnetic effects in weakly magnetized plasmas — •Sreenivasa chary Thatikonda[1], Felipe nathan De Oliveira lopes[1], Aleks Mustonen[2], Rainer Grauer[2], Daniel Told[1], and Frank Jenko[1] — [1]Max planck institute for plasma physics, Garching, Germany — [2]Ruhr-Universität Bochum

We aim to study instabilities, turbulence and reconnection phenomena in weakly magnetized plasmas. Such conditions may be found in natural plasmas such as the solar wind, but also in laboratory applications, e.g. in the edge of fusion plasmas. Due to steep gradients in the edge of fusion plasmas and high frequencies in space plasmas, the ordering assumptions of gyrokinetic theory (like low frequency or moderate gradients) may be challenged, particularly for ions. To overcome these limitations, we derived equations for a hybrid model that includes fully kinetic physics for the ions, but gyrokinetic physics for the electrons. The hybrid model's electrostatic version has been numerically implemented into the existing simulation code, ssV. Semi-Lagrangian schemes (e.g., the PFC scheme [Filbet et al., JCP 2001])are employed in ssV.When implementing EM effects, we have to overcome some numerical problems such as the Ampere cancellation problem. To solve this problem, we need to have sufficient velocity space and evaluate the integrals with utmost care. Ongoing work on ssV includes it's applications to space and astrophysical plasmas: For example, magnetic reconnection at the ion scales.

P 12.21 Tue 16:30 ELP 6: Foyer

Plasma-neutrals fluid turbulence modeling in the tokamak edge — •Konrad Eder, Wladimir Zholobenko, Andreas Stegmeir, and Frank Jenko — MPG-IPP, Garching, Germany

Predictive studies of the plasma edge in prospective fusion reactors require self-consistent modeling of the turbulent transport involving an interplay of plasma, neutral gas, and impurity dynamics.

We present extensions to the edge turbulence code GRILLIX, which implements a drift-fluid plasma model and a diffusive neutral gas model. The latter has been upgraded to a 3-moment fluid, i.e. neutral gas density, momentum, and pressure. Furthermore, we show a scheme to implement neutrals recycling for the Flux-Coordinate-Independent (FCI) approach, on which GRILLIX is based and which enables it to handle complex diverted geometries.

The updated model is validated against ASDEX-Upgrade L-mode discharge #36190, demonstrating improved agreement in the divertor profiles of density and electron temperature. We note that: first, the recycling boundary conditions allow for a more realistic in-homogeneous neutrals distribution at the divertor. Second, the evolution of neutrals temperature allows it to decouple from the ion temperature, causing significant change in the poloidal morphology.

Simulations of a density ramp in AUG are carried out, which aim to reproduce detached divertor regimes observed in experiments. Finally, in fully detached conditions, we perform simulations with an X-point radiator to study its impact on turbulent transport, paving the way for predictive reactor simulations of ELM-free regimes.

P 12.22 Tue 16:30 ELP 6: Foyer

Electromagnetic turbulence simulations of the tokamak edge plasma in the quasi-continuous exhaust regime — •Kaiyu Zhang, Wladimir Zholobenko, Andreas Stegmeir, and Frank Jenko — Max Planck Institute for Plasma Physics, Garching, Germany

The global fluid turbulence code GRILLIX has undergone recent advancements to include electromagnetics. This extension has revealed that the electromagnetic flutter effectively reduces ExB transport by intervening in the dynamics of drift-wave turbulence on the tokamak edge [1]. As a result, it imparts stabilizing factors of 2 in L-mode and a remarkable 100 in H-mode.

With the improved capability to resolve electromagnetic turbulence, GRILLIX is now simulating the quasi-continuous exhaust (QCE) regime. QCE is acknowledged as a promising H-mode regime for reactors due to its suppressed type-I ELMs and broadened heat fall-off length [2]. Previous research suggested that these QCE advantages stem from enhanced transport near the separatrix. Our simulations establish self-consistent turbulence transport in QCE, and the turbulence mode structures will be diagnosed to unveil the underlying mechanisms for this enhanced transport.

[1] K. Zhang , et al. arXiv:2309.07763, 2023.

[2] M. Faitsch , et al. Nuclear Fusion, 2023, 63(7): 076013.

P 12.23 Tue 16:30 ELP 6: Foyer

Validation of theoretical upper bounds on local gyrokinetic instabilities — •Linda Podavini, Per Helander, Gabriel Plunk, and Alessandro Zocco — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald, Germany

Turbulence in magnetic confinement fusion devices is driven by the presence of microinstabilities. In the last decades these instabilities have been studied considering various assumptions about plasma parameters and magnetic geometry, thus hampering a desirable unified theory.

The theory of upper bounds on the growth rates of local gyrokinetic instabil-

ities [1,2,3] aims at filling this gap by introducing results which are valid for all microinstabilities. Moreover, they are independent of magnetic geometry and many plasma parameters, such as the number of particle species, beta and collisions.

We compare the upper bounds to solutions of the linear gyrokinetic equation. The latter are obtained through flux-tube simulations performed with the gyrokinetic code stella. The validation focuses on fusion-relevant instabilities and it is carried out for different magnetic field geometries and plasma parameters, to highlight the universality of the theory. The validation also includes a comparison with analytical results obtained in simple magnetic field geometries.

[1] P. Helander, and G. G. Plunk, PRL (2021)
[2] P. Helander, and G. G. Plunk, JPP (2022)
[3] G. G. Plunk and P. Helander, JPP (2022)

P 12.24 Tue 16:30 ELP 6: Foyer

Adding global parallel magnetic fluctuations to the GENE code — •Facundo Sheffield[1], Tobias Goerler[1], Felix Wilms[1], Gabriele Merlo[2], and Frank Jenko[1] — [1]Max-Planck-Institut für Plasmaphysik — [2]The University of Texas at Austin, USA

One of the main challenges of controlled nuclear fusion is the turbulent nature of the plasma itself, which causes increased transport of energy and particles. While great progress has been made, there are still many areas of active research. Among these, the inclusion of parallel magnetic fluctuations ($B_{1||}$) in turbulence simulations has become more and more relevant due to their impact on high beta and reactor relevant scenarios, potentially affecting the constraint of the edge/pedestal profiles in KBM driven scenarios.

Therefore, a long wavelength ($k_\perp \rho_s \ll 1$) approximation for parallel magnetic fluctuations was implemented on the global version of the gyrokinetic delta-f code GENE in order to improve its predictive power and asses its importance for global physics.

The approximation has been successfully tested with convergence tests and comparisons with the local version of GENE. The latter were done by porting the approximation to local GENE, which possesses an arbitrary wavelength solver, and verifying how well it agrees with the full local model. The LW approximation performs much better than previously established treatments for $B_{1||}$ and surprisingly good agreement with the full model is found even at smaller wavelengths. These results are encouraging to all global GK codes implementing or employing a LW approximation for $B_{1||}$. Further studies are ongoing.

P 12.25 Tue 16:30 ELP 6: Foyer

Analysis of Nonlinear Dynamics of Shear Alfvén Waves Driven by Energetic Trapped Particles — •Farah Atour — IPP Garching

In controlled fusion devices, shear-Alfven waves can be driven unstable by resonant interactions with energetic alpha particles. This results in many issues regarding the confinement of the particles and therefore can prevent thermalization of the plasma core or increase the thermal load on the material wall. The source of these particles is either from the nuclear fusion reaction produced by the background plasma and/or external heating systems. Due to the importance of these issues, there exists an extensive literature on this topic. These studies mostly focus on the nonlinear dynamics of passing particles since they have more significant impacts. However, the nonlinear dynamics of shear-Alfven waves driven by energetic trapped and anomalous particles deserves also depth analysis and will be the focus of this study. The overall goal of this work is to investigate on a deeper level the fundamental physical processes regarding both the linear stability properties and the nonlinear saturation. For this reason, to keep the context of the dynamical study simplified, these phenomena are investigated by HMGC code, which has a simple circular geometry and is based on the hybrid reduced MHD gyrokinetic model.

P 12.26 Tue 16:30 ELP 6: Foyer

Research plan for investigating differences and similarities between hydrogen and deuterium operation in negative ions sources for fusion applications — •Joey Rubin, Nicolaas den Harder, Dirk Wuenderlich, Christian Wimmer, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik (IPP), Boltzmannstr. 2, 85748 Garching

Negative ion sources for fusion applications face demanding requirements. The ITER NBI system requires extracted negative ion current densities of 329 A/m^2 in hydrogen for 1000s and 286 A/m^2 in deuterium for 3600s, with co-extracted electron fraction below 1 for both isotopes. Testbeds BATMAN Upgrade and ELISE in operation at IPP Garching, have successfully demonstrated the feasibility of meeting these requirements in hydrogen. However, deuterium operation presents a challenge due to a higher and more unstable co-extracted electron current density. The increase in co-extracted electron current density limits the pulse length as the heat load on the extraction reaches the limit. The focus of this thesis is to delve into the physics underlying the different performance of negative ion sources for fusion in hydrogen and deuterium. The present poster outlines the research plan designed to reach this objective.

P 12.27 Tue 16:30 ELP 6: Foyer

Influence of the presence of hydrogen isotopes on damage evolution in tungsten — •Zeqing Shen, Thomas Schwarz-Selinger, Mikhail Zibrov, and Armin Manhard — Max-Planck-Institut für Plasmaphysik, Boltzmannstrasse 2, Garching D-85748, Germany

The influence of the presence of deuterium (D) on damage evolution at elevated temperatures was studied for self-ion irradiated tungsten (W). W samples were irradiated by 20 MeV W ions at room temperature to the peak damage dose of 0.23 dpa and loaded with a low-temperature D plasma at 370 K to decorate the created defects. To study the evolution of the defects with D being present, samples were heated during plasma loading to 4 different temperatures, ranging from 470 K to 770 K. The annealing time was calculated by the rate equation modelling code TESSIM-X. For comparison, annealing experiments at each temperature were carried out also in vacuum. After annealing, all samples were re-exposed to the same D plasma as before to decorate the surviving defects. The duration was calculated again by TESSIM-X. At various steps of the experiment, nuclear reaction analysis (NRA) was used to determine the deuterium depth profile. After the last re-exposure thermal desorption spectroscopy (TDS) was used to measure the total amount of deuterium and de-trapping energy of D. The final results will give a quantitative understanding of the influence of the presence of hydrogen isotopes on defect evolution at elevated temperature.

P 12.28 Tue 16:30 ELP 6: Foyer

Atomic cascade computations for astro and plasma physics — •Stephan Fritzsche — Helmholtz-Institut Jena, Germany — Friedrich-Schiller University Jena, Germany

Electronic structure calculations of atoms and ions have a long tradition in physics with many applications in astro and plasma physics. With the Jena Atomic Calculator (JAC), I here present a modern implementation of a (relativistic) electronic structure code for the computation of atomic amplitudes, properties and cascades. JAC [1,2] is based on Julia, a new programming language for scientific computing, and provides an easy-to-use but powerful platform to model excitation and decay processes of open-shell atoms and ions across the periodic table. This toolbox also provides useful features to predict plasma rate coefficients for different capture and ionization processes.

[1] S. Fritzsche. A fresh computational approach to atomic structures, processes and cascades. Comp.Phys.Commun., 240, 1 (2019), DOI:10.1016/j.cpc.2019.01.012.

[2] S. Fritzsche. JAC: User Guide, Compendium & Theoretical Background. https://github.com/OpenJAC/JAC.jl, unpublished (02.11.2023).

P 12.29 Tue 16:30 ELP 6: Foyer

Influence of Plasma Instability for the Energy-loss of Relativistic Pair Beams from TeV Blazars — •Suman Dey and Günter Sigl — II. Institut für Theoretische Physik, Universität Hamburg, 22761 Hamburg

The interaction of TeV photons from blazars with the extragalactic background produces a relativistic beam of $e^- e^+$ pairs streaming through the intergalactic medium, producing a cascade through up-scattering low-energy photons. Plasma instability is considered one of the underlying energy-loss processes of the beams. This study aims to investigate the energy loss of beams due to plasma instability using a particle-in-cell (PIC) simulation. We extrapolated the instability growth trend observed in laboratory settings to the astrophysical scale, assuming no other important mechanisms. For relativistic jets, the beam undergoes a continuous influx of new particles by pair production, which persists in driving the instability. We estimated the saturated value of the energy-loss term and diffusion coefficient when equilibrium is achieved. Moreover, in extrapolating to astrophysical scales, we noted that the system started to develop secondary instability and emerged from a reactive to kinetic regime. Momentum broadening suppresses the secondary instability and saturates. We compared the energy-loss time scale ($\tau_{\rm loss}$) and diffusion time scale ($\tau_{\rm diff}$) with inverse Compton (IC) cooling time ($\tau_{\rm IC}$). We observed that the $\tau_{\rm loss}$ is almost comparable to $\tau_{\rm IC}$, whereas $\tau_{\rm diff}$ exceeds both. This opens a future scope to explore the effect of intergalactic magnetic field (IGMF) on instability using the modular structure of CRPropa code.

P 12.30 Tue 16:30 ELP 6: Foyer

Turbulence in Molecular Clouds — •Christian Heppe[1], Alexei Ivlev[2], and Frank Jenko[1] — [1]Max-Planck-Institut für Plasmaphysik — [2]Max-Planck-Institut für extraterrestrische Physik

In the Interstellar Medium a vast array of different plasma can be observed. Ranging from the almost fully ionized low density plasma in between stars to the cold, dense gas in Molecular clouds where ionization is solely governed by the presence of high energy cosmic rays. Where either magnetic or thermal pressure can dominate. In these environments the dynamics of the medium are governed by turbulence.

As the coupling between neutral and ionized gas can strongly vary in such inhomogeneous environments two fluid effects become necessary to account for. The coupling of the neutral and ionized gas is mediated by collisions and current theory suggests that one can identify three coupling regimes. At large scales, in

the strongly coupled regime, the ionized and neutral gas move together as one fluid. Beyond this, in the weakly coupled regime, the dynamics of both species begin to decouple. Finally, in the decoupled regime at even smaller scales, both gases move independent of each other. Despite this, the current models lack physical insight and yield qualitative results that do not match relevant simulations.

By systematically probing different turbulent environments with two fluid MHD simulations we hope to find a phenomenological explanation as to how the turbulent cascade manages to bridge the decoupling regime and transport energy to smaller scales, possibly identifying an elementary turbulent interaction.

P 12.31 Tue 16:30 ELP 6: Foyer

Study of structure and electron acceleration processes at planetary and astrophysical shocks using Particle-In-Cell simulations. — •Valentine Devos, Artem Bohdan, and Frank Jenko — Max Planck Institut for Plasma Physics, Germany

The first aim of the project is to study the structure of shocks, at planetary and astrophysical scales, for intermediate Mach numbers using Particle-In-Cell simulations. More precisely, the transition between low Mach numbers instabilities (as shock whistler precursor, modified 2-stream instabilities, etc.) to high Mach numbers instabilities (Weibel instabilities, Buneman instabilities, etc.). The different processes of electron acceleration within these shocks will be also discussed. Those processes are notably the Diffusive Shock Acceleration, the Shock Surfing Acceleration or the Shock Drifting Acceleration

P 13: Magnetic Confinement IV/HEPP IV

Time: Wednesday 11:00–12:20 Location: ELP 6: HS 3

P 13.1 Wed 11:00 ELP 6: HS 3

Non-linear free boundary simulations of resonant magnetic perturbations in ASDEX Upgrade — •Verena Mitterauer[1], Matthias Hoelzl[1], Matthias Willensdorfer[1], and ASDEX Upgrade Team[2] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]See author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

The suppression of ELMs by resonant magnetic perturbations RMPs in an ASDEX Upgrade plasma is modeled using the free boundary MHD code JOREK-STARWALL. The simulations are performed with fully realistic plasma parameters and plasma flows, which allows qualitative and quantitative comparisons with experimental observations, reveals important mechanisms, and forms a basis for more accurate predictive studies than previously possible. Simulations of the ELM suppressed state show a local structure in the radial displacement of the plasma around resonant surfaces that can be linked to the presence of magnetic islands. Together with recent experimental findings, this provides strong indications for the presence of a magnetic island chain at the pedestal top during ELM suppression in an ASDEX Upgrade discharge, contributing to resolving a long-standing open question. Furthermore, the transition out of the ELM-suppressed phase into an ELM-unstable state is modeled through an increase of the pedestal density values. The simulations allow to disentangle the role for suppressing ELM instabilities of the edge pressure profile evolution on one hand and non-linear coupling between peeling-ballooning instabilities with the RMP-driven perturbations on the other hand.

P 13.2 Wed 11:25 ELP 6: HS 3

Alfvenicity to Damping: Computational Insights from IMAS FALCON Integration and beyond — •Virgil - Alin Popa, Philipp Lauber, and Thomas Hayward-Schneider — Max Planck Institute for Plasma Physics, Garching, Germany

Building upon the robust infrastructure given by the Energetic Particle Workflow, we have integrated a new actor into the IMAS (Integrated Modeling and Analysis Suite) compliant workflow. The name of the new computational tool is FALCON (Floquet ALfven CONtinuum code). The model focuses on the continuous spectrum of SAWs in the ideal magnetohydrodynamic (MHD) limit. A formula for mapping Alfvenicity (given by FALCON) and kinetic damping (given by LIGKA) was developed. For this, various ITER scenarios were used for obtaining and validating the mapping formula. Furthermore, the workflow has been able to achieve significant speed-up in calculating the global linear properties of modes by exploiting analytical features and equilibrium profile information. This is of great importance when integrating the workflow into a transport code, where computational time is important.

P 13.3 Wed 11:50 ELP 6: HS 3

The change of Jacobian of Poincaré map of magnetic island X/O-cycles under three-dimensional perturbation field — •Wenyin Wei[1,2,3] and Yunfeng Liang[1,2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, Jülich 52425, Germany — [2]Institute of Plasma Physics, Hefei Institutes of Physical Science, Chinese Academy of Sciences, Hefei 230031, People's Republic of China — [3]University of Science and Technology of China, Hefei 230026, People's Republic of China

Based on the first-order shift formula of X/O-cycles under perturbation, the change of Jacobian (denoted as DP^m) of Poincaré map of X/O-cycles (of m toroidal turns) under perturbation is further investigated and formulated. Notably, neither the perturbation field nor the field to be perturbed is required to be axisymmetric or divergence-free for the formulae to apply.

In divertor configurations, the connection lengths of magnetic field lines in the scrape-off layer (SOL) are significantly affected by the DP^m eigenvalues of the outmost X-cycle(s). The number of the outmost X-cycle(s) depends on the experiment setup. Tuning the eigenvalues of DP^m of the X-cycle(s) closer to unity can markedly increase the connection lengths in the SOL, as the neighboring field lines will be more parallel to the X-cycles(s). Additionally, the width of a magnetic island is largely determined by the included angle of the two eigenvectors of DP^m of the adjacent X-cycle(s).

P 13.4 Wed 12:05 ELP 6: HS 3

Pedestal destabilization by 3D magnetic perturbation fields in tokamaks — •Jonas Puchmayr[1], Mike Dunne[1], Erika Strumberger[1], Matthias Willensdorfer[1], Hartmut Zohm[1], Florian Hindenlang[1], and ASDEX Upgrade Team[2] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]See U. Stroth et al 2022 Nucl. Fusion 62 042006

In H-mode tokamak plasmas, edge localized modes (ELMs) limit the achievable pressure gradient in the edge region and might cause severe damage in future fusion devices. Consequently, it is crucial to understand the onset of ELMs and methods to mitigate or suppress them. The onset of an ELM is typically well-described by the growth of magnetohydrodynamic instabilities at the plasma edge.

One method to mitigate or suppress ELMs is the application of magnetic perturbation (MP) fields. In this work, we use the linear extended MHD stability code CASTOR3D to show for the first time that symmetry-breaking by MP fields can significantly reduce the achievable stable pedestal pressure by up to 30%, resulting in mitigated ELMs. The destabilizing effect on the achievable stable pedestal pressure due to MP fields remains if ion diamagnetic drift effects, which strongly stabilize high-n ballooning modes, are included. The lowest pedestal top pressure resulting in the onset of MHD modes in 3D AUG plasmas has been found by interpolating between two equilibria featuring ELM mitigation and suppression, corresponding to the empirically observed pedestal pressure limit for complete ELM suppression.

P 14: Low Pressure Plasmas and their Application I

Time: Wednesday 11:00–12:30 Location: WW 1: HS

Invited Talk P 14.1 Wed 11:00 WW 1: HS

Insights into the Non-Thermal Character of Molecular Plasmas from Optical Frequency Comb Spectroscopy — •Ibrahim Sadiek, Norbert Lang, and Jean-Pierre H. van Helden — Leibniz Institute for Plasma Science and Technology (INP)

Our ability to model, optimize and control plasma-activated chemical processes depends strongly on the knowledge of the absolute concentrations and temperatures of reactive species in the plasma, and their reaction kinetics. This knowledge can be acquired through absorption spectroscopy using continuous wave (CW) lasers. However, the narrow spectral tuning range of these CW lasers limits the number of detectable molecules and cannot provide precise information about the non-thermal nature of plasma-generated species, particularly the distribution of energy among different molecular degrees of freedom. We overcome this hurdle by using state-of-the-art optical frequency combs as diagnostic light

sources. We develop and apply frequency comb-based detection techniques, offering a unique combination of broad bandwidth and high spectral resolution. This enables the simultaneous detection of multiple species in the plasma.

In this paper, we will present insights into the non-thermal nature of low-pressure molecular plasmas containing nitrogen, hydrogen, and methane through frequency comb-based Fourier transform spectroscopy measurements. This technique enables us to provide quantum-state-resolved knowledge of plasma-generated molecular species, thereby paving the way for precise modelling of plasma chemical processes.

P 14.2 Wed 11:30 WW 1: HS

Ro-vibrationally resolved corona modelling for the Fulcher-α band of H_2 plasmas: a powerful tool for spectra analysis — •Richard C. Bergmayr[1], Dirk Wünderlich[1], Liam H. Scarlett[2], Mark C. Zammit[3], Igor Bray[2], Dmitry V. Fursa[2], and Ursel Fantz[1] — [1]IPP Garching, Germany — [2]Curtin University, Australia — [3]Los Alamos National Laboratory, USA

Collisional radiative (CR) modelling combined with emission spectroscopy enables the derivation of the plasma parameters (e.g. n_e and T_e) from the naturally emitted radiation of molecular hydrogen (H_2) plasmas. Under certain conditions discussed in this contribution the simplified approach of corona modelling is valid, wherein collisional excitation from the ground state is balanced with spontaneous emission in the form of rate equations depending on reaction probabilities (e.g. cross sections) as input. The flexible Yacora code can solve the underlying system of equations coupling the manifold of ro-vibrational levels in H_2. An electronically resolved CR model can determine for which plasma regimes the corona approximation must be extended by further process channels (e.g. cascades). This contribution discusses a corona model for the Fulcher-α band of H_2 applying fully ro-vibrationally resolved MCCC cross sections. The MCCC (molecular convergent close-coupling) method in the adiabatic-nuclei formulation is an ab initio approach for electron scattering problems able to provide accurate ro-vibrationally resolved cross sections. The model derived spectra are compared with various benchmark cases demonstrating the model's suitability as part of a non-invasive diagnostic.

P 14.3 Wed 11:45 WW 1: HS

Plasma sheath tailoring by a magnetic field for three-dimensional plasma etching — •Elia Jüngling[1], Sebastian Wilczek[2], Thomas Mussenbrock[2], Marc Böke[1], and Achim von Keudell[1] — [1]Chair Experimental Physics II, Ruhr University Bochum, Bochum, Germany — [2]Chair of Applied Electrodynamics and Plasma Technology, Ruhr University Bochum, Bochum, Germany

Three-dimensional (3D) etching of materials by plasmas is an ultimate challenge in microstructuring applications. A method is proposed to reach a controllable 3D structure by using masks in front of the surface in a plasma etch reactor in combination with local magnetic fields to steer the incident ions in the plasma sheath region towards the surface to reach 3D directionality during etching and deposition. This effect can be controlled by modifying the magnetic field and/or plasma properties to adjust the relationship between sheath thickness and mask feature size. Since the guiding length scale is the plasma sheath thickness, which for typical plasma densities is at least tens of microns or larger, controlled directional etching and deposition target the field of microstructuring, e.g. of solids for sensors, optics, or microfluidics. In this proof-of-concept study, it is shown that $\vec{E}\times\vec{B}$ drifts tailor the local sheath expansion, thereby controlling the plasma density distribution and the transport when the plasma penetrates the mask during an RF cycle. This modified local plasma creates a 3D etch profile. This is shown experimentally as well as using 2d3v Particle-In-Cell/Monte Carlo collisions simulation.

P 14.4 Wed 12:00 WW 1: HS

Simulation and Modeling of DC Glow Discharges — •Tim Bolles[1], Maximilian Klich[1], Katharina Nösges[1], Máté Vass[1,2], and Thomas Mussenbrock[1] — [1]Ruhr University Bochum, 44780 Bochum, Germany — [2]Wigner Research Centre for Physics, 1121 Budapest, Hungary

DC (Direct Current) discharges are well established systems with extensive applications, particularly in the high gas pressure regime. Their physics is more complex than initially assumed. The reason for this is that they are very sensitive to external conditions and internal fluctuations such as the plasma density or the electron temperature. The simulation of DC discharges, especially if kinetic effects need to be considered, can be rather complex, as it needs to accurately capture the variable and often unstable properties of the discharge. Kinetic models, which consider the movements and interactions of individual particles within the plasma, must be able to handle these instabilities and fluctuations, presenting a significant challenge. This contribution focuses on addressing the complexities in the kinetic simulation of DC discharges, outlining the challenges and proposing solutions. Specifically, it will illustrate the indispensable elements of a kinetic simulation model for DC discharges, as demonstrated through a case study. Valuable discussions with Zoltan Donko (Wigner Research Center for Physics) are gratefully acknowledged.

P 14.5 Wed 12:15 WW 1: HS

Deposition system for graphene nanostructures — •Simeon Marinov, Ivan Ivanov, and Zhivko Kissovski — Faculty of Physics, Sofia University, St. Kl. Ohridski, Sofia, Bulgaria

A microwave plasma system has been developed for the deposition of carbon nanostructures on metal and ceramic substrates at low and atmospheric pressure. The microwave surface wave discharge at frequency of 2.45 GHz is applied for PECVD (Plasma Enhanced Chemical Vapor Deposition), because it produces a dense plasma providing efficient decomposition of the carbon precursor (methane CH_4 or ethanol C_2H_5OH). At atmospheric pressure a plasma jet is used while at low pressure (0.4-8 Torr) a planar microwave plasma source as both discharges create a large number of reactive particles which results in lower substrate temperature for graphene deposition compared to CVD method. Optimization of the gas mixture of H_2, Ar and the precursor, and the gas pressure in the chamber for the second setup results in a homogeneous graphene structures deposition on the substrates of Ni-foil, Ni-foam and ceramic substrates (SiC) at substrate temperatures in the range 600-750 °C. The plasma parameters such as gas temperature, electron temperature and density are obtained by measuring OH and CN-bands, H_β broadening and Ar-lines using optical emission spectroscopy. The morphology of the carbon structures is obtained using SEM analysis and the characteristics of the graphene layers are determined by Raman spectroscopy. A self-consistent model of the atmospheric plasma jet is developed in COMSOL Multiphysics and plasma parameters in argon gas are obtained.

P 15: HEPP V

Time: Wednesday 14:00–16:10 Location: ELP 6: HS 3

Invited Talk P 15.1 Wed 14:00 ELP 6: HS 3

Particle fueling, profiles and transport in neutral beam heated plasmas at Wendelstein 7-X — •Sebastian Bannmann, Oliver Ford, Peter Poloskei, Jakob Svensson, Samuel Lazerson, Hakan Smith, and Robert Wolf — Max-Planck-Institut für Plasmaphysik, Greifswald, DE

A spontaneous reduction in anomalous particle transport in the plasma core is seen experimentally in reproducible, purely neutral beam (NBI) heated plasma phases at Wendelstein 7-X (W7-X). A significant acceleration of the density peaking occurs after a certain onset time and is examined with a detailed particle transport analysis in several discharges. By invoking the particle continuity equation, the total experimental radial electron flux is deduced from the time evolution of the electron density profile and the radially resolved particle sources. To calculate the neutral beam particle deposition a full collisional-radiative (CR) neutral beam injection model based on Gaussian pencil (Gausscil) beams and a diffusive CR neutral halo model is implemented and verified. All important parameters defining the neutral beams are inferred from Balmer-alpha (Halpha) emission data and compared to available reference values. By employing Bayesian inference techniques provided by the Minerva framework, the full electron density profile from the plasma core to the edge is inferred solely from neutral hydrogen beam and halo Halpha emission data. Exploiting the evolving plasma conditions, anomalous diffusion and convection coefficients are successfully computed from the flux variation with density and density gradients.

P 15.2 Wed 14:30 ELP 6: HS 3

Effect of the newly installed cryo-vacuum pump on neutral gas pressures and particle exhaust — •Victoria Haak, Chandra Prakash Dhard, Thierry Kremeyer, Dirk Naujoks, Georg Schlisio, and W7-X Team — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Gas exhaust is a key requirement for density control in a fusion device and, apart from the pumping speed and the subdivertor geometry, strongly dependent on the neutral gas pressure in the subdivertor and in front of the pumps. In each of the ten island divertor modules in Wendelstein 7-X, a cryo-vacuum pump (CVP) has been installed for the last campaign (OP2.1) to improve the particle exhaust capabilities. During dedicated gas injection tests, the pumping speed of the CVPs has been determined for hydrogen (70 m^3/s), nitrogen (21 m^3/s), neon (22 m^3/s) and argon (9 m^3/s). No significant differences in the neutral gas pressures in the subdivertor have been observed in discharges with and without CVPs in operation. Overall, neutral gas pressures on the order of few times 10^{-4} mbar were measured in the subdivertor region, which still corresponds to the molecular flow regime in which the effect of the cryo-vacuum pump on particle exhaust is limited.

P 15.3 Wed 14:55 ELP 6: HS 3

Heat Load Optimization for the Island Divertor of the Wendelstein 7-X Stellarator — •Amit Kharwandikar[1], Dirk Naujoks[1], Felix Reimold[1], Ralf Schneider[2], and The W7X-Team[1] — [1]Max Planck Institute for Plasma Physics, Greifswald — [2]Universität Greifswald, Greifswald

The Wendelstein 7-X (W7-X) stellarator implements the island divertor concept and has demonstrated the viability of using magnetic islands as a exhaust solution for low-shear stellarators. During the experiments, the divertor design revealed challenges in two aspects in particular: unexpected hotspots that limited operation and a poor neutral particle exhaust, motivating an investigation of new geometries to advance the W7-X island divertor. Early stages of such an exploratory challenge calls for fast and simple tools to scan the large 3D design space. In the same spirit, this contribution proposes a framework to analyse the heat flux compatibility of new divertor geometries.

The problem is approached in 2 steps - first, obtaining a simple picture of heat transport in an island scrape-off layer (SOL) to build fast predictive models of target heat flux distribution, followed by shape exploration of target geometries. In terms of tools, we utilize the Monte-Carlo code for 3D SOLs, EMC3-Lite, and compliment it with a newly developed empirical approach - Simple model for loads in island divertor (SMoLID) - based on estimating the SOL width and perpendicular transport length scales for a given magnetic topology and plasma conditions. Eventually, these tools are applied to investigate the heat load compatibility of certain "closed" divertor geometries.

P 15.4 Wed 15:20 ELP 6: HS 3

Investigations of impurity concentration in seeded divertor plasmas of W7-X via line ratio spectroscopy — •Frederik Henke, Maciej Krychowiak, Felix Reimold, Ralf König, Dorothea Gradic, Erik Flom, and Victoria Winters — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

In future fusion power plants, managing power exhaust in the divertor poses a significant challenge, requiring seeding of extrinsic impurities. Retaining these impurities at the plasma edge is crucial to avoid fuel dilution and radiative energy losses in the core, limiting the reactor's operational space.

Ongoing research explores power exhaust scaling with spectroscopically measured impurity concentration and machine parameters in tokamak plasmas. This study focuses on measuring multiple spectral lines of the same impurity ion using passive divertor spectroscopy, employing their ratios to reconstruct local plasma parameters.

W7-X's recent operational campaign featured experiments with various seeded impurity species, revealing challenges in the analysis. Notable variations in measured line ratios among different magnetic configurations indicate distinct local plasma parameters. Due to different plasma conditions in the divertor, line-ratio analysis methods require re-validation. This study presents initial results of impurity concentrations, discussing factors influencing the diverse behavior of line ratio measurements.

P 15.5 Wed 15:45 ELP 6: HS 3

Investigation of radiation distribution and scaling for power exhaust in W7-X — •Gabriele Partesotti[1], Felix Reimold[1], Glen Wurden[2], Daihong Zhang[1], and Byron Peterson[3] — [1]Max-Planck Institute for Plasma Physics, Greifswald, Germany — [2]Los Alamos National Lab, Los Alamos (NM), USA — [3]National Institute for Fusion Science, Toki, Japan

Radiation emission is one of the main heat loss channels for magnetically confined fusion plasmas. In terms of performance, its effect can be either beneficial - e.g. mitigation of power load on the plasma-facing components - or detrimental - e.g. core cooling, radiation collapse. Still, the toroidal distribution of radiated power in a stellarator machine and its behavior in the island divertor are not fully understood yet. In light of this, the present work aims to study the three-dimensional characteristics of radiation in the stellarator geometry of Wendelstein 7-X (W7-X), and its sensitivity to magnetic configuration and plasma parameters. The analysis begins with an introduction of the diagnostic systems, including both resistive and infrared imaging bolometers. It follows a description of the principal features of the W7-X edge radiation resulting from EMC3-EIRENE simulations. Based on these findings, a new concept of Compact Bolometer Camera (CBC) is designed and tested to improve diagnostic coverage and assess poloidal and toroidal radiation asymmetries. Finally, the toroidal variation of the radiated power distribution is investigated by comparing local measurements with projected tomographic reconstructions.

P 16: Atmospheric Pressure Plasmas and their Applications III

Time: Wednesday 14:00–16:00 Location: WW 1: HS

Invited Talk P 16.1 Wed 14:00 WW 1: HS

CO_2 dissociation by microwave plasmas: experimental studies on interfaces in view of industrial applications — •Rodrigo Antunes[1], Christian K. Kiefer[1], Ante Hecimovic[1], Katharina Wiegers[3], Arne Meindl[1], Andreas Schulz[3], and Ursel Fantz[1,2] — [1]Max Planck Institute for Plasma Physics, 85748 Garching b. München, Germany — [2]University of Augsburg, 86159 Augsburg, Germany — [3]University of Stuttgart, Stuttgart 70569, Germany

Microwave plasma (MW) torches are known to be an efficient technology for the conversion of CO_2 to CO up to atmospheric pressure. However, in order to evaluate its industrial applicability, the interfaces of the process in which the plasma torch will be integrated should be considered. For example, the CO_2 upstream might contain impurities such as that from carbon capture facilities, while the plasma-produced downstream mixture must have very low amounts of O_2 if to be used as feed gas in a Fischer-Tropsch reactor for fuel synthesis.

This talk provides an overview of the state-of-the-art for the dissociation of CO_2 by means of MW plasma torches. The influence of various relevant parameters on the conversion and energy efficiency is discussed. From the insights gained by the wall-plug efficiency, optimisation routes can be outlined. Using multiple membranes accommodated in the plasma effluent, the removal of O_2 from the outlet stream is demonstrated. Long-term performance stability and compatibility with intermittent power sources showcases that the plasma technology is a relevant addition to the portfolio of gas conversion techniques.

P 16.2 Wed 14:30 WW 1: HS

Development of a hybrid reactor for plasma-enhanced electrocatalysis for NH3 production — •Martin Leander Marxen[1], Luka Hansen[1], Gustav Sievers[2], Volker Brüser[2], and Holger Kersten[1] — [1]Plasmatechnology Group, IEAP, Kiel University, Kiel, Germany — [2]Plasma Process Technology, INP Greifswald, Greifswald, Germany

Plasma-catalytic approaches are promising for the conversion of mixtures of nitrogen (N_2) and hydrogen (H_2) into ammonia (NH_3) [1,2]. Activation of the reaction sluggish N_2 molecules is achieved by collisions with the highly energetic electrons present in the discharge.

In proton-exchange-membrane-electrolysis (PEM-electrolysis), water (H_2O) is split up into oxygen (1/2 O_2), protons (2 H^+) and electrons (2 e^-) at the anode. The protons permeate the membrane and are reduced at the cathode [3].

A hybrid reactor was developed, in which a surface dielectric barrier discharge (SDBD) is located right underneath the cathode of a PEM-cell. By operating the SDBD with N_2, excited, ionized and dissociated N_2 species will be present at the cathode of the PEM-cell, where they can react with the produced H / H^+ and, thus, be reduced to NH_3. The development and characterization of the reactor will be presented.

[1] K. H. R. Rouwenhorst, Green chem 22 (2020), 19
[2] A. Bogaerts et al., J Phys D: Appl Phys 53 (2020), 44
[3] S. S. Kumar und V. Himabindu, Mater Sci for Energy Technol 2 (2019), 3

P 16.3 Wed 14:45 WW 1: HS

CFD and Heat Transfer Modeling of a Microwave Atmospheric Plasma Torch for CO_2 Conversion — •Stefan Merli, Katharina Wiegers, Marc Bresser, Andreas Schulz, Matthias Walker, and Günter Tovar — IGVP, University of Stuttgart, Stuttgart, Germany

Microwave plasma torches at atmospheric pressure offer an interesting way to split CO_2 and convert it to O_2 and CO, the latter of which is an important base material for chemical synthesis. The investigated microwave plasma torch creates a CO_2 plasma inside a quartz tube via two resonators. To protect the quartz tube from the hot plasma of around 6000 K, tangential gas inlets generate a rotational cold gas flow around the tube surface. The hot gas from the plasma and the cold gas are then mixed in a nozzle to increase the amount of converted gas. The nozzle and the subsequent expansion zone also cause the gas to cool quickly, which quenches back reactions from CO and O_2 to CO_2. Since the gas flow conditions and the temperature distribution are of great importance for a high conversion efficiency, CFD and heat transfer simulations were carried out in Comsol Multiphysics. The aim is to improve the conversion efficiency by optimizing geometry of the torch and the nozzle with regard to hot/cold gas mixing and effective quenching. A comparison of simulations and experiment reveals different flow regimes of the effluent for different gas flows which are attributed to increasing turbulences in the expasion zone. Since the turbulences increase cooling and the contact with the wall, they are beneficial for quenching and therefore for a high conversion efficiency.

P 16.4 Wed 15:00 WW 1: HS

Ammonia synthesis in an atmospheric catalytic RF plasma — •Steijn Vervloedt and Achim von Keudell — Experimental Physics II, Ruhr University Bochum, Bochum, Germany

The synthesis of ammonia is a vital part of the production of nitrogen-based artificial fertilisers. Also, in the future, it might prove a worthy candidate for energy storage, by acting as a hydrogen carrier. In this contribution, the recent results of ammonia synthesis in an atmospheric RF-plasma are presented, as well as the impact of introducing various catalysts. The plasma physics and chemistry are simplified by using helium as a buffer gas. The nitrogen and hydrogen are admixed up to ~1%, to minimise their impact on the plasma dynamics. The products of the plasma are measured with ex-situ infrared Fourier transform (FTIR) absorption spectroscopy. The plasma dynamics are probed by observing trends in the emission of the second positive and first negative systems of nitrogen. Furthermore, a kinetic model is able to explain the experimentally observed trends. The results indicate that the synthesis is very sensitive to the plasma properties, e.g. the electron energy distribution and differences of less than 0.1 eV are sufficient to explain the results. This likely originates from the sensitivity of the NH_3 production - which happens mostly at the surface - to the atomic nitrogen flux towards the surface where the rate-limiting step is the electron-induced dissociation of nitrogen molecules.

P 16.5 Wed 15:15 WW 1: HS

Enhancing CO_2 Conversion and Oxygen Separation Performance by Optimizing the Gas Flow of an Atmospheric Plasma Torch — •Katharina Wiegers, Stefan Merli, Marc Bresser, Andreas Schulz, Matthias Walker, and Günter Tovar — IGVP, University of Stuttgart, Stuttgart, Germany

The chemical industry needs to switch from processes that use fossil raw materials to renewable sources. Carbon dioxide (CO_2) is the base product for closing the carbon cycle. One possibility to convert CO_2 is through a plasma process at atmospheric pressure that splits CO_2 into carbon monoxide (CO) and oxygen (O_2). Since out of the two products, only CO is needed for industrial purposes, a gas separation step is required. By using oxygen-conducting ceramic hollow fiber membranes, oxygen can be removed from the product gas in situ. A promising candidate for the membrane material is $La_{0.6}Ca_{0.4}C_{0.5}Fe_{0.5}O_3$, which results in fibers with a high thermal stability of up to 1200°C inside CO_2 plasma. Moreover, the amount of produced CO can be further increased by improving the quenching of unwanted back reactions. This can be achieved by optimizing the gas management by introducing a restriction in the flow regime. Therefore, a nozzle has been designed with the aim to improve the quenching effect and, at the same time, increase the volume of the plasma interacting with the membranes and thus the amount of O_2 removed. The O_2 permeation in the fiber could thus be increased from 2.2 to 4.6 mL · min^{-1}.

P 16.6 Wed 15:30 WW 1: HS

Experimental observations on microsecond and nanosecond pulses applied to a surface dielectric barrier discharge — •Gerrit Hübner, Nils Schoeneweihs, Dominik Filla, Sebastian Wilczek, Thomas Mussenbrock, and Ihor Korolov — Ruhr-Universität Bochum

The conversion of volatile organic compounds (VOCs) has long been an area of interest in the plasma community. Surface dielectric barrier discharges (SDBD) have been used for such conversions, however the details behind the formation and behaviour of plasma streamers, typically observed in such discharges, are yet to be fully understood. This work focuses on investigation of a SDBD driven by microsecond and nanosecond pulses operated in mixtures of Helium and Nitrogen (or Oxygen). We use phase resolved optical emission spectroscopy (PROES) to study the spatio-temporal surface streamer dynamics on a nanosecond timescale. The quenching rates by He and N2 of the Helium-I 706 nm emission line are also determined from the measured effective lifetime. We have calculated and compared the streamer propagation speed for different discharge conditions. The experimental findings are compared with fluid (nonPDPSIM) simulations and a very good qualitative agreement is found providing a deep understanding of the streamer behaviour on the ns time scale. **This work is supported by the DFG via SFB1316 (A5)

P 16.7 Wed 15:45 WW 1: HS

Influence of EHD Force on Gas Dynamics in Atmospheric Pressure Plasma Discharges: A Computational Analysis — •Sebastian Wilczek, Máté Vass, Alexander Böddecker, Ihor Korolov, and Thomas Mussenbrock — Chair of Applied Electrodynamics and Plasma Technology, Faculty of Electrical Engineering and Information Technology, Ruhr University Bochum

Recent advancements in plasma technology have led to the development of various atmospheric pressure plasma discharges for gas conversion. Most of these discharges, such as dielectric barrier discharges, ignite streamers that significantly impact the gas dynamics. The electrohydrodynamic (EHD) force plays a crucial role in this context, exerting a significant momentum transfer on the process gas and altering the overall gas dynamics. This work presents an analysis of results obtained from 2D plasma simulations, which are subsequently integrated into pure fluid simulations via OpenFOAM. The study highlights the formation of vortices in the gas dynamics, demonstrating significant consistency with experimental measurements, including particle image velocimetry (PIV) and Schlieren techniques. The findings offer valuable insights into the complex interactions between EHD forces and gas dynamics in plasma-based gas conversion processes, contributing to the broader understanding and optimization of these applications.

**This work is supported by the DFG via SFB1316

P 17: Magnetic Confinement V/HEPP VI

Time: Wednesday 16:30–18:35 Location: ELP 6: HS 3

Invited Talk P 17.1 Wed 16:30 ELP 6: HS 3

Finite Element Method to Describe Magnetic Measurements of Tearing Modes in ASDEX Upgrade — •Magdalena Bauer, Hartmut Zohm, Marc Maraschek, Anja Gude, Wolfgang Suttrop, Felix Klossek, Bernhard Sieglin, and Louis Giannone — MPI for Plasma Physics, Garching

In large tokamaks a disruption, i.e. a sudden loss of plasma current terminating the discharge, has to be avoided or at least mitigated. Tearing modes (TMs), resistive plasma instabilities, are common precursors to disruptions, particularly TMs with toroidal mode number n=1. Electromagnetic interaction with the vacuum vessel can slow down rotating TMs, which can eventually lock to the wall. Here, toroidal coupling, i.e. the coupling of modes with the same n but different poloidal mode numbers, m, plays an important role. Magnetic perturbations associated with TMs are detected by coils outside the plasma with different orientations and distances to conducting structures. To analyse TMs at all times, the frequency dependence of these measurements has to be described. For this purpose, a three-dimensional model using the finite element method is employed. A TM is introduced as a radially-localized helical current, while the plasma is modelled as vacuum. The vessel and additional conducting structures are integrated in a simplified form. The perturbed magnetic field measured by the coils is calculated taking into account induced currents in the conducting structures. In order to determine the mode composition in all stages of the locking process, agreement between model and measurement is required. The steps performed to achieve this are presented.

P 17.2 Wed 17:00 ELP 6: HS 3

Effect of magnetic islands on fast ion confinement in toroidal devices — •David Kulla[1,2], Samuel Lazerson[2], Athina Kappatou[1], Robert Wolf[2], and Hartmut Zohm[1] — [1]MPI für Plasmaphysik, Garching — [2]MPI für Plasmaphysik, Greifswald

We present applied modeling work with the newly validated BEAMS3D code for simulating neutral beam deposition and fast ion slowing down in tokamaks and stellarators. Fast alpha particles generated by fusion reactions have to heat the thermal plasma collisionally to reach self-sustaining conditions in a reactor and therefore be well confined in the magnetic field. Tokamaks are largely axisymmetric, but suffer from dynamic magnetic perturbations which can break this property and lead to increased fast ion transport and losses. Stellarators are intrinsically three-dimensional but are generally less prone to transient perturbations. In present experiments, neutral beam injection can be used to generate and study fast ions. Magnetic islands arise from helical perturbations of the background magnetic field, either internally from the plasma or externally from magnetic coils.

BEAMS3D has recently been verified against NUBEAM as well as validated against experimental data at the ASDEX Upgrade tokamak using fast-ion D-alpha light (FIDA). We present simulations studying the effect of internal magnetic islands in ASDEX-Upgrade (tokamak) and Wendelstein 7-X (stellarator), showing similarities and differences. The simulations are compared to experimental measurements where applicable.

P 17.3 Wed 17:15 ELP 6: HS 3

Neural Networks as ideal magnetohydrodynamic equilibrium solvers — •Timo Thun[1], Andrea Merlo[2], and Daniel Böckenhoff[1] — [1]Max-Planck-Institute for Plasma Physics, Wen- delsteinstraße 1, 17491 Greifswald, Germany — [2]Proxima Fusion, Am Kartoffelgarten 14, 81671 Munich, Germany

Quick and accurate solvers for the ideal magnetohydrodynamic (MHD) equilibrium in non axisymmetric magnetic fields can accelerate stellarator optimisation, facilitate high-fidelity real-time control and enable other data-driven algorithms like symbolic regression. Unfortunately, current MHD equilibrium solvers either require high computational wall-time or suffer from a lack of accuracy. Neural Network (NN) based solvers enable very fast inference by transferring the bulk

of computational load to model training and the creation of datasets, possibly overcoming this dilemma.

Recent work presented a fast NN based ideal MHD surrogate model in the magnetic configuration space defined by the stellarator research device Wendelstein 7-X. Training the model required a dataset calculated by conventional solvers, but results improved with the addition of the physics-based ideal MHD equilibrium force-residual as an additional training target. Training without a dataset removes implicit biases of its solution strategy and avoids computational costs associated with its creation.

We present a first step towards this physics-based NN training paradigm by training a NN model only on the force residual of a single non-axisymmetric ideal MHD equilibrium.

P 17.4 Wed 17:30 ELP 6: HS 3

Electron cyclotron resonance during plasma formation in nonuniform magnetic fields — •Albert Johansson and Pavel Aleynikov — Wendelsteinstraße 1, 17491 Greifswald

Electron cyclotron resonance is used to start up various fusion experiment devices. In Wendelstein 7-X (W7-X), the second harmonic extraordinary mode (X2) is used for breakdown. Third harmonic extraordinary mode (X3) breakdown is of particular interest, as some future experiments intend to investigate the effects of a lower magnetic field strength. Presently, no experiment at W7-X has successfully used X3 for breakdown. Because the resonance depends on the gyrofrequency, proportional to magnetic field strength over Lorentz factor B/γ, an energy increase is associated with an increase in γ and the resonance condition breaks, causing a finite resonance width. It has been shown that for a uniform magnetic field this resonance width is not enough to ensure a breakdown process [1].

However, the magnetic field of a stellarator is not homogeneous. This opens the possibility of field gradients along the electron trajectory. When the magnetic field strength is increasing in step with the electron energy, the "width" of the resonance is extended considerably. In addition, when several beams are used, a "resonance overlap" can be constructed such that electrons gain almost hundred times the ionization energy of 13.6 eV. We discuss the effect of magnetic field inhomogeneity on energy gain and show how the composition of multiple beams can be optimised.

[1] D Farina. *Nuclear Fusion* 2018, 58(6):066012

P 17.5 Wed 17:55 ELP 6: HS 3

Development of an ECRH plasma start-up scenario for X3 heating at $1.8\,T$ **at Wendelstein 7-X** — •Niklas Simon Polei, Torsten Stange, Frank Noke, Frank Hollmann, Heinrich Peter Laqua, and W7-X Team — Max-Planck-Institut für Plasmaphysik, 17491 Greifswald

One of the main goals of the Wendelstein 7-X stellarator is to show good confinement of fast particles in high beta scenarios. Beta is the ratio of kinetic pressure and magnetic pressure $\beta = \frac{2\bar{n}\bar{T}}{B^2/2\mu_0}$. The available power of the electron cyclotron resonance heating (ECRH) system is not sufficient to reach the necessary beta of 4-5% at 2.5 T, but higher beta values are expected at lower magnetic field. To still use the existing gyrotrons at 140 GHz, X3 heating has to be used at a field of 1.8 T, but a plasma start-up is not possible because $T_e > 0.5keV$ is needed for sufficient absorption. Therefore, the combination of ion cyclotron resonance heating and neutral beam injection has been considered as the start-up scenario so far. The usual ECRH X2 start-up is also possible, if one gyrotron is operated near its other operating point at 104 GHz.

However, operation at 101 GHz is necessary and was succesfully demonstrated for 100 ms with a power of 300 kW. Additionally, a multi-pass scenario with six passes through the plasma axis was developed to maximise the power density during the first 10−20 ms of plasma initiation. For this purpose, two new tiles were designed and the beam positions of the different passes were verified in the plasma vessel in preperation for the next operation phase 2.2.

P 17.6 Wed 18:10 ELP 6: HS 3

The Disruptive H-Mode Density Limit and MARFE Behaviour — •Felix Klossek, Anja Gude, Marc Maraschek, Bernhard Sieglin, Matthias Bernert, Hartmut Zohm, and the ASDEX Upgrade Team — Max-Planck Insitute for Plasma Physics, Boltzmannstr. 2, 85748 Garching

The high confinement mode (H-mode) is an operational regime in tokamaks with suppressed turbulence near the edge, so that particles and energy are confined better. High densities, which are desirable in terms of fusion power, are prone to a density limit: a degradation of confinement and subsequent disruption.

When approaching a density limit disruption, a Multifaceted Asymmetric Radiation From the Edge (MARFE) forms as toroidal ring. It is strongly radiating and is therefore altering the power balance in the plasma and reducing the temperature in its vicinity. During the MARFE evolution, this effect becomes more pronounced. The MARFE starts near the X point, where it is also called X point radiator (XPR). It will subsequently move up on the high field side near the separatrix and stay some time at the top of the plasma, before approaching the low field side, entering the core and triggering MHD instabilities which finally lead to the disruption.

The MARFE position can be reconstructed using measurements from bolometer pinhole cameras. A robust and fast approach based on angular probability distributions for each camera is presented.

P 18: Atmospheric Pressure Plasmas and their Applications IV

Time: Wednesday 16:30–18:30 Location: WW 1: HS

Invited Talk P 18.1 Wed 16:30 WW 1: HS

Diffusion of reactive species in aqueous solutions treated by a humid atmospheric pressure plasma jet — •Steffen Schüttler, Emanuel Jess, and Judith Golda — Plasma Interface Physics, Ruhr-University Bochum, Universitätsstraße 150, 44801 Bochum, Germany

Plasma-treated liquids are used in various fields such as plasma medicine or plasma-assisted biocatalysis. Atmospheric pressure plasma jets are suitable for production of reactive species such as H2O2 and introducing them into liquids under very good control [1]. The use of reactive species in the liquid requires their solubility and transport through the liquid. In this work, the delivery of reactive species from a humid atmospheric pressure plasma jet into a liquid and the diffusion of OH and H2O2 in the plasma-treated liquid were investigated. The capillary plasma jet used is comparable to the COST reference jet and was operated in humid He. UV absorption was used to measure H2O2 in the liquid, the distribution of OH was visualised by the chemiluminescence of luminol and particle imaging velocimetry (PIV) was used to study convective transport. At low gas flow rates, diffusion of H2O2 through the liquid was measurable, whereas at high gas flow rates, convective transport dominates. In all treatments studied, OH was found to be present mainly at the liquid surface, even at high gas flow rates.

This work is supported by the DFG within CRC1316 (Subproject B11, project number 327886311).

[1] Schüttler et al., Plasma. Process Polym. 2023, e2300079

P 18.2 Wed 17:00 WW 1: HS

Hyperspektrale Untersuchungen von Reaktionen an Plasma-Flüssigkeit-Grenzflächen — •Daniel Tasche[1,2], Kai Bröking[1,2], Christoph Gerhard[1,3] und Wolfgang Viöl[1,2,4] — [1]HAWK Hochschule für angewandte Wissenschaft und Kunst, Fakultät Ingenieurwissenschaften und Gesundheit, Göttingen, Deutschland — [2]Technische Universität Clausthal, Fakultät für Natur- und Materialwissenschaften, Clausthal-Zellerfeld, Deutschland — [3]Politecnico di Milano, School of Industrial and Information Engineering, Mailand, Italien — [4]Fraunhofer-Institut für Schicht- und Oberflächentechnik IST - Anwendungszentrum für Plasma und Photonik, Göttingen, Deutschland

Mittels hyperspektraler Bildgebung können physikalische und chemische Vorgänge spektral, zeitlich und räumlich aufgelöst werden. Hierbei wird das Spektrum einer Szene mittels eines abbildenden Spektrographen aufgezeichnet. Die auf den Spektrographenspalt abgebildeten räumlichen Details bleiben über das gesamte optische System erhalten. Bei der plasmainduzierten Bildung von Silbernanopartikeln werden im violetten Spektralbereich lokale Informationen über Partikeleigenschaften und Bildungsraten zugänglich [1]. Durch Nutzung weiterer Wellenlängenbereiche erhält man Informationen über das Plasma und den optischen Einfluss des Mediums, in dem die Reaktion stattfindet. Damit wird die Möglichkeit gegeben, die Prozesse an der Grenzfläche genauer zu verstehen.

[1] Tasche et al., Nanomaterials 2020, 10, 555.

P 18.3 Wed 17:15 WW 1: HS

Impact of admixtures of H2O on the properties of a He jet plasma — •Tao Zhu[1], Margarita Baeva[1], Florian Sigeneger[1], Peter Bruggeman[2], and Shubham Dongawar[2] — [1]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany — [2]Department of Mechanical Engineering, University of Minnesota

Low temperature He plasma containing admixtures of H2O is currently investigated by modelling and experiments related to plasma catalysis in confined spaces in automotive exhaust. The RF plasma jet is operated in a capillary at atmospheric pressure at a power of a few watts. A global model describes the plasma chemistry and the gas heating. The model is extended to a plug flow model, which converts the temporal evolution of a volume element flowing with

the gas into a spatial distribution. A power density profile is defined in the active region between the RF electrodes. This model provides the species densities, the electron mean energy and gas temperature. Experiments based on laser induced fluorescence deliver the density of OH radicals and the gas temperature. A fair agreement was found between modelling and experiments for two power values. The model delivered values of about 5e18 m-3 for the electron density and about 2.5 eV for the electron mean energy which are hardly influenced by the H2O admixture. The analysis of the dominant gain and loss processes of OH revealed pronounced changes of contributions from electron and heavy particle reactions depending on the power.

This work was supported by the DFG-NSF project 509169873.

P 18.4 Wed 17:30 WW 1: HS

Effect of PAW on Rice Seedling Growth and the Expression of Related Genes — Junwei Guo, Dan Zhang, Cheng Yang, and •Huang Feng — College of Science, China Agricultural University, Beijing 100083, China

In plasma agriculture, plasma activated water (PAW) has been shown to improve seed germination, plant growth and resistance to abiotic and biotic stress [1-2]. Due to the complex regulatory mechanism of PAW promoting plant growth, the molecular level hasn't been fully clarified. In this study, RNA-seq was used to analyze the expression levels of related genes after using PAW in rice seedling growth and real-time quantitative PCR was used to verify the expression levels. The key synthetic genes involved in the stress response of rice seedlings to PAW were identified. References [1] Judée, F., Simon, S., Bailly, C., & Dufour, T. (2018). Plasma-activation of tap water using DBD for agronomy applications: Identification and quantification of long lifetime chemical species and production/consumption mechanisms. Water Research, 133, 47-59. [2] Lukacova, Z., Svubova, R., Selvekova, P., & Hensel, K. (2021). The effect of plasma activated water on maize (Zea mays L.) under arsenic stress. Plants, 10(9), 1899.https://doi.org/10.3390/plants10091899

P 18.5 Wed 17:45 WW 1: HS

The ring-shaped spatial distribution of argon excimer, Ar_2^*, in the effluent of the kINPen-Sci — •Andy Nave, Jente Wubs, Philipp Mattern, and Jean-Pierre van Helden — Leibniz institute for Plasma Science and Technology (INP), Felix-Hausdorff-Str. 2, 17489 Greifswald, Germany

The argon excimer (Ar_2^*) species is considered to play an important role in the chemistry of cold atmospheric plasma jets (CAPJs), notably in the formation of reactive oxygen and nitrogen species (RONS). In the present work, we demonstrate that cavity ring-down spectroscopy (CRDS) can be used to detect and quantitatively measure Ar_2^* in the effluent of a cold atmospheric plasma jet, the so-called kINPen-Sci. The spectroscopic features of the $5p\pi\,^3\Pi_g \leftarrow a\,^3\Sigma_u^+$ $\Delta v = 0$ and $7p\sigma\,^3\Sigma_g^+ \leftarrow a\,^3\Sigma_u^+$ ($v' - v''$) systems were clearly identified allowing unambiguous assignment to the Ar_2^* species.

Moreover, spatially resolved measurements allowed to distinguish two distinct Ar_2^* populations in the effluent of the kINPen-Sci: a Gaussian and a toroidally shaped distribution. The production mechanisms of these populations seem to differ. On the one hand, a strong correlation was found between the Gaussian Ar_2^* population and the spatial distribution of the filaments produced in the effluent of the kINPen-Sci. On the other hand, the mechanism of formation of the toroid Ar_2^* population remains unclear. However, further measurements were performed while varying the experimental conditions under which the kINPen-Sci was operated. It was found that gas flow velocity must play a major role in the formation of the toroid Ar_2^* population.

P 18.6 Wed 18:00 WW 1: HS

Durability of metal-organic-frameworks (MOFs) in non-equilibrium atmospheric pressure plasmas — •Alexander Quack[1], Hauke Rohr[2], Kerstin Sgonina[1], Norbert Stock[2,3], and Jan Benedikt[1,3] — [1]Institute of Experimental and Applied Physics, Kiel University — [2]Institute of Inorganic Chemistry, Kiel University — [3]KINSIS, Kiel University

Metal-organic-frameworks (MOFs) have a high porosity and large surface area, which gives them potential catalytic properties. Nevertheless, MOFs mostly can not withstand high temperatures and pressures, which are needed in classical catalytic reactions. Non-equilibrium atmospheric pressure plasmas provide reactive and internally excited species and allow for plasma assisted catalysis at lower temperatures. For these processes MOFs can be used as a catalyst if they withstand the plasma conditions.

We have developed a DBD reactor (21 kHz, 16 kV_{pp}) to determine the stability and suitability of different MOFs for plasma assisted catalysis. Reactive plasmas using gas mixtures based on N_2, H_2 and CO_2 gases and in-plasma treatment under externally controlled temperature up to 200 °C have been applied to several MOFs including ZIF-8, ZIF-67 and MAF-6. The plasma exhaust is analyzed for chemical products like NH_3 or CH_4 using a quadrupole mass spectrometer. Additionally, the structural and chemical stability of the MOFs is examined with methods like XRD and FTIR. The results of both measurements are combined to judge the stability and suitability of the different MOFs and their chemical components for in-plasma catalysis applications.

P 18.7 Wed 18:15 WW 1: HS

Elucidating heat transfer occurring during the interaction of a helium jet with ambient air — •Bruno Honnorat[1], Fellype do Nascimento[2], Konstantin Georgiev Kostov[2], and Torsten Gerling[1,3] — [1]ZIK plasmatis, Leibniz Institute for Plasma Science and Technology (INP), 17489 Greifswald, Germany — [2]Faculty of Engineering in Guaratinguetá, São Paulo State University-UNESP, Guaratinguetá 12516-410, Brazil — [3]Diabetes Competence Centre Karlsburg (KDK), Leibniz Institute for Plasma Science and Technology (INP), 17495 Karlsburg, Germany

One of the simplest experimental setup imaginable, which consist of injecting helium at ambient temperature (Tamb) into air at Tamb, with a flow rate of a few SLM, leads to an extraordinary phenomenon. Without plasma discharge, the gas temperature rises by several degrees Kelvin. The underlying physics of this observation remained unclear. The Dufour effect is a thermodynamic phenomenon where a concentration gradient causes heat transfer. This study quantifies the contribution of the Dufour effect on helium jet temperatures. Order-of-magnitude calculations confirm the relevance of the Dufour effect. 2D-axisymmetrical laminar CFD simulations were done with OpenFOAM for different gas flows and gas composition. A fiber optic sensor was moved in the outstream of the jet to realize a 3D map of the temperature. Beside helium, argon and nitrogen jet temperatures were measured. The results show temperature increase in the center of up to 9.4 K and a radial cooling down by 8.4 K. The confrontation of simulations and experiments shows a good agreement.

P 19: Members' Assembly

Time: Wednesday 18:45–19:45 Location: ELP 6: HS 3

All members of the Plasma Physics Division are invited to participate.

P 20: Magnetic Confinement VI

Time: Thursday 11:00–12:45 Location: ELP 6: HS 3

Invited Talk P 20.1 Thu 11:00 ELP 6: HS 3

Modelling of tungsten erosion and deposition in fusion devices — •Andreas Kirschner, Sebastijan Brezinsek, and Juri Romazanov — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany

In magnetically confined fusion devices plasma-wall interaction and resulting erosion and deposition at the wall components is a major concern due to lifetime limitations of the wall components, long-term tritium retention via co-deposition and plasma contamination by eroded impurities. Tungsten is currently the favoured wall material for future fusion devices due to comparably low sputtering and high melting point. However, as high-Z material, tungsten can lead to unacceptably high radiation in the core plasma resulting in plasma collapse. Therefore, detailed understanding of tungsten erosion, migration and redeposition is needed to minimise the net erosion of tungsten. The present contribution provides an overview of the main processes involved in tungsten erosion and migration. The role of the eroding species will be discussed in view of fuel ions (including isotope effects) and CX neutrals compared to plasma impurities and tungsten self-sputtering. Also, the contribution of intra- and inter-ELM phases to the tungsten erosion will be analysed. The importance and extent of tungsten prompt redeposition, which reduces the net erosion, will be examined. Besides more generic studies, ERO modelling in combination with experimental findings in particular from the divertor of JET will be shown.

Invited Talk P 20.2 Thu 11:30 ELP 6: HS 3

Drift flows in the island divertor of W7-X — •Carsten Killer[1], Sean Ballinger[2], Seung-Gyou Baek[2], Dario Cipciar[1], Olaf Grulke[1,3], Adrian von Stechow[1], and Jim Terry[2] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [2]MIT Plasma Science and Fusion Center, Cambridge, MA, USA — [3]Technical University of Denmark, Lyngby, Denmark

The plasma boundary in the W7-X stellarator is formed by a chain of intrinsic resonant magnetic islands that are partially intersected by the modular divertor targets. Transport of heat and particles in the island plasma is subject to the interplay of field-parallel gradients, drift flows and turbulent cross-field transport. Two new diagnostic tools, a gas-puff imaging system and a 2D array of Langmuir probes, provide insight into the role of poloidal and radial drift flows and the 3D equilibrium structure of plasma parameters. Stationary radial electric fields within the magnetic islands measured with probes are consistent with the direct imaging of poloidal drift flows with velocities of a few km/s. As parallel transport has to span several 100m of connection length to the divertor targets in W7-X, these drift flows on the island flux surfaces are a significant (and sometimes dominant) transport channel. We observe - sensitively depending on size and position of the magnetic island - multiple shear layers of opposing flows / electric fields with typical widths of just 1-2 cm. In addition, small poloidal electric fields and corresponding radial flows can be present in some scenarios. Turbulent radial transport levels are rather small, particularly when compared to the plasma edge in tokamaks.

P 20.3 Thu 12:00 ELP 6: HS 3

Edge impurity behavior and plasma distribution after boronization on W7-X — •Pei Ren[1,3], Yunfeng Liang[1,3], Yu Luo[1,3], Erhui Wang[1], Stepan Sereda[1,3], Ralph W.T. König[2], Maciej Krychowiak[2], Sebastijan Brezinsek[1], Dorothea Gradic[2], Marcin W. Jakubowski[2], Petra Kornejew[2], Olaf Neubauer[1], Arun Panaey[2], Shuai Xu[1], and The w7-x Team[1,2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany — [2]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [3]Faculty of Mathematics and Natural Science, Heinrich Heine University Düsseldorf, 40225 Düsseldorf, Germany

Controlling the impurity source and wall particle re-cycling is necessary to achieve long-pulse high-performance steady-state plasma operation on the W7-X stellarator. In the experimental campaign OP1.2b, the passively cooled test divertor unit made of graphite has been used. The low-Z impurities, oxygen and the carbon, were identified as mostly contributing to the radiated power in the initial phase of OP1.2b. With the help of boronized wall conditions, a significant reduction in impurity concentration was observed by a newly installed divertor spectroscopy endoscope on W7-X. These results demonstrate the potential of boronization for edge plasma parameter optimization and control in upcoming high-power steady-state plasma operations. In this paper, the changes in impurity content and distribution in the divertor area, as well as the related changes in the edge plasma profiles (Te, ne) before and after boronization will be discussed.

P 20.4 Thu 12:15 ELP 6: HS 3

Experimental investigation of the turbulent drive of the shear flow at the stellarator TJ-K — •Nicolas Dumérat and Mirko Ramisch — IGVP, University of Stuttgart, Germany

Drift wave turbulence has been found to be the dominant instability in the edge of the stellarator TJ-K. Naturally driven by the density gradient, drift waves play a key role in the turbulent transport of particles and energy at the edge of magnetically confined experiments. Inherently related to the coupling between density and potential fluctuations, the drift waves become unstable in case of a non-adiabatic response of the electrons to a density perturbation. Another key agent in such two- dimensional turbulence systems, the zonal flows (ZF) is tied to this cross-coupling. Its interplay with background turbulence is investigated in this work. To this end, convergent cross mapping, a method measuring the causal coupling between variables measured in the same dynamical system is used. By means of multi-dimensional Langmuir probe measurements, and conditional sampling, the plasma fluctuations can be resolved and studied from a new perspective: causality. The causal coupling between density and potential fluctuations during ZF occurrence indicates a clear causality of the density over potential while penetrating the ZF shear layer. Both fluctuations are shown to cause the growth of the ZF, following the drift wave character of the turbulence in the edge of TJ-K. Extending this analysis to wave-number space, the coupling between k_θ modes of plasma fluctuations, unveils the non-locality of the turbulence drive of the ZF as well as evidence of an inverse energy cascade.

P 20.5 Thu 12:30 ELP 6: HS 3

Estimation of turbulent diffusion by conditional variance — •Tobias Tork[1,2], Nicolas Bian[3], Felix Reimold[1], Carsten Killer[1], Wladimir Zholobenko[4], Peter Manz[2], Gustavo Grenfell[4], ASDEX Upgrade Team[4], and Wendelstein 7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, 17491 Greifswald, Germany — [2]Institue of Physics, University of Greifswald, 17489 Greifswald, Germany — [3]Department of Space Sciences and CSPAR, University of Alabama in Huntsville, USA — [4]Max-Planck-Institute for Plasma Physics, 85748 Garching, Germany

Particle and heat transport is of key importance for the optimization of magnetic confinement devices. Transport in magnetized plasmas is the result of interactions between different fields and therefore cannot be measured directly with just one observable. We conjecture estimating the turbulent diffusion coefficient by analyzing the growth of the variance conditioned on small perturbations. This transport estimate relies solely on a time series and the local spatial gradient of one measured variable in the relevant transport direction. We heuristically verify the conjecture with gyrofluid simulations and probe measurements from ASDEX Upgrade and Wendelstein 7-X. The vast majority of estimations demonstrate a considerable accuracy, typically within a factor of two of the actual transport.

P 21: Low Pressure Plasmas and their Application II

Time: Thursday 14:00–15:30 Location: ELP 6: HS 3

Invited Talk P 21.1 Thu 14:00 ELP 6: HS 3

The collisionally modified Bohm criterion: Insight or illusion? — •Ralf Peter Brinkmann — Ruhr-Universität Bochum

In low pressure plasmas, where the Debye length λ_D is much smaller than the mean free path λ, the transition from the quasineutral plasma to the electron-depleted sheath is governed by the Bohm criterion [1]: Ions exit the plasma into the sheath with a speed $v_B = \sqrt{T_e/m_i}$. (T_e denotes the electron temperature and m_i the mass of the ions.) Long-standing debates surround the application of the Bohm criterion in plasmas where the λ_D/λ ratio is not small, prompting questions about the necessity of adjusting the critical velocity.

This contribution investigates a stationary model of a plasma-sheath transition where the electrons are in Boltzmann equilibrium and the ion motion is governed by the ambipolar field, the space-charge field, collisional friction, and inertia. Within the quasi-neutral presheath, the ambipolar field prevails over friction, while in the sheath, the space charge field balances the inertia. The mathematical description of this scenario results in a differential equation for the ion speed v_i as a function of a transformed spatial coordinate q. A removable singularity at a specific ion speed resembles a *collisionally modified Bohm criterion* [2]. The presentation will explore the physical significance of this feature, examining whether it truly reflects system characteristics (*insight*) or simply arises as a mathematical artifact (*illusion*).

[1] D. Bohm, in *The Characteristics of Electrical Discharges in Magnetic Fields*, A. Guthry and R.K. Wakerling (eds.) New York (1949)

[2] R.P. Brinkmann *J. Phys. D: Appl. Phys.* **44**, 042002 (2011)

P 21.2 Thu 14:30 ELP 6: HS 3

Optically trapped microparticles in a dual-frequency capacitively coupled rf discharge — •Jessica Schleitzer, Viktor Schneider, and Holger Kersten — Institute of Experimental and Applied Physics, Christian-Albrechts-University, Kiel, Germany

Many different diagnostics can be used to measure the spatial distribution and temporal evolution of plasma parameters. Over the past decade, the concept of utilizing externally injected small microparticles as non-invasive probes, influenced by various forces and energy fluxes in plasmas, has been implemented. Especially the manipulation of microparticles by an optical tweezer is of great interest, as it enables the microprobe to be positioned in areas of the plasma that are typically inaccessible by conventional diagnostic methods, such as the plasma sheath. In this study, optically trapped microparticles in an optical tweezer are used to investigate the sheath of a dual-frequency CCRF discharge. This discharge is known, in particular, for its ability to control the ion flux and the ion energy almost separately. It is generated by a superposition of two consecutive harmonics with variable phase angle between them. The crucial parameter to measure when employing optical tweezers is the external force acting on the microprobe. This force is determined by observing the displacement of the particle within the optical trap, while the confined microprobe is moved through the plasma and sheath. On the basis of the force profiles, the strength of the electric field force in the sheath as a function of the phase angle between the two harmonics, the extent of the sheath, as well as the particle charge evolution within the sheath are determined.

P 21.3 Thu 14:45 ELP 6: HS 3

Electron dynamics in partially magnetized low pressure plasma discharges — •Lukas Vogelhuber, Denis Eremin, Kevin Köhn, Dennis Krüger, and Ralf Peter Brinkmann — Department of Electrical Engineering and Information Science, Ruhr University Bochum, D-44780, Bochum, Germany

Partially magnetized plasma discharges in magnetron configurations are versatile and offer a wide range of applications in science and industry. These applications range from space propulsion systems that utilize Hall-effect thrusters to the deposition of thin films in the physical vapor deposition technology using "high power impulse magnetron sputtering" (HiPIMS). Their magnetic field configuration is described in cylindrical geometry (r, θ, z) with the magnetic field lines in the r-z plane. In such magnetron discharges, plasma non-uniformities are observable in the form of the rotating spokes phenomenon moving in the azimuthal (θ) direction. These structures exhibit a heightened ionization rate and increased potential, altering the electron dynamics in these regions and the overall plasma dynamics. The focus of this talk is the investigation of electron dynamics of partially magnetized electrons under the influence of a simplified but realistic axisymmetric magnetic field in the r-z plane. As a key diagnostic method serves the magnetic moment in higher-order approximations to understand the energization process of electrons under such conditions. Understanding the electron trajectories in these regions influenced by the spatially inhomogeneous magnetic field may contribute to future understanding of the adiabatic and non-adiabatic energy gain of electrons.

P 21.4 Thu 15:00 ELP 6: HS 3

Atomic oxygen measurements with THz absorption spectroscopy, ps-TALIF, and CRDS: A comparison — Jente R. Wubs[1], Uwe Macherius[1], Andy S. C. Nave[1], Laurent Invernizzi[2], Kristaq Gazeli[2], Guillaume Lombardi[2], Xiang Lü[3], Lutz Schrottke[3], Klaus-Dieter Weltmann[1], and •Jean-Pierre H. van Helden[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Laboratoire des Sciences des Procédés et des Matériaux (LSPM), CNRS, Université Sorbonne Paris Nord, Villetaneuse, France — [3]Paul-Drude-Institut für Festkörperelektronik, Leibniz-Institut im Forschungsverbund Berlin e.V., Berlin, Germany

Terahertz (THz) absorption spectroscopy with quantum cascade lasers (QCLs) has recently been developed and implemented as a new diagnostic technique for investigating ground state atomic oxygen densities in plasmas. It is based on the detection of the $^3P_1 \leftarrow {}^3P_2$ fine structure transition at approximately 4.75 THz (i.e., approximately 63 μm). In this contribution, we will compare the results obtained with this method with those obtained by picosecond two-photon absorption laser-induced fluorescence (ps-TALIF) at 226 nm, as this is currently the most established method for measuring atomic oxygen densities, and cavity ring-down spectroscopy (CRDS) using the forbidden $^1D_2 \leftarrow {}^3P_2$ transition at approximately 630 nm. All measurements were performed on the same low-pressure capacitively-coupled radio frequency plasma generated in pure oxygen, for a variation of the applied power and gas pressure.

P 21.5 Thu 15:15 ELP 6: HS 3

Investigation of geometric asymmetric electronegative capacitively coupled radio frequency discharges using a hybrid PIC/MCC simulation — •Katharina Noesges, Maximilian Klich, Sebastian Wilczek, and Thomas Mussenbrock — Ruhr University Bochum, Germany

Capacitively coupled radio frequency (CCRF) discharges are pivotal in numerous etching processes in the semiconductor industry. Operating at low pressures in the range of a few Pascals and requiring voltages of about hundreds of volts, these discharges facilitate anisotropic ion bombardment essential for precision etching. Carbon tetrafluoride (CF_4) discharges are significant in this context. These discharges are investigated using a one-dimensional hybrid particle-in-Cell/Monte Carlo collisions (PIC/MCC) simulation in the low-pressure regime (p = 6.67 Pa), assuming a spherical geometry. This approach considers the electrons kinetically and simultaneously utilizes the drift-diffusion approximation to solve a continuity equation; one each for the ion species. This work examines the influence of varying electrode gap sizes and applied voltages, demonstrating that the electronegativity strongly affects the electron dynamics. Because of the geometric asymmetry, a strong electric field reversal during the sheath collapsing phase accelerates many electrons toward the powered electrode. A spatially and temporally resolved analysis of the high-energy electron density reveals a sharp beam structure formed by electrons near the electrode. This beam structure is an accumulation of electrons accelerated by the expanding boundary sheath towards the grounded electrode.

P 22: Plasma Wall Interaction II/HEPP VII

Time: Thursday 14:00–15:50 Location: ELP 6: HS 4

Invited Talk P 22.1 Thu 14:00 ELP 6: HS 4

First Results of Laser-Induced Desorption - Quadrupole Mass Spectrometry (LID-QMS) at JET — •Miroslaw Zlobinski[1], Gennady Sergienko[1], Ionut Jepu[2,3], and et al[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]United Kingdom Atomic Energy Authority, Culham Centre for Fusion Energy, Culham Science Centre, OX14 3DB Abingdon, UK — [3]National Institute for Laser, Plasma and Radiation Physics, Magurele, Romania

Monitoring the tritium retention at the walls of fusion devices is important due to radiation safety, the fuel cycle and material degradation. In 2023 a new fuel retention diagnostic has been installed on JET and the first results are presented here. LID-QMS allows direct in situ measurements of the fuel inventory of plasma facing components. The diagnostic desorbs the retained gases by heating a 3 mm diameter spot on the wall using a 1 ms long laser pulse and detects them by Quadrupole Mass Spectrometry (QMS). The successful detection of tritium retention in the tritium campaign at JET has been demonstrated. Thus, this diagnostic is already foreseen as tritium monitor diagnostic for ITER.

Invited Talk P 22.2 Thu 14:30 ELP 6: HS 4

Deuterium retention analysis in pre-damaged tungsten using laser-induced breakdown spectroscopy — •Erik Wüst[1,2], Christoph Kawan[1,2], Sebastijan Brezinsek[1,2], and Thomas Schwarz-Selinger[3] — [1]Forschungszentrum Jülich GmbH, Institut für Energie und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]Faculty of Mathematics and Natural Sciences, Heinrich Heine University Düsseldorf, 40225 Düsseldorf, Gernany — [3]Max-Planck-Institut für Plasmaphysik, D-85748 Garching, Germany

Energetic neutrons are a product of the DT-fusion reaction and can induce material damage in Plasma-Facing Components (PFCs) in future nuclear fusion reactors. The damage increases with time and causes enhanced fuel, tritium (T) and deuterium (D), retention in tungsten (W) PFCs, which imposes issues for safety and closure of the T cycle in the fusion plant. Laser-Induced Breakdown Spectroscopy (LIBS) is a potential in-situ technique to monitor tritium inventory in W PFCs. LIBS on pre-damaged W (W-ions, 10.8 MeV, 0.23 dpa) with D contents of 0.1-1% owing to D plasma exposure in PlaQ and subsequent outgasing, was carried out to measure the depth-resolved fuel content in a laboratory set-up. LIBS was done using an Nd:YAG laser (35 ps, 355 nm, 20 mJ), ablating 15 nm per laser pulse. D was detected up to a depth of 1.3μm by observing Balmer α line from the laser-induced plasma plume. The depth profile and total amount was compared with nuclear reaction analysis (NRA) and showed good agreement. Deviations can only be observed for the first ablation cycle near the surface.

P 22.3 Thu 15:00 ELP 6: HS 4

Ion-driven deuterium permeation in tungsten-heavy-alloy-like multi-layer membranes — •Philipp Sand[1,2] and Armin Manhard[1] — [1]Max-Planck Institut für Plasmaphysik, 85748 Garching, Germany — [2]Techn. Univ. München, 85748 Garching, Germany

Tungsten heavy alloy (97W-2Ni-1Fe, %wt., THA) is a possible candidate as plasma-facing material in future nuclear fusion devices. It exhibits a similar heat conductance at high temperature and sputter yield as pure W, whilst showing an improved ductility [1]. Hydrogen isotope (HI) retention behaviour [2] was also shown to be favourable, which was attributed to the microstructure of this dual phase material: Upon plasma loading, the percolating matrix phase provides fast diffusion paths to vacuum [3], while W domains remain at low HI concentrations due to a low HI solubility. To predict HI uptake of THA under reactor relevant conditions, the parameters of HI transport across respective phase boundaries must be quantified. An ion-driven permeation experiment was benchmarked using pure W samples irradiated with of 170 eV/D at $5x10^{19}$ D/m^{2}s between 650 K and 900 K. D transport across the interface was studied at the same conditions in both directions using W substrates coated with matrix-like alloy on one side. The influence of surface oxides on permeation is investigated on both sides. It is confirmed that uptake from matrix into W is strongly suppressed while no significant barrier was observed for HI transport from W into matrix. [1] R. Neu, et al., Fusion Eng. Des. 124 (2017) 450-454, [2] H. Maier, et al., J. Nucl. Mater 18 (2019) 245-259, [3] A. Manhard, et al., Nucl. Mater 36 (2023) 101498

P 22.4 Thu 15:25 ELP 6: HS 4

Characterization of ionization pressure gauges for magnetic confinement fusion devices — •Bartholomäus Jagielski — Max Planck Institut für Plasmaphysik, Greifswald, Germany

This work describes advanced gas pressure gauges designed for use in strong magnetic fields during plasma operation in fusion devices. The performance

of novel cathode designs and emitter materials, including LaB_6, ZrC, HfC, and TW, were systematically studied in terms of sensitivity and reliability in different gases. The study presents the setup of a unique laboratory featuring a high field magnet, enabling experiments with adjustable pressures and magnetic fields up to 6 T.
Conditioning and stability of the emitters were explored in a magnetic field up to 6 T, revealing fluctuations in the electron and ion current, which have been studied in more detail using simulations, suggesting the existence of virtual cathodes within the potential well, affecting the potential distribution. Thermal studies using pyrometers and an infrared camera, alongside heat transfer analysis with Ansys, identified optimal LaB_6 emitter conditions. Additionally, Energy-Dispersive X-ray Surface Spectroscopy provided evidence of surface oxidation and emitter material emission under non-optimal conditions.
The optimized potential distribution and operating ranges for various cathodes were determined, achieving record values for a stable operation in a strong magnetic field. The results showcase the suitability of LaB_6 emitters in Wendelstein 7-X and for advancing fusion research, particularly in the context of large-scale projects like ITER and DEMO.

P 23: Complex Plasmas and Dusty Plasmas II

Time: Thursday 16:30–18:00 Location: ELP 6: HS 3

Invited Talk P 23.1 Thu 16:30 ELP 6: HS 3
Characterizing electron depleted, nanodusty plasmas recent developments and future outlooks — •Andreas Petersen and Franko Greiner — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany
Although astrophysical issues and research on fundamental questions in the field of dusty plasmas remain topical, the synthesis of nanoparticles with selectable properties has become increasingly popular in recent years. Nanodusty plasmas can be characterized in various ways, but determining multiple parameters simultaneously can be problematic. The analysis of dust density waves enables a comprehensive characterization of all components of complex plasmas by modelling the two-stream instability that occurs in dusty plasmas. The dust density wave diagnostic (DDW-D) is presented and its results are considered in the context of other characterization methods. Additionally, new perspectives are discussed.

P 23.2 Thu 17:00 ELP 6: HS 3
The asynchronous melting process of binary mixtures — •Yang Liu and Dietmar Block — IEAP, Christian-Albrechts-Universität, D-24098 Kiel, Germany
Melting processes in binary mixtures are compared to their single-component counterparts a sophisticated task. Already the collective crystalline behavior within the mixture is poorly understood [1]. The glass-like formation of irregular and stable structures in the mixing region of binary mixtures does not allow to employ methods based on empirical rules derived from topological structures to describe lattice melting issues. This contribution utilizes the local relative interparticle fluctuation (IDF) method to investigate the melting process of finite binary monolayers and its dependence on component concentrations and size differences [2]. Our results indicate that, unlike monodisperse systems, the two components of binary mixtures exhibit asynchronous melting. The individual melting points strongly depend on particle size. Especially the hopping motion of particles, i.e. the fast transition of a particle from a local potential minimum to a neighboring lattice point, is studied in detail. Based on six fundamental particle arrangements and related escape models, i.e. calculations of the energy barriers, the melting process in binary mixtures is discussed.
[1] G. Gompper and M. Schick, in Soft Matter, Complex Colloidal Suspensions Vol. 2 (Wiley, Weinheim, 2006).
[2] V. S. Nikolaev and A. V. Timofeev, Physics of Plasmas, 2021, 28(3): 033704.

P 23.3 Thu 17:15 ELP 6: HS 3
Mach cones in Dusty Plasmas under Weigthlessness — •Daniel Maier, Christina Knapek, André Melzer, Daniel Mohr, and Stefan Schütt — Institute of Physics, University of Greifswald, Germany
The concept of the Mach cone is well known from objects moving through air when the velocity of the moving object is higher than the speed of sound. But theoretically a Mach cone can appear in every environment if the velocity of a moving object is higher than the characteristic wave velocity of the surrounding medium.
Accordingly this phenomenon has also be seen in dusty plasmas where micrometer sized particles are added into a low temperature plasma creating a complex system. If now a single particle or a bigger agglomerate of many particles moves through the plasma at a sufficient speed a Mach cone like structure can be observed.
During our last experimental campaign with dusty plasma under weightlessness using a capacitive coupled RF - discharge Mach cone structures caused by particle agglomerates travelling through the plasma were visible. In this contribution first results on the investigations of these Mach cone structures observed with a stereoscopic camera system will be shown.
This project has been funded under the DLR grant 50WM2161.

P 23.4 Thu 17:30 ELP 6: HS 3
Agglomeration, structure and dynamics of binary dust systems — Baoxia Li[1], Yang Liu[2], Hanyu Tang[2], Xiaojiang Tang[1], Eric Guo[2], and •Feng Huang[2] — [1]College of Information and Electrical Engineering, China Agricultural University, Beijing 100083, China — [2]College of Science, China Agricultural University, Beijing 100083, China
Agglomeration and spatial distribution of a binary dusty system formed by dust particles with different sizes were experimentally studied. The agglomeration process of dust particles was characterized by direct micrograph image and the evolution of scattered light as time. The fractal dimension and average particle area in the steady state changing in space were used to show the spatial distribution of the binary dusty system. The effects of temperature and dust particle number on the structure and dynamics of a binary complex plasma system are investigated through two-dimensional (2D) Langevin dynamics simulation. Two kinds of dust particles with different masses are considered in the binary complex system. The particle distribution, Voronoi structure diagram and pair correlation function are used to characterize the system structure. The evolution process of kinetic energy, speed and trajectories of binary particles as time are used to study the dynamical characteristics of the system. The investigations indicate that the structures and dynamics of the binary complex plasma can be obviously affected by system temperature and particle number. This study is helpful for the application of phase separation in practical plasma environment related to different particle species.

P 23.5 Thu 17:45 ELP 6: HS 3
The low-energy electron sticking coefficient of dielectric materials — •Armin Mengel and Franko Greiner — Institute of Experimental and Applied Physics, Kiel University
An important property of surfaces is their interaction with electrons, which often depends on the electron energy. In particular, the electron sticking coefficient affects the plasma-surface interaction, amongst others, and has an impact on dust charging in a plasma. While it can be measured well using electron beams for conducting surfaces or at high energies, this conventional approach fails for dielectric materials at low energies ($< 10\,\mathrm{eV}$). By introducing a micrometer-sized grain of dielectric material into a low-pressure discharge, we can investigate the interaction of the dielectric surface with the ambient electrons of the plasma ($T_e \approx 2...5\,\mathrm{eV}$). Using a relative measurement scheme employing electric particle excitation methods like PRRM or PEOM as well as long-distance microscopy, the sticking coefficient of the dielectric material can then be determined in relation to particles with a conducting surface.

P 24: Codes and Modeling II

Time: Thursday 16:30–17:45 Location: ELP 6: HS 4

Invited Talk P 24.1 Thu 16:30 ELP 6: HS 4
Electron surface scattering kernel for plasma simulations — •Franz Xaver Bronold and Felix Willert — Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany
Applying the invariant embedding principle, originally developed for the calculation of the albedo of planetary and stellar atmospheres, to secondary electron emission from surfaces, we construct an electron surface scattering kernel to be used in the boundary condition for the electron Boltzmann equation of a simulation of a plasma confined by a solid. In principle, the kernel takes the microphysics responsible for electron emission and backscattering from the plasma-solid interface fully into account. To demonstrate the potential of the approach, we apply it to a polycrystalline silicon surface using a semiempirical jellium-randium model for the solid. It contains the Schottky barrier, impact ionization across the band gap as well as scattering on phonons, defects, and ion cores. The

emission yields we deduce from the kernel, which in turn is obtained by solving the nonlinear embedding equation for the electron backscattering function without approximate decoupling of the angle and energy variables, agree well enough with measured data to support using the kernel in the boundary condition of the electron Boltzmann equation of a simulation describing a plasma in contact with a polycrystalline silicon surface. [1] F. X. Bronold and F. Willert, arXiv:2309.00534.

P 24.2 Thu 17:00 ELP 6: HS 4

Unveiling the non-linear Zeeman effect in isotopes of krypton and xenon at the linear plasma device PSI-2 — •Marc Sackers[1], Oleksandr Marchuk[1], D Dipti[2], Stephan Ertmer[1], Yuri Ralchenko[3], and Arkadi Kreter[1] — [1]Forschungszentrum Jülich GmbH - Institut für Energie- und Klimaforschung - Plasma- physik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]International Atomic Energy Agency, Vienna, Austria — [3]National Institute of Standards and Technology - Atomic Spec- troscopy Group, 20899 Gaithersburg, USA

Isotopic broadening alters the line shape of atomic transitions and contributes noticeably to the laser absorption spectra of neutral Kr and Xe investigated at the linear plasma device PSI-2. Of high interest are the odd-numbered isotopes having a nonzero nuclear spin resulting in the hyperfine interaction. The main challenge in analyzing such isotopes is that the hyperfine and Zeeman terms can be of the same order of magnitudes, rendering conventional weak field and strong approximation formulas inadequate for analysis.

The magnetic field at PSI-2 of < 90 mT creates such conditions for the Kr I 760.4 nm, Kr I 785.7 nm, and Xe I 764.4 nm lines. This contribution shows how to correctly account for the Zeeman effect by using a Hamiltonian containing both hyperfine and Zeeman interaction terms as the perturber. Standard atomic physics procedures allow us to derive the energy eigenvalues and relative intensities. Crucially, the theoretical analysis is backed by experimental data, confirming the validity of the methodology in modeling observed spectral features.

P 24.3 Thu 17:15 ELP 6: HS 4

Modelling study of the effects of gas temperature on self-pulsing spark discharges in atmospheric-pressure argon — •Aleksandar P. Jovanović[1], Hans Höft[1], Detlef Loffhagen[1], Markus M. Becker[1], and Torsten Gerling[1,2,3] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Kompetenzzentrum Diabetes Karlsburg (KDK), Karlsburg, Germany — [3]ZIK plasmatis, Greifswald, Germany

Self-pulsing discharges, such as transient sparks, are commonly used to generate non-thermal atmospheric pressure plasmas. Although the self-pulsing prevents excessive gas heating and thermalisation of the discharge, gas might still heat to some extent. The increase in gas temperature could alter the discharge stability and the characteristics of the plasma, such as mode transitions and the excitation of ion acoustic waves. In the present contribution, the self-pulsing discharges in argon at atmospheric pressure are analysed by means of a fluid-Poisson model coupled with a circuit equation. The effects of gas heating on the discharges and self-pulsing modes are investigated by treating the gas temperature as a parameter in the model and by coupling a heat equation for the background gas to the fluid-Poisson model. The modelling results show that higher gas temperatures affect both the frequency and the periodicity of the discharges, noting that the change in gas density has the most significant influence, while temperature-dependent collisional processes play a minor role.

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P 24.4 Thu 17:30 ELP 6: HS 4

The Poisson-Boltzmann equation and quasi-neutrality assumption in the presence of electron number perturbations — •Kevin Köhn[1], Lukas Vogelhuber[1], Dennis Krüger[1], Denis Eremin[1], Liang Xu[2], and Ralf Peter Brinkmann[1] — [1]Ruhr University Bochum, Germany — [2]Soochow University, China

The Poisson-Boltzmann (PB) equation is a 3D elliptical partial differential equation used to determine the electric potential in a plasma chamber with appropriate boundary conditions. Solutions of the PB equation usually exhibit a typical bulk-sheath structure, with strong gradients in the sheath and approximately constant potential in the quasi-neutral bulk. In recent years, much research in the field of partially magnetized discharges, e.g. high power impulse magnetron sputtering, was dedicated to the so-called spoke phenomenon. These spokes can be characterized as self-emerging rotating structures of increased ionization, density and potential that rotate in the ExB direction. As these structures clearly break the discharge symmetry, researchers suggested that in order to fully capture the plasma potential dynamics of such a discharge the quasi-neutrality assumption in the bulk must be dropped and the full 3D PB equation would be required. In this talk, we present investigations of the PB equation in simple geometry with small and large scale periodic electron number perturbations to find a criterion if the quasi-neutrality assumption holds based on pertubation scale, bulk length and Debye length.

P 25: Poster III

Time: Thursday 16:30–18:30 Location: ELP 6: Foyer

P 25.1 Thu 16:30 ELP 6: Foyer

Optical damage threshold of plasma density gratings — •Sophie Opara and Götz Lehmann — Heinrich-Heine-Universität, Düsseldorf

Plasma density gratings are periodic structures allowing the manipulation of high-power laser pulses with intensities far beyond the damage threshold level of solid state material. Such structures can be used as e.g. Bragg-type mirrors, polarizers, wave-plates and holographic lenses. The gratings are driven by beating laser pulses in underdense plasma and exist on the timescale of tens of picoseconds, i.e. sufficiently long to manipulate high-power femto-second pulses. Since they can be re-created for every shot of the high-intensity pulse, they are usually considered as damageless optics.

However, the optical properties of density gratings depend on their periodic structure. Period and modulation amplitude determine their transmissive and reflective properties. Sufficiently strong laser pulses can manipulate the density distribution via their ponderomotive force and thus change the optical properties. The presented work aims to identify the intensity limit at which the gratings can not be anymore considered static and describe the underlying physical processes going along with the degradation of their structure.

P 25.2 Thu 16:30 ELP 6: Foyer

Uncertainty Quantification for Magnetohydrodynamic Equilibrium Reconstruction: A data driven approach — •Robert Köberl[1,2], Robert Babin[3], and Christopher G. Albert[3] — [1]MPI for Plasma Physics, Garching, Germany — [2]CIT, TU Munich, Garch- ing, Germany — [3]Fusion@ÖAW, ITPcp, TU Graz, Graz, Austria

We report on progress towards a probabilistic framework for uncertainty quantification and propagation in analysis and numerical modeling of physics in magnetically confined plasmas in the stellarator configuration. A frequent starting point in this process is the calculation of a magnetohydrodynamic equilibrium from plasma profiles. Profiles and therefore the equilibrium are typically reconstructed from experimental data. What sets equilibrium reconstruction apart from usual inverse problems is that profiles are given as functions over a magnetic flux derived from the magnetic field, rather than spatial coordinates. This makes it a fixed-point problem that is traditionally left inconsistent or solved iteratively in a least-squares sense. The aim here is towards a straightforward and transparent process to quantify and propagate uncertainties and their correlations for function-valued fields and profiles in this setting. We propose a Bayesian inference framework that utilizes a low dimensional prior distribution of equilibria, constructed with principal component analysis. Additionally, neural-network- and polynomial-regression-surrogates of the forward model for synthetic diagnostics are trained. This enables faster sam- pling when approximating the posterior distribution of equilibria via Markov chain Monte Carlo sampling.

P 25.3 Thu 16:30 ELP 6: Foyer

Adding fluid neutrals to the gyrokinetic turbulence code GENE-X — •Sabine Ogier-Collin, Philipp Ulbl, Wladimir Zholobenko, and Frank Jenko — Max Planck Institute for Plasma Physiscs, Garching bei München, Germany.

Key objectives in the design of future magnetic confinement fusion reactors are the management of heat and particle exhaust to the wall, as well as optimal core confinement. Understanding the turbulent transport at the boundaries of the confined region, i.e. the plasma edge and the scrape-off layer (SOL), is critical in assessing these objectives. In addition to the main plasma, several ionic impurity species along with molecules and neutral atoms (neutrals) are present, especially in the SOL, and interact with the plasma through a complex set of collision processes. This has several non-negligible effects on the plasma parameters and confinement, e.g. changes in the radial plasma profiles and particle transport across the last closed flux surface.

GENE-X is a gyrokinetic code dedicated to the study of the edge and SOL turbulence in realistic geometries. To improve its predictive capabilities, a neutrals model and the plasma-neutrals interactions are added. The neutrals are evolved using a pressure-diffusion equation and interact with the gyrokinetic plasma through ionisation, recombination and charge exchange channels. The evolution of neutrals has been implemented using a 4th order central finite difference scheme. In a verification study, the order of accuracy has been recovered in multiple geometries including slab, circular and s-alpha. This allows for first test simulations in realistic geometries.

P 25.4 Thu 16:30 ELP 6: Foyer

structure-preserving hybrid code, STRUPHY: energy-conserving hybrid MHD-driftkinetic models. — •Byung Kyu Na[1,2], Stefan Possanner[1], Xin Wang[1], Dominik Bell[2], Yingzhe Li[1], and Nathan Marín[1,2] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technical University of Munich, Garching, Germany

A Python package STRUPHY (STRUcture-Preserving HYbrid codes) features a collection of PDE solvers based on Geometric finite element method (FEEC) and Particle-in-cell method (PIC). One of the main applications of the STRUPHY is a simulation of hybrid MHD-kinetic systems in curved three-dimensional spaces where the bulk plasma is treated as a MHD fluid and energetic particles(EPs) are described kinetically. We introduce energy-conserving hybrid MHD-driftkinetic models which were newly implemented in STRUPHY. Existing hybrid MHD-kinetic models often suffer from not conserving the total energy, especially when reduced kinetic models are used to describe EPs such as driftkinetic or gyrokinetic. However, this property was recently recovered by adding additional terms derived from variational principles. The investigation of the conservation laws on the discrete level will be considered with the preliminary results of the ITPA benchmark case.

P 25.5 Thu 16:30 ELP 6: Foyer

Numerical methods for stellarator simulations in BOUT++ — •David Bold[1], Brendan Shanahan[1], Jessica Bold[2], and Ben Dudson[3] — [1]Max Plank Institute for Plasma Physics, Greifswald, Germany — [2]University of Greifswald, Greifswald, Germany — [3]Lawrence Livermore National Laboratory, Livermore, California, USA

There is a significant need for reliable modelling of the scrape-off layer of fusion devices, which is challenging for stellarators due to the complex geometry involved. As field aligned approaches are challenging, the Flux Coorinate Independent (FCI) method is often employed.

In the FCI grid generator, Zoidberg, the fidelity to the experimental geometry has been improved, and several improvements have been made to ensure the grid is feasible even with such challenging conditions. At the same time options have been added to reduce the fidelity and improve runtime.

For the BOUT++ framework, a new finite volume operator has been implemented that does not fail in the case of non differentiable contours. The parallel FCI operators have also been rewritten to allow MPI parallelisation of the perpendicular slices, in addition to OpenMP. Scaling will be presented, showing the improved scaling using the new PETSc-based operators. The parallel boundary conditions generally rely on points within the domain to extrapolate into the boundary. However, this breaks down in the case of short connection lengths, where a field line is outside of the domain in the previous and next plane. In this case a lower order scheme is used automatically.

P 25.6 Thu 16:30 ELP 6: Foyer

Linear extended mhd equations in struphy — •Nathan Marin[1,2] and Stefan Possanner[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technische Universität München, Garching, Germany

In this project, a Finite Elements Exterior Calculus discretization for the linearized homogeneous extended mhd equations is developed and implemented to obtain a solver of arbitrary degree of convergence that simulates plasma behavior. The discretization has been implemented as the newly available LinearExtendedMHD model in struphy ('A python package for energetic particles in plasma, developed since 2019 at Max Planck Institute for Plasma Physics in the Numerical Methods for Plasma Physics division'. Look at https://struphy.pages.mpcdf.de/struphy/index.html for more information about struphy).

The discretization was devised to preserve critical physical quantities that the continuous model conserves (magnetic helicity, energy, and magnetic field's divergence) so the simulation adequately describes the relevant physical phenomena. Finally, the analytical dispersion relation for the extended mhd equation was derived to use it as a test case for the code.

P 25.7 Thu 16:30 ELP 6: Foyer

The STØR experiment - a spherical toroidal magnetic confinement concept applied as a radiation source — •Nils Fahrenkamp, Sebastian Haag, Stefan Knauer, and Peter Manz — Institute of Physics, University of Greifswald, Greifswald, Germany

Extreme Ultraviolet (EUV) lithography is a crucial technology nowadays. EUV light is used to project high-resolution patterns onto silicon wafers, enabling the production of smaller and more powerful microchips. At the desired wavelength lasers are no longer available as light sources, so plasma sources have to be used. They need to generate extremely high power emitted in a very narrow spectral band around 13.5 nm (±0.135 nm, the so-called in-band) in a small source volume necessary for efficient radiation. Laser-produced plasmas (LPPs) prevailed because the discharge-produced plasmas (DPPs) did not achieve the desired parameters of $n_e \sim 10^{24}$ m^{-3} and $T_e \sim 30$ eV. Current state-of-the-art sources use laser irradiated tin (Sn) droplets as emitter because it has strong in-band emission. But a single unit weighs over 180 tons, consumes more than 1 MW electrical power and costs more than 100 million dollars. The inevitable high cost of LPPs means that low-cost or table-top systems will continue to rely on DPPs. Alternative magnetic confinement concepts are particularly well suited as radiation sources, as they contribute to reducing costs and improving accessibility for various research institutions. We present here an experimental setup allowing for magnetically confined compact plasma tori without external toroidal and poloidal magnets. These are ideal properties for a radiation source.

P 25.8 Thu 16:30 ELP 6: Foyer

Overview of mode observations at the Wendelstein 7-X stellarator — •Kian Rahbarnia[1], Ksenia Aleynikova[1], Tamara Andreeva[1], Jan-Peter Bähner[2], Charlotte Büschel[1], Christian Brandt[1], Neha Chaudhary[1], Dario Cipciar[1], Mykola Dreval[3], Carsten Killer[1], Ralf Kleiber[1], Axel Könies[1], Andreas Krämer-Flecken[4], Sara Vaz Mendes[1], Christoph Slaby[1], Adrian von Stechow[1], Henning Thomsen[1], Gavin Weir[1], and Wendelstein 7-X[1] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]MIT Plasma Science and Fusion Center, Cambridge, MA, USA — [3]Kharkov Institute of Physics and Technology, Kharkov, Ukraine — [4]Forschungszentrum Jülich GmbH, Jülich, Germany

During the recent operational phase OP2.1 at the optimized stellarator Wendelstein 7-X in Greifswald, Germany, a large variety of mode activity in a broad frequency range from about 1-1000 kHz has been observed. This work provides an overview of measurements, which are partly accompanied by theoretical calculations. The focus lays on Alfvénic activity around 200 kHz and potentially fast ion driven modes in plasmas heated by neutral beam injection or ion cyclotron resonance heating. Additionally observations of trapped electron modes are discussed. Mode activity around 10-50 kHz, which is specifically observed in higher beta plasmas, is related to theoretically predicted kinetic ballooning modes and finally low frequency island localized modes around 1 kHz are investigated. Both last aspects might have impact on confinement properties in future highest beta plasmas.

P 25.9 Thu 16:30 ELP 6: Foyer

Development of advanced accumulation techniques for a multi-cell Penning-Malmberg trap — •Martin Singer[1,2], Eve Stenson[3], and Lutz Schweikhard[2] — [1]Institut für Plasma Physik, Greifswald, Germany — [2]Institut für Physik, Universität Greifswald, Germany — [3]Institut für Plasma Physik, Garching, Germany

Penning-Malmberg (PM) traps are employed to accumulate large quantities of charged particles. However, this accumulation in single PM traps is often limited by the space charge. The multi-cell PM trap (MCT) avoids large space charges by distributing the particles into many traps [1]. These small-diameter storage traps are arranged on and off axis next to a large-diameter master trap that is used to catch and bunch of charged particles and to transfer them to the storage traps. The APEX ("A Positron Electron eXperimet") collaboration plans to use the MCT to accumulate unprecedented amounts of positrons. Subsequently, these positrons will be used to form the first confined electron-positron plasma either in the magnetic field of a levitating dipole magnet, or in an optimized tabletop stellarator [2]. This contribution will detail the latest MCT developments, and the techniques developed for the off-axis transfer [3]. We aim for the accumulation of 3×10^9 positrons in each off-axis cell. This will function as a proof of principle for the MCT concept and allow for the accumulation of up to 1×10^{10} positrons, the number needed for the positron-electron plasma creation. [1] D.R. Wittemann, et al. J. Plasma Phys. 89.4 (2023). [2] M.R. Stoneking, et al. J. Plasma Phys. 86.6 (2020). [3] M. Singer, et al. J. Plasma Phys. 89.5 (2023).

P 25.10 Thu 16:30 ELP 6: Foyer

Dynamics of impurity injection events in Wendelstein 7-X stellarator analysed by tomography — •Henning Thomsen, Thomas Wegner, Christian Brandt, Charlotte Büschel, Sara Mendes, Kian Rahbarnia, and W7-X team — Max-Planck Institute for Plasma Physics, Greifswald, Germany

The soft-X-ray tomography system [1] installed in the Wendelstein 7-X stellarator is capable of tracing the spatio-temporal dynamics of plasma perturbations in a poloidal plasma cross-section. The diagnostic has more than 300 lines of sight and a high bandwidth of more than 100 kHz. In this contribution we analyse the dynamics of a laser blow-off injection [2] of a high-Z impurity species into the plasma by means of tomographic inversion of the line-integrated soft-X-ray data. A singular value decomposition of the time sequence of tomographic images clearly shows the poloidal motion of the perturbation following the injection. We find that the propagation is following the direction of the ExB-rotation of the core plasma (the radial electric field in stellarators is predominantly governed by neoclassical transport processes). For sufficiently small plasma perturbation, this technique could be used to experimentally constrain the estimation of the radial electric field profile.

[1] C Brandt et al., Plasma Phys. Control. Fusion 62 (2020) 035010

[2] Th. Wegner et al., Rev. Sci. Instrum. 89 (2018) 073505

P 25.11 Thu 16:30 ELP 6: Foyer

Development of real-time control scheme for power exhaust via impurity seeding in Wendelstein 7-X — •Anastasios Tsikouras[1,3], Felix Reimold[3], Gabriele Partesotti[3], Matthijs van Berkel[2], Jesse T.W. Koenders[1,2], Victoria Winters[3], Valeria Perseo[3], Daihong Zhang[3], Marco de Baar[1,2], and W7-X Team[3] — [1]Eindhoven University of Technology, Eindhoven, Netherlands — [2]DIFFER, Eindhoven, Netherlands — [3]Max Planck Institute of Plasma Physics, Greifswald, Germany

In Wendelstein 7-X (W7-X) real-time control of operational parameters is crucial for the performance of the stellarator. The radiated power is such an operational parameter that can be controlled with injection of gaseous impurities (seeding). This contribution identifies the seeding-radiation dynamics, from the latest W7-X experiments, and optimizes controller parameters for specific operating conditions.

In W7-X, bolometers are used for calculating the total radiated power, which is assessed for control purposes. First, the seeding-radiation response is identified and modelled, by analysing square wave seeding pulses. Then simulations on the dynamics models, show the response of the system and its limits. An error of less than 1% in under 200 milliseconds in tracking a unit step reference is possible for optimized controller parameters, whereas different operational conditions require different control parameters to achieve optimal performance in terms of tracking accuracy and speed. Finally, we outline proposals for the input signal in perturbative experiments to accurately identify the W7-X radiation dynamics in future experiments.

P 25.12 Thu 16:30 ELP 6: Foyer

Theoretical investigation of impurity turbulent transport in W7-X — •Hugo Isaac Cu Castillo[1], Alejandro Bañón Navarro[1], Thilo Romba[2], Felix Reimold[2], Oliver Ford[2], Sebastian Bannmann[2], Péter Zsolt Pölöskei[2], Markus Wappl[2], Adrian von Stechow[2], Frank Jenko[1], and the W7-X team[2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

The presence of impurities in the core of fusion plasmas has a detrimental effect on the overall plasma performance via fuel dilution and core cooling through increased radiative losses. While steepened density profiles of the main plasma species, i.e. electrons and hydrogen ions, correlate with high-performance plasmas [1], these scenarios also lead to an undesired accumulation of impurities within the core. Previous experiments conducted under these conditions in the stellarator Wendelstein 7-X (W7-X) appear to indicate that for $\rho < 0.5$, impurity transport can be fully described by neoclassical transport in contrast to the turbulence-dominated transport observed for the main plasma species [2]. This work investigates the physical mechanism for this suppression of turbulent transport of impurities under steep density gradients of the main species using the gyrokinetic code GENE.

[1] S.A. Bozhenkov, et al. Nuclear Fusion 2020, 60: 066011
[2] T. Romba, et al. Nuclear Fusion 2023, 63: 076023

P 25.13 Thu 16:30 ELP 6: Foyer

Plasma termination due to tungsten TESPEL injection in large stellarators — •Hjördis Bouvain[1,2], Andreas Dinklage[1], Naoki Tamura[3], Hiroshi Kasahara[3], Kieran McCarthy[4], Daniel Medina-Roque[4], Hiroe Igami[3], and The LHD Experiment Team[3] — [1]Max-Planck-Institut for Plasma Physics, Greifswald, Germany — [2]Universität Greifswald, Greifswald, Germany — [3]National Institute for Fusion Science, Toki, Japan — [4]Centre for Energy, Environmental and Technical Research, Madrid, Spain

Tungsten is being assessed to replace carbon as material for plasma-facing components in W7-X. In stellarators, it is assumed that exposure to massive amounts of tungsten may lead to thermal quenches but not to current quenches like in tokamaks. Still, a thermal quench releases energy rapidly and localised heat loads may affect the integrity of the plasma facing components. For first quantitative assessments of the impact of thermal quenches in helical devices, the plasma response to massive tungsten TESPEL injections ultimately leading to plasma termination was analysed in LHD. Above a threshold, plasma termination within one energy confinement time is due to the formation of cold fronts propagating from the injection point inwards to the plasma centre. We could show that the application of additional ECRH mitigates the termination process.

P 25.14 Thu 16:30 ELP 6: Foyer

Reduction of maximum gyrokinetic instability growth in maximum-J stellarators — •Paul Costello, Gabriel G. Plunk, and Per Helander — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald, Germany

For the last decade, it has been known that the growth of many local gyrokinetic instabilities, which cause turbulence, is greatly reduced in stellarators which possess the maximum-J property [1]. This a result from linear, normal mode theory.

Here, we show that this benefit of the maximum-J property is also reproduced by gyrokinetic optimal mode theory [2,3]. In this analysis, upper bounds on the maximum allowable growth of instabilities are derived by finding the perturbations which can instantaneously maximise the growth of an energy measure of the gyrokinetic system. These optimal modes may not maintain their growth indefinitely, but their growth rate is greater than any normal mode in the system. Moreover, the optimal mode growth also bounds the total growth of instabilities in the nonlinear system. We apply this optimal mode analysis to a gyrokinetic system with gyrokinetic ions and bounce-averaged electrons. We construct the optimal modes of the generalised free energy [3] of this system in toy-model magnetic fields and find that those which possess the maximum-J property show a reduced optimal growth rate.

[1] J. H. E. Proll, P. Helander, J. W. Connor, and G. G. Plunk. PRL 2012.
[2] G. G. Plunk and P. Helander. JPP 2022.
[3] G. G. Plunk and P. Helander. JPP 2023.

P 25.15 Thu 16:30 ELP 6: Foyer

Onto Island Localized Modes in the Wendelstein 7-X scrape off layer — •Dario Cipciar[1], Carsten Killer[1], Jiri Adamek[2], Olaf Grulke[3], Kian Rahbarnia[1], Christian Brandt[1], and W7-X Team[1] — [1]Max- Planck-Institut für Plasmaphysik Greifswald, Germany — [2]IPP of the CAS Prague, Czech republic — [3]Technical University of Denmark, Lyngby, Denmark

In the Wendelstein 7-X stellarator scrape off layer, magnetic islands are present and partly intersected by divertor targets. Around the "O-point" of the islands, a region of uninterrupted, closed field lines can remain. Measurements with electric probes indicate that low frequency mode activity, which is also seen by other plasma diagnostics such as magnetics and X-ray tomography, is associated to this particular region. These modes challenge the current picture of the magnetic islands as stationary resonances of the external magnetic field. We investigate the possibility of local currents existing in the islands, which periodically modify the magnetic structure of the islands (compress and expand). These changes in the shape of the islands can lead to self-regulation of island transport channels might and provide an explanation to the observed low-frequency modulation of island density electron and ion temperature, and plasma potential.

P 25.16 Thu 16:30 ELP 6: Foyer

A high power, galvanically isolated power supply for current drive in the STØR experiment — •Sebastian Haag[1], Nils Fahrenkamp[1], Stefan Knauer[1], Simone Mannori[2], Alessandro Lampasi[2], and Peter Manz[1] — [1]Institute of Physics University of Greifswald, Greifswald, Germany — [2]ENEA, Rome, Italy

Extreme Ultraviolet (EUV) lithography is a crucial technology for projecting high-resolution patterns onto silicon wafers, enabling the production of smaller and more powerful microchips. At the desired wavelength, lasers are no longer available as light sources, so plasma sources have to be used. Laser-produced plasmas (LPPs) prevailed as radiation source because the discharge-produced plasmas (DPPs) did not achieve the desired parameters. The STØR experiment introduces an alternative magnetic confinement concept which is particularly well suited as radiation source, as it contributes to reducing costs and size. To ignite the plasma and drive the helical plasma current, a power supply has to be designed. It is capable of applying a voltage high enough to ignite the plasma and drive currents of up to 2 kA. By utilizing Supercaps as energy storage devices, we can achieve a high power system which is galvanically isolated to minimize plasma interactions with the vessel and provide a steady input voltage over the operating time. Voltage and current are controlled via a high-side and a low-side IGBT module in a buck converter configuration. Together with a custom design of the electrodes this allows for the setup of a magnetically confined compact plasma tori without external toroidal and poloidal magnets, which are ideal properties for a radiation source.

P 25.17 Thu 16:30 ELP 6: Foyer

Influence of collisionality on the electron dynamics in CCRF discharges — •Jens Kallähn, Denis Eremin, and Ralf Peter Brinkmann — TET, Ruhr University Bochum

In this contribution we investigate the influence of the pressure on the power absorption dynamics and electron transport in an rf cylindrical magnetron plasma.

Kinetic PIC simulations were utilized to gain insight into the electron heating and transport across the magnetic field.

They revealed the Hall heating to be a new magnetized electron heating mechanism different from the Ohmic heating it was classified as before. This mechanism is caused by an electric field at the edge of the sheath during the sheath expansion and by a reversed electric field during the sheath collapse. The related new operation mode was proposed to be called "mu-mode", because of its dominance in magnetized CCRF discharges and to differentiate it from other modes in rf plasmas.

While the Hall heating is dominant at low pressures, the collisional heating mechanism prevails in the high-pressure regime with a transition region where both are important.

The reversed electric field is generated for the charge balance at the powered electrode to be maintained during the sheath collapse via enhancing the electron flux. This increase occurs due to three different mechanisms: collisionless transport of electrons due to the polarization drift, collisional drift in the reversed electric field, and collisional diffusion through Hall heating.

P 25.18 Thu 16:30 ELP 6: Foyer

Tungsten Observation at Wendelstein 7-X — •Birger Buttenschön[1], Daihong Zhang[1], Thomas Pütterich[2], and W7-X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [2]Max-Planck-Institut für Plasmaphysik, Garching, Germany

In the first part of the second operation phase of the Wendelstein 7-X (W7-X) stellarator, some 280 wall and divertor tiles were made from tungsten or a tungsten-coated material. Those tiles were located in differently loaded regions of the wall. The purpose was to investigate how plasma-wall interaction might lead to contamination of the plasma with tungsten. As a tool to assess the tungsten concentration in the plasma, vacuum-ultraviolet (VUV) spectroscopy is used in combination with 2D bolometry.

While a detailed analysis requires somewhat advanced fitting methods (e.g. for the 5nm quasi-continuum), first - mostly qualitative - results can be readily obtained from the measured VUV spectra. For example, the acquired data allows to roughly determine the tungsten concentrations in specific plasma discharges, and it is used to define a minimum tungsten concentration at which the VUV spectrometer registers a signal above noise.

This contribution shows a number of different tungsten experiments performed in W7-X, the corresponding VUV spectra and what can be learned from the existing data set.

P 25.19 Thu 16:30 ELP 6: Foyer

Computer Vision Deep Learning-Based Shattered Pellet Injection (SPI) Shard Tracking at ASDEX Upgrade — •Johannes Illerhaus[1,2], Paul Heinrich[1,2], Mohammad Miah[1,2], Gergely Papp[1], Tobias Peherstorfer[3], Wolfgang Treutterer[1], Bernhard Sieglin[1], Udo von Toussaint[1], Hartmut Zohm[1], Frank Jenko[1], and the ASDEX Upgrade Team[4] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Technische Universität München, Garching, Germany — [3]Technische Universität Wien, Vienna, Austria — [4]see the author list of U. Stroth et al. 2022 \textit{NF} 62 042006

A computer vision deep learning pipeline was constructed to automate the analysis of the more than 1000 videos created in lab experiments on the SPI test bench at ASDEX Upgrade. Our machine learning (ML) models provide highly accurate segmentation of the fragments shown in these videos. This allows for the labeling of the entire dataset, of which previously only 177 videos had been labeled using a pipeline based on traditional computer vision. The ML models eliminate the previously necessary human supervision, reduce the run time from months to a few hours and increase the accuracy and robustness of labeling. The shards are then tracked between frames with the goal of estimating their size and speed distributions. This enables using the experimental results to validate theoretical models predicting the right system setup and pellet attributes to produce the fragment distributions for optimal disruption mitigation. This will ultimately help inform design decisions for the ITER SPI, ITER's primary disruption mitigation system.

P 25.20 Thu 16:30 ELP 6: Foyer

Spatially and temporally resolved simulations of the Cs dynamics in large negative hydrogen ion sources assisted by TDLAS measurements — •Daniele Mussini, Adrian Heiler, Dirk Wünderlich, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik (IPP), Boltzmannstr. 2, 85748 Garching

Negative hydrogen ion sources for the ITER neutral beam injectors rely on the production of negative hydrogen ions on a low work function surface (plasma grid). To reduce the surface work function, a Cs layer is formed on the plasma grid by steadily evaporating Cs into the source. However, mainly due to plasma-surface interaction and Cs redistributions, it is not straightforward to generate a temporally stable and homogeneous Cs layer. In particular, this is a major challenge for the long pulse operation required for ITER (1000 s in H, 3600 s in D). To gain insight into the Cs dynamics by numerical modeling, the Monte-Carlo Test-particle code CsFlow3D was developed at IPP. The code uses many input parameters such as EM fields, plasma temperature and density profiles to determine the Cs dynamics within sources of different sizes. The current main objective is to investigate the Cs behavior during long pulses for both H or D operation. To do so, an updated version of input parameters must be implemented. In addition, the synthetic laser absorption diagnostic (TDLAS) needs to be simulated to benchmark the code against experimental results. This contribution is intended to show some preliminary results and to provide an outlook on future steps for the further development and improvement of the code.

P 25.21 Thu 16:30 ELP 6: Foyer

Deuterium Uptake in Tungsten Damaged at High Temperature — •Laurin Hess, Mikhail Zibrov, and Thomas Schwarz-Selinger — Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching b. München

Retention of hydrogen fuel in the tungsten wall of future fusion reactors is an essential area of research, as it is an integral part of modelling the tritium inventory. It has been shown that hydrogen retention significantly increases due to displacement damage produced by 14 MeV neutrons. Until now, many experiments have simulated the displace- ment damage in a reactor by damaging the tungsten at low temperatures using high energy ions. However, recent experiments have shown that retention behaves differently when the damaging happens at high temperatures, as in a fusion reactor. One possible explanation for this would be the formation of nm-sized voids. It has been suggested that the formation of vacancy clusters depends on the damaging rate. To account for this, two damaging modes have been compared. One with a high intermittent damaging rate using a raster scanned focused beam and one with a low continuous damaging rate using a wobbled defocused beam. In addition, the lateral homogeneity of the two modes has been examined using proton Elastic Backscattering Analysis of gold implantation. Then, the deuterium uptake of tungsten damaged at 1350 K has been studied by decorating the samples with 5 eV deuterium ions.

P 25.22 Thu 16:30 ELP 6: Foyer

A Gyrokinetic Electron Model for BSL6D — •Maximilian Pelkner — Max Planck Institute for Plasma Physics, Garching

The goal of numerical plasma physics is to understand the behaviour of plasmas numerically, since analytical tools for solving the underlying Vlasov equation are limited. Only in recent years has computing power increased to the point where fully kinetic simulations of plasmas, i.e. simulations of the full phase space, are within reach. The BSL6D code is an example of such a "fully kinetic" code, but for computational reasons it so far simulates only fully kinetic ions with adiabatic electrons. The main goal of my work is to improve the simulation by implementing a drift kinetic electron model. In my poster I will present the principle of BSL6D, how the electron model will be implemented and also some comparisons between the code and existing analytical solutions (e.g. Ion Sound Wave).

P 25.23 Thu 16:30 ELP 6: Foyer

Atomic hydrogen density measurements with TALIF above a sample surface — •Julian Hörsch, Christan Wimmer, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2D-85748, Garching bei München, Germany

Two photon Absorption Light Induced Fluorescence (TALIF) is a diagnostic technique that will be used in an upcoming research program in combination with other diagnostics to characterize the production of negative hydrogen ions in negative ion sources. These negative hydrogen ions can be produced by surface conversion of neutral hydrogen atoms on a low work function material as cesium. As TALIF allows the direct determination of the density and temperature of neutral hydrogen atoms it is of particular interest for characterizing the negative ion production mechanisms. In this project TALIF is applied to a small-scale experiment to study the available density of neutral hydrogen atoms for negative ion production above a sample, but without negative ion production itself. The TALIF signal is measured with varying distance to the surface of the sample and for various sample materials. In particular, the influence of the distance to the surface on the hydrogen properties and the isotopic differences between hydrogen and deuterium are investigated.

P 25.24 Thu 16:30 ELP 6: Foyer

heat conduction in the vicinity of an island — •Gregor Pechstein and Per Helander — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald

In magnetically confined fusion plasmas, energy is transported across flux-surfaces toward the plasma edge and the surrounding vessel. It is a challenge to control and limit the wall loads since the tolerable energy flux onto plasma facing component is limited by a number of technical constraints. In order to control and reduce the loads, tokamaks and stellarators exploit divertor magnetic fields guide the heat flux onto target plates, and try to maximise radiation from the edge plasma. When the radiative losses are particularly high, the plasma sometimes "detaches" from the walls and the energy flux to the latter drops dramatically.

The key feature of plasma energy transport that allows for the use of a divertor is the fact that the transport is highly anisotropic. As a result, if the magnetic field is shaped in such a way that different field lines have different topology, the the heat flux can vary greatly across any surface across which the topology changes. We consider anisotropic heat conduction and radiation in the simplest possible mathematical setting in which the field lines change topology, namely, in the geometry of a single chain of magnetic islands. The aim is to shed light on the basic question of how a variation in field-line topology affects the location and amount of plasma radiation.

P 25.25 Thu 16:30 ELP 6: Foyer

Design of a new imaging diagnostic at ASDEX Upgrade for divertor fluctuation studies — •Manuel Herschel[1,2], Michael Griener[2], Tim Happel[2], Daniel Wendler[1,2], Ulrich Stroth[1,2], and The ASDEX Upgrade Team[3] — [1]Technical University of Munich, Physics Department, Chair for Plasma Edge and Divertor Physics, 85747 Garching, Germany — [2]Max-Planck-Institute for Plasma Physics, Garching, Germany — [3]See author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

The divertor will play a critical role in future fusion power plants. The ASDEX Upgrade tokamak experiment (AUG) is currently being equipped with a flexible divertor that will offer new magnetic configurations such as compact radiative or snowflake divertors. To investigate the plasma exhaust in this divertor, good diagnostic coverage is required.

Gas Puff Imaging (GPI) is a well-established technique to observe the microscopic structures that constitute plasma turbulence. Active injection of thermal helium gas creates a spatially localized light emission depending on the local plasma conditions, while a fast camera captures the image with high spatial and temporal resolution.

In this work, an improved GPI diagnostic is designed for the new AUG divertor. A fast in-vessel piezo valve is combined with an optimized line-of-sight geometry and optics to image multiple spectral lines simultaneously, which is necessary for the correct interpretation of the data. This promises better understanding of the X-point and divertor region.

P 25.26 Thu 16:30 ELP 6: Foyer

Hybrid kinetic-MHD simulations of runaway electron beam termination events in realistic 3D tokamak geometry — •Hannes Bergstroem[1], Matthias Hoelzl[1], and Vinodh Bandaru[2] — [1]Max Planck Institute for Plasma Physics, Garching b. M. — [2]Indian Institute of Technology Guwahati, Assam

Disruption events and the associated generation of highly energetic runaway electrons (REs) remain one of the largest threats to future high current tokamak reactor designs like ITER and DEMO. Studies have indicated that even with systems in place to mitigate these events, a multi-MA RE beam may be unavoidable during the nuclear phase of ITER operation. The transport of REs in 3D MHD fields is however difficult to model and presents one of the largest uncertainties for these estimates, since it can have a substantial impact on the beam formation and the details of the ensuing termination. This is particularly challenging since REs carry most of the current at these stages and therefore dominate the dynamics of the plasma, rendering test particle approaches insufficient.

In this work we present a newly implemented hybrid kinetic-MHD model in JOREK, where the kinetic RE population is coupled to the MHD equations in realistic 3D tokamak geometry using a particle-in-cell approach. At first, results from analytical validation with respect to the force balance in a plasma with high RE current are shown. In addition we present results from a RE beam termination scenario in JET, as it occurs due to a burst of 3D MHD activity.

P 25.27 Thu 16:30 ELP 6: Foyer

Towards a stochastic variational principle for quasi-neutral two fluids — •Sayyed Amin Raiessi Toussi[1], Tomasz Tyranowski[2], and Omar Maj[1] — [1]Max Planck Institute for Plasma Physics, D-85748 Garching, Germany. — [2]Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente, 7522NH Enschede, The Netherlands

Quasi-neutral multi-fluid models are commonly used to describe particle and energy transport in the edge and scrape-off layer (SOL) of magnetically confined fusion plasmas [R. Schneider, Contrib. Plasma Phys., 46, 2006].

For the purpose of developing particle schemes, a variational formulation is desirable and useful. In this work we use stochastic Euler-Poincaré reduction [Chen, Cruzeiro & Ratiu, J Nonlinear Sci 33, 5 (2023)] in order to formulate a variational principle for quasi-neutral two-fluid models, including non-ideal effects such as viscosity and heat fluxes. In this approach, the quasi-neutrality condition is treated as a constraint, the electric potential being the corresponding Lagrange multiplier. Therefore this variational principle combines elements from the theory of compressible non-ideal flows with Lagrangian constraints [Morrison, Andreussi, Pegoraro, J.Plasma Phys. 86 (2020)]. As a proof of concept, we discuss here simple models of viscosity and heat fluxes, together with some preliminary considerations about generalization to more realistic physics.

P 25.28 Thu 16:30 ELP 6: Foyer

Simulation of fully global electromagnetic turbulence in the stellarator W7-X — •Yann Narbutt[1], Alexey Mishchenko[1], Ralf Kleiber[1], Matthias Borchardt[1], and Edilberto Sánchez[2] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstraße 1, 17489 Greifswald, Germany — [2]Laboratorio Nacional de Fusión, CIEMAT, Avda. Complutense 40, Madrid 28040, Spain

Magnetic confinement fusion requires high $\beta = \langle p \rangle / (B^2/2\mu_0)$, the ratio of plasma pressure to magnetic pressure, to access high performances. Moderate β can be beneficial for ion-temperature-gradient (ITG) driven turbulence. However, as β is increased above a certain threshold, the so-called kinetic-ballooning-mode (KBM) can be destabilized. This is a plasma pressure gradient driven instability which is inherently electromagnetic and can lead to strong outwards directed heat fluxes, degrading plasma confinement in the process. While, linearly, KBMs have been successfully studied in the stellarator Wendelstein 7-X with flux-tube simulations, it was also shown that the instability tends to be most unstable while developing a global structure on the magnetic surface. While investigating linear simulations in Wendelstein 7-X geometry with the global gyrokinetic code Euterpe both KBMs and high-β trapped electron modes have been observed. Using this code non-linear simulations are conducted on the MareNostrum supercomputer to investigate the turbulent behaviour of these electromagnetic instabilities.

P 25.29 Thu 16:30 ELP 6: Foyer

In-situ spectral calibration of the Thomson scattering system at W7-X using Rayleigh scattering — •Jannik Wagner, Golo Fuchert, Ekkehard Pasch, Jens Knauer, Kai Jakob Brunner, Sergey A. Bozhenkov, Marcus Beurskens, Matthias Hirsch, Robert C. Wolf, and W7-X Team — Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald

In most high temperature fusion experiments, Thomson scattering is one of the main diagnostics for measuring electron temperature and density. So far, the spectral calibration at W7-X uses the light of a supercontinuum laser in combination with a monochromator scattered diffusively by a plate in front of the observation optics. Using this approach, however, the window between the plasma vessel and the observation optics is not part of the calibration and its transmission can vary during an experimental campaign due to coating.

To overcome these issues, a new in-situ calibration has been developed in recent years. Using an optical parametric oscillator (OPO), Rayleigh scattering inside the plasma vessel acts as tunable volumetric light source that can be observed with the exact same setup used for the Thomson scattering measurements. A proof-of-principle was demonstrated in 2018/19, but so far the quality was not sufficient to replace the existing calibration method.

In this work, improvements of the optical setup and in particular a more reliable energy measurement are presented. These measures reduce the experimental uncertainties in a new Rayleigh scattering experiment from which improved calibration curves could be determined.

P 25.30 Thu 16:30 ELP 6: Foyer

Design of a dispersion interferometer at ASDEX Upgrade for disruption studies — •Andrew Moreau[1,2], Alexander Bock[2], Kai Jakob Brunner[3], Andres Cathey[2], Matthias Hoelzl[2], Jens Knauer[3], Jens Meineke[3], and Thomas Puetterich[2] — [1]Ludwig Maximilian University of Munich, Faculty of Physics, 80799 Munich, Germany — [2]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [3]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany

Disruptions significantly challenge the successful utilization of future tokamak-class fusion power plants which are predicted to be larger and operate at higher magnetic fields and plasma currents. The electron density is a key quantity needed in the investigation of plasma dynamics to understand the mechanisms of thermal and current quenches, the generation and suppression of runaway electrons and the mitigation or control of disruption effects. At ASDEX Upgrade (AUG) there are currently no interferometer diagnostics which can explore disruption or disruption mitigation scenarios free of fringe jumps, low signal-to-noise or vibration errors. We present work towards the commissioning of a dispersion interferometer at AUG which would harness the coherence conservation principle of second-harmonic generation in order to alleviate the need for a reference beam path. This reduces the complexity significantly and becomes intrinsically free of vibrational errors. With state-of-the-art nonlinear crystals, we increase the capabilities of this system in signal-to-noise. We then show how JOREK simulations can contribute to diagnostic modelling.

P 25.31 Thu 16:30 ELP 6: Foyer

Modelling ion orbits in the W7-X neutral beam box — •Lucas van Ham[1], Samuel Lazerson[1], Björn Hamstra[2], Paul McNeely[1], Norbert Rust[1], and Dirk Hartmann[1] — [1]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany — [2]Eindhoven University of Technology, 5612 AZ Eindhoven, The Netherlands

Neutral beam injection (NBI) on Wendelstein 7-X (W7-X) is limited in duration by the heat loads experienced by the NBI components. Deposition patterns on these components have been observed to shift upwards when the main magnetic field of W7-X is on, suggesting stray magnetic fields are penetrating the neutral beam box. We aim to investigate the cause of this shift and how to mitigate this issue. In this work, ion orbits inside the W7-X NBI box will be investigated using the Monte Carlo particle following code BEAMS3D. Simulations will be performed to estimate calorimeter heat loads which will be compared against experimental results. Next, the bending magnet will be included in simulations and a similar investigation will be carried out for the H+ and H2+ ion dumps. Future simulations will focus on including the effect of the magnetization of the magnetic material inside the NBI box on the orbits of the ions.

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Overview of Invited Talks and Sessions

(Lecture hall ELP 6: HS 4; Poster ELP 6: Foyer)

Plenary Talk of the Environmental Physics Division

PV I	Mon	9:00– 9:45	ELP 6: HS 3+4	**The role of the North Atlantic Ocean for European Climate** — •Johanna Baehr

Invited Talks

UP 1.1	Mon	11:00–11:30	ELP 6: HS 4	**Atmospheric impact of energetic particle precipitation from the lower thermosphere to the surface** — •Miriam Sinnhuber
UP 2.2	Mon	16:45–17:15	ELP 6: HS 4	**Increasing water limitation of global ecosystems in a changing climate** — •Rene Orth, Jasper Denissen, Wantong Li, Sungmin O
UP 5.1	Wed	11:00–11:30	ELP 6: HS 4	**Melting from below: An abrupt transition in Antarctic sea ice-ocean system** — •Alexander Haumann, et al.

Invited Talks of the joint Symposium How to Cope with Apocalyptic Narratives? (SYAN)

See SYAN for the full program of the symposium.

SYAN 1.1	Mon	14:00–14:40	ELP 6: HS 4	**The Apocalyptic Moment Is Over - And It Won't Come Back Anytime Soon** — •Frank Uekoetter
SYAN 1.2	Mon	14:40–15:20	ELP 6: HS 4	**Shaping Cold War Futures through the Nuclear Winter Study: Narratives, Imaginaries and Legitimacy** — •Egle Rindzeviciute
SYAN 1.3	Mon	15:20–16:00	ELP 6: HS 4	**The Role of Storytelling in Climate Communication** — •Denise Müller-Dum

Invited Talks of the joint Symposium Lasers and Photonic Technologies for Environmental Challenges (SYEC)

See SYEC for the full program of the symposium.

SYEC 1.1	Tue	11:10–11:40	ELP 6: HS 1	**Nanostructured optical waveguides inside YAG crystals as a crucial step towards the development of microlasers for advanced sensing applications** — •Omar de Varona, Franzette Paz-Buclatin, Paul Santos, Pablo Molina, Leopoldo Martín, Airán Ródenas
SYEC 1.2	Tue	11:40–12:10	ELP 6: HS 1	**Laser surface modification of graphite anodes for lithium-ion batteries with improved fast-charging capability** — •Max-Jonathan Kleefoot, Jens Sandherr, Jiri Martan, Volker Knoblauch, Harald Riegel
SYEC 2.1	Tue	14:00–14:30	ELP 6: HS 4	**Development of soft glass optical fibers based on 3D printed preforms** — •Ryszard Buczynski, Pawel Wiencław, Przemyslaw Golebiewski, Dariusz Pysz, Adam Filipkowski, Grzegorz Stepniewski, Olga Czerwinska, Andrzej Burgs
SYEC 2.2	Tue	14:30–15:00	ELP 6: HS 4	**Three-dimensional Ultrashort-Pulse Laser Nanolithography of Optical Materials** — •Airán Ródenas, Omar de Varona, Franzette Paz-Buclatin
SYEC 2.3	Tue	15:00–15:30	ELP 6: HS 4	**Fibre-based plasmonic micro reactor CO2 reduction** — •Devin O'Neill, Patrick Spath, Wiebke Albrecht
SYEC 5.1	Tue	17:15–17:45	ELP 6: HS 4	**Studying atmospheric dynamics with lasers in remote places** — •Bernd Kaifler

Sessions

UP 1.1–1.5	Mon	11:00–12:30	ELP 6: HS 4	**Atmospheric Trace Gases and Aerosols**
UP 2.1–2.5	Mon	16:30–18:00	ELP 6: HS 4	**Soil and Water**
UP 3.1–3.4	Tue	11:00–12:00	ELP 6: HS 4	**Remote Sensing**
UP 4	Tue	12:30–13:15	ELP 6: HS 4	**Members' Assembly**
UP 5.1–5.5	Wed	11:00–12:30	ELP 6: HS 4	**Cryosphere and Arctic Oceans**
UP 6.1–6.3	Wed	14:30–15:15	ELP 6: HS 4	**Other Topics**
UP 7.1–7.7	Wed	16:30–18:30	ELP 6: Foyer	**Posters**

Members' Assembly of the Environmental Physics Division

Tuesday 12:30–13:15 ELP 6: HS 4

- Report on last year's activities
- Update of statutes
- Vacant position in the executive board: *representative of young scientists*
- Nomination of candidates for DPG prizes
- Any other business

Sessions

– Invited Talks, Contributed Talks, and Posters –

UP 1: Atmospheric Trace Gases and Aerosols

Time: Monday 11:00–12:30 Location: ELP 6: HS 4

Invited Talk UP 1.1 Mon 11:00 ELP 6: HS 4

Atmospheric impact of energetic particle precipitation from the lower thermosphere to the surface — •Miriam Sinnhuber — Karlsruher Institut für Technologie

Energetic charged particles - protons, electrons and heavier ions with energies from tens of keV to hundreds of MeV - precipitate into the atmosphere at high latitudes, guided by the Earth's magnetic field. They originate from the sun, accelerated in the solar corona during flares or coronal mass ejection events, or from the terrestrial magnetosphere, accelerated during geomagnetic storms or auroral substorms by variations in the high-speed solar wind. In the atmosphere, they interact with the most abundant species by collision reactions, starting a chain of chemical-dynamical coupling mechanism. The first step is atmospheric ionization and the formation of radicals of the NOx and HOx families mainly in the mesosphere and lower thermosphere, and subsequent ozone loss. NOx can be transported into the stratosphere during polar winter, and contribute significantly to ozone loss at the top of the ozone layer. Radiative feedbacks in turn affect atmospheric dynamics possibly even down to tropospheric weather systems. This so-called geomagnetic forcing of the climate system is modulated by the quasi-continuous solar wind and sporadic solar eruptions and varies over the 11-year solar cycle; since CMIP6, it is also recommended as part of the solar forcing of the climate system. In this presentation, an overview of the state of the art will be provided, focusing on the 11-year variability as well as on the impact of extreme solar events.

UP 1.2 Mon 11:30 ELP 6: HS 4

Improvements of the HAGAR-V instrument and its performance during the HALO mission PHILEAS — •Ronja van Luijt, Valentin Lauther, Johannes Strobel, Andrea Rau, Lars Zlotos, and Claus Michael Volk — Institute for Atmospheric and Environmental Research, University of Wuppertal, Germany

Precise airborne in situ measurements of VOCs are useful to understand atmospheric processes and can be achieved by GC/MS. The need for high spatial resolution conflicts with typical time resolutions of 3 to 10 minutes for mobile GC/MS. We present the recently improved HAGAR-V (High Altitude Gas AnalyzeR-5 channel version), developed at the University of Wuppertal for use on the HALO aircraft, with a time resolution of 2 minutes while measuring about 30 VOC species in the ppt range by employing two identical GC channels with a single MS. Additionally, it includes a NDIR CO2 analyzer and a 2-channel GC/ECD. For the GC/MS, innovative multitasking of various processes and strong sample refocusing result in detection limits of a few ppq and precisions of 1-5% and a shorter sampling time of 40 s, yielding a significant improvement in resolving fine-scale atmospheric structure. We show the performance of the HAGAR-V instrument during the HALO mission PHILEAS investigating the impact of the Asian summer monsoon on the extratropical UTLS. HAGAR-V GC/MS measured with high resolution species with anthropogenic Asian sources, species with biomass burning sources and very short-lived NMHCs, providing key information for understanding the evolution of convectively uplifted pollutants in the UTLS.

UP 1.3 Mon 11:45 ELP 6: HS 4

A novel method of measuring the viscosity and surface tension of supercooled levitated droplets — Mohit Singh[1], Stephanie Helen Jones[1], Alexei Kiselev[1], Denis Duft[1], and •Thomas Leisner[1,2] — [1]Institut of Meteorology and Climate Research, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Institut für Umweltphysik, Universität Heidelberg, Germany

Viscosity and surface tension of aerosol particles influence e.g. the rate of heterogeneous and photochemical reactions, the evaporation and growth processes leading to CCN formation, and the ability to act as ice nuclei. Both quantities can vary significantly during the atmospheric processing of aerosol particles. Following these changes requires a fast and reliable measurement technique, which can be applied to airborne particles under realistic atmospheric conditions where noneequilibrium conditions like supersaturation and superooling are widespread. We report a novel method to simultaneously measure the time-dependent viscosity and surface tension of charged droplets levitated in an environmental electrodynamic balance. In addition to the alternating electric field required for levitation, a secondary electric field of variable frequency is applied to induce shape oscillations in the levitated droplet. The shape oscillations are analysed by light scattering and the phase shift in the induced shape oscillations with respect to the driving field is used to determine droplet viscosity and surface tension.

UP 1.4 Mon 12:00 ELP 6: HS 4

New results from the joint research project VolImpact — •Christian von Savigny[1], Claudia Timmreck[2], Ali Hoshyaripour[3], Akos Horvath[4], Alexei Rozanov[5], John Burrows[5], Ulrike Niemeier[2], Felix Wrana[1], Anna Lange[1], Corinna Hoose[3], Johannes Quaas[6], Sandra Wallis[1], Hauke Schmidt[2], and Christopher Kadow[7] — [1]Institut für Physik, Universität Greifswald — [2]MPI für Meteorologie, Hamburg — [3]Institut für Meteorologie und Klimaforschung, KIT — [4]Institut für Meteorologie, Universität Hamburg — [5]Institut für Umweltphysik, Universität Bremen — [6]Institut für Meteorologie, Universität Leipzig — [7]DKRZ, Hamburg

Volcanic eruptions are one of the most important natural drivers of climate change on time scales from a few years up to a decade. In the DFG funded Research Unit VolImpact we investigate relevant aspects of volcanic eruptions on the atmosphere and climate in five projects, i.e. the initial development of volcanic plumes on time scales from hours to a few days, the evolution of volcanic aerosol layers in the stratosphere, interactions of volcanic aerosols and tropospheric clouds, dynamic and thermal effects of volcanic eruptions on the middle atmosphere as well as volcanic effects on the hydrological cycle. After a short overview of the VolImpact project, this talk will focus on recent results from the second phase of the VolImpact project, including results on the unusual eruption of Hunga-Tonga Hunga Ha'apai in January 2022, satellite remote sensing of microphysical parameters of stratospheric aerosols, as well as unusual optical phenomena in the atmosphere.

UP 1.5 Mon 12:15 ELP 6: HS 4

Tracing the Hunga Tonga - Hunga Ha'apai H_2O anomaly through the mesosphere — •Sandra Wallis and Christian von Savigny — University of Greifswald, Germany

The 2022 Hunga Tonga - Hunga Ha'apai eruption emitted an exceptionally large amount of approximately 150 Tg H_2O into the middle atmosphere (10 - 100 km). After an immediate subsidence, the volcanic H_2O anomaly began to rise in the tropics and crossed the stratopause (1 hPa) by the end of March 2023. We use MLS H_2O mixing ratios to trace its subsequent transport through the mesosphere (50 - 100 km altitude). This research is especially relevant to the noctilucent cloud community, because upon reaching the summer mesopause region (approximately 90 km) the H_2O anomaly could potentially have an impact on the properties of noctilucent clouds such as occurrence frequency or brightness.

UP 2: Soil and Water

Time: Monday 16:30–18:00 Location: ELP 6: HS 4

UP 2.1 Mon 16:30 ELP 6: HS 4

Das Klima-Endspiel in Zukunftsdiskursen. Potentiale katastrophaler Szenarien in der Klimakommunikation — •Gunther Seckmeyer und •Gerriet Schwen — Leibniz Universität Hannover, Institut für Meteorologie und Klimatologie

Vor 50 Jahren kristisierte die New York Times mit vernichtender Schärfe "Die Grenzen des Wachstums", wobei sie anmerkte: "Today the vision is mass death from insecticide poisoning, climatic changes, or some other form of retribution from an angry biosphere." Das sei als Zukunftsprognose vielleicht nicht falsch, aber "a false inevitability of doom do not speed the day of salvation" - Angst- und Panikmache helfen nicht, die richtigen Entscheidungen zu treffen um Lösungen zu finden. Diese Kritik wird immer wieder vorgebracht.

Im Jahr 2022 veröffentlichten Kemp et.al. "Climate Endgame: Exploring catastrophic climate change scenarios", um mehr Aufmerksamkeit auf wahrschein-

licher werdende katastrophale Szenarien zu lenken. Gefördert vom Land Niedersachen haben wir als transdisziplinäres Team Wissenschaftler*innen zu der Bedeutung des 'Climate Endgame' in unseren Zukunftsdiskursen befragt und planen nun Veranstaltungen als soziale Realexperimente mit Akteuren aus Politik, Medien und Aktivismus, um solidarische Weltuntergangsnarrativen zu erforschen.

Die öffentliche Kommunikation ist weiterhin vom Ideal dominiert positiv zu kommunizieren. Würde ein ungeschönter Blick auf unsere Lage Kräfte freisetzen, um die schlimmsten Folgen der Klimakrise abzumildern? Und: Wie klingt eine Kommunikation klingen, welche das Ausmaß der Klimakrise vermittelt ohne Überforderung auszulösen?

Invited Talk UP 2.2 Mon 16:45 ELP 6: HS 4

Increasing water limitation of global ecosystems in a changing climate — •Rene Orth[1], Jasper Denissen[2], Wantong Li[3], and Sungmin O[4] — [1]University of Freiburg, Germany — [2]European Centre for Medium-Range Weather Forecasting, Germany — [3]Max Planck Institute for Biogeochemistry, Germany — [4]Ewha Womans University, Korea

Climate change involves changes in temperatures and precipitation in many regions. These changes in turn affect terrestrial ecosystems that require sufficient water and energy to provide essential services such as food security and the uptake of human-caused CO2 emissions.

This presentation will introduce the concept of ecosystem water and energy limitation, and identify areas where each limitation prevails. These areas are characterised by different sensitivities of evapotranspiration and vegetation productivity to temperature and precipitation. A special focus will be on the global trends of ecosystem water limitation, where our results show increased water sensitivity across recent and future decades in many regions.

The presentation will also illustrate that this increasing ecosystem water limitation has diverse implications including (i) increased vulnerability of vegetation to droughts which can lead to more frequent and pronounced drought impacts on vegetation functioning and (ii) a weakening of the greening trend of global vegetation, thereby counter-acting the effect of rising temperatures and CO2 levels in many regions.

UP 2.3 Mon 17:15 ELP 6: HS 4

Dürren in Deutschland: Warum der Klimawandel hydrologische Extreme verstärkt — •Axel Kleidon — Max-Planck-Institut für Biogeochemie

Die wärmeren Temperaturen des globalen Klimawandels verstärken den Wasserkreislauf, Verdunstung und Niederschlag nehmen zu. Aber auch Extremereignisse wie Starkregen, Hochwasser, Trockenperioden und Dürren häufen und intensivieren sich. Wie passt das zusammen? Einfache physikalische Betrachtungen zeigen, welche Faktoren hauptsächlich die Stärke des Wasserkreislaufs im Erdsystem regulieren und wie dies die Wasserverfügbarkeit auf dem Festland bestimmt. Damit lassen sich die beobachteten Änderungen der Wasserbilanz in Deutschland interpretieren und die zunehmende Trockenheit in Deutschland erklären.

UP 2.4 Mon 17:30 ELP 6: HS 4

Metrology for multi-scale monitoring of soil moisture — •Markus Köhli for the SoMMet collaboration — Physikalisches Institut, Heidelberg University, Germany

Soil moisture as a key variable in agriculture, forestry, groundwater recharge, weather, climate, and greenhouse gases emission in the environment. Several measurement methods exist on multiple scales, however, poorly harmonized. Despite its significance this lack of precision marginalized the topologically complex assessment of soil moisture. Thus, there is a need to establish the chain of traceability - the metrological determination of uncertainties. In addition, there is an urgent need for real-time, high-quality, temporally and spatially consistent data on soil moisture. Such are needed to optimise water management strategies as well as climate change monitoring, modelling and mitigation. To address these needs, the project 'Soil Moisture Metrology' (SoMMet) has been set up in the framework of the European Partnership on Metrology. The consortium consists of nine National Metrology Institutes and nine research institutions. Its aim is to develop sound metrological tools and establish a metrological foundation for soil moisture measurement methods. On the point scale (10^{-1} m - 10^{1} m), novel primary and secondary standards of measurements will be developed specifically for soil samples. On the intermediate range (10^{2} m - 10^{3} m), the metrological basis of the cosmic-ray neutron sensing method will be established, in laboratory and outdoors. On the large scale (10^{3} m - 10^{4} m), satellite-based remote sensing products will be utilized to derive the soil moisture products.

UP 2.5 Mon 17:45 ELP 6: HS 4

Correcting cosmic-ray neutrons for everything: latest attempts to isolate the soil water signal from external influences — •Martin Schrön[1], Markus Köhli[2], Jannis Weimar[2], Daniel Rasche[3], and Lasse Hertle[1] — [1]Helmholtz-Zentrum für Umweltforschung GmbH - UFZ, Leipzig — [2]Physikalisches Institut, Heidelberg University — [3]Geoforschungszentrum - GFZ, Potsdam

Cosmic rays on Earth interact with the soil and are substantially moderated by hydrogen atoms. Since the reflected neutron flux is a function of the soil water content, cosmic-ray neutron measurements above the ground are widely used to estimate the average field soil moisture. However, many exernal factors spoil the accuracy of the product, which need to be corrected for. Cosmic rays do travel a long way from supernovae remnants through the solar system, the Earth's magnetosphere, the atmosphere, the biosphere, and the lithosphere, where each component has their challenges in store. Relevant effects are caused by, e.g., solar activity, the geomagnetic field, air pressure, air humidity, temperature, landscape heterogeneity, vegetation, snow, and even by scientists themselves. The list of influencing factors is long, and so is the number of approaches and proposed solutions. We will present the major influencing factors and discuss the latest attempts to tackle their correction.

UP 3: Remote Sensing

Time: Tuesday 11:00–12:00 Location: ELP 6: HS 4

UP 3.1 Tue 11:00 ELP 6: HS 4

Assessing the Impact of the 2023 Storm Daniel Flood in Pineios River Estuaries: An Analysis of Crop-Type and Inundation Mapping Using Sentinel-1/2 Imagery — •Rizos-Theodoros Chadoulis[1,2], Ioannis Manakos[1], and Constantine Kotropoulos[2] — [1]Centre for Research and Technology Hellas, Information Technologies Institute, 6th km Harilaou-Thermi Road, 57001 Thessaloniki, Greece — [2]Department of Informatics, Aristotle University of Thessaloniki, Box 451, Thessaloniki 54124, Greece

The 2023 Storm Daniel significantly affected the Pineios River estuaries, causing widespread flooding and impacting the agricultural landscape. This study aims to assess the impact of the floods on the area, utilizing Sentinel-1 and Sentinel-2 imagery for crop-type and inundation mapping. For the crop-type mapping, a time-series analysis was conducted over the 2022-2023 agricultural cycle, capturing the phenological changes of different crops, and a detailed crop-type map was produced using Machine Learning techniques and validated against in-situ observations conducted during the summer of 2023. The inundation mapping was achieved through a synergistic analysis of Sentinel-1 radar imagery and Sentinel-2 optical data, and the output was juxtaposed with the Copernicus EMS Rapid Mapping products. The proposed methodology provides accurate, evidence-based information to decision-makers, aiding in understanding the immediate effects of such events on agricultural regions but also providing valuable data for future flood mitigation and agricultural resilience planning in Thessaly.

UP 3.2 Tue 11:15 ELP 6: HS 4

Studying the global distribution of water vapour isotopologues with the Sentinel-5P mission — •Hartmut Bösch[1], Tim Trent[2], Matthias Schneider[3], Christopher Diekmann[3,4], Amelie Röhling[3], Farahnaz Khosrawi[3,5], Iris Thurnherr[6,7], and Harald Sodemann[6] — [1]Institut für Umweltphysik, Universität Bremen — [2]University of Leicester, UK — [3]Karlsruhe Institut of Technology — [4]Telespazio GmbH — [5]Forschungszentrum Jülich — [6]University of Bergen, Norwegen — [7]ETH Zuerich, Schweiz

Atmospheric moisture is a key factor for the redistribution of heat in the atmosphere and there is strong coupling between atmospheric circulation and moisture pathways which is responsible for most climate feedback mechanisms. Water isotopologues can make a unique contribution for better understanding this coupling. In recent years, global observations of water vapour isotopologues have become available from different satellite missions. With the launch of Sentinel 5P, water isotopologue total column retrievals with much improved spatial and temporal coverage compared to previous SWIR sensors thus representing a major advance for scientific and operational applications.

In this presentation, we describe the water isotopologues retrieval from Sentinel 5P, its assessment against ground-based reference data and against IR data from IASI which are mostly sensitive to the free troposphere. We will compare our water isotopologues dataset against isotope-enabled model calculations and discuss case studies to demonstrate how we can gain insights into hydrological regimes and processes. We will conclude with an outlook outlining future developments

UP 3.3 Tue 11:30 ELP 6: HS 4

Towards continuous, semi-automatic ship-borne measurements of columnar CO_2, CH_4, CO and NO_2 for regional-scale emission monitoring — •Vincent Enders[1], Ralph Kleinschek[1], Matthias Max Frey[3], Frank Hase[2], Isamu Morino[3], Astrid Müller[3], Hiroshi Tanimoto[3], Karolin Voss[1], and André Butz[1] — [1]Institute for Environmental Physics, Heidelberg University — [2]Karlsruhe Institute of Technology — [3]National Institute for Environmental Studies, Tsukuba, Japan

Previously, we successfully deployed an EM27/SUN Fourier transform spectrometer on research vessels to measure the column-averaged mixing ratios of CO_2, CH_4 and CO above the ocean. Here, we report on its first deployment on a commercial cargo vessel paving the way towards autonomous, ship-borne operations for the validation of satellite observations as well as monitoring and quantification of anthropogenic emission sources. For this purpose, we have supplemented the setup with a VIS spectrometer for simultaneous NO_2 measurements, a tracer of fossil combustion. The new spectrometer setup is particularly aimed at validating upcoming greenhouse gas monitoring satellites designed for measuring CO_2 together with NO_2.

Since mid-September 2023, the instrument is deployed on a commercial vessel, traveling back and forth along the East Coast of Japan. The current study focuses on testing the autonomous operations and on acquiring a dataset that allows us to evaluate the potential for identifying anthropogenic emission sources from Japan and the upwind Asian continent using the ratio between CO_2 and NO_2.

UP 3.4 Tue 11:45 ELP 6: HS 4

Portable ground-based scattered sunlight spectrometer for carbon dioxide and methane measurements — •Lukas Weis[1], Benedikt Löw[1], Ralph Kleinschek[1], Tobias Schmitt[1], Frank Hase[2], and André Butz[1] — [1]Institute of Environmental Physics, Heidelberg University, Germany — [2]Institute for Meteorology and Climate Research, Karlsruhe Institute of Technology, Germany

As atmospheric greenhouse gases continue to increase, there is a strong interest in understanding their sources and sinks. Quantifying urban emissions is vital to mitigating human-induced climate change. Our ground-based 'reflected sunlight' approach offers sensitivity to horizontal greenhouse gas distributions across kilometers, bridging the gap between localized in-situ and regional total column measurements.

We've adapted a portable EM27/SUN Fourier transform spectrometer (EM27/SCA) for carbon dioxide (CO_2) and methane (CH_4) retrieval from ground-scattered sunlight within the NIR spectral range. Deployed in an elevated position the EM27/SCA points into a source region along a multi-kilometer horizontal slant path. In 2022 the prototype demonstrated good agreement with CLARS-FTS during side-by-side measurements overlooking the Los Angeles Basin in California, USA.

We present results from this campaign and ongoing work on our second-generation instrument. The most notable improvement is a modular tracking system with optical fiber coupling, enhancing both flexibility and field of view homogenization to reduce the impact of target inhomogeneity on retrievals.

UP 4: Members' Assembly

Time: Tuesday 12:30–13:15 Location: ELP 6: HS 4

(for members of PA Environmental Physics)

UP 5: Cryosphere and Arctic Oceans

Time: Wednesday 11:00–12:30 Location: ELP 6: HS 4

Invited Talk UP 5.1 Wed 11:00 ELP 6: HS 4

Melting from below: An abrupt transition in Antarctic sea ice-ocean system — •Alexander Haumann[1,2] and et al.[3] — [1]Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany — [2]Ludwig Maximilian University of Munich, Munich, Germany — [3]other institutions

After increasing for more than three decades, Antarctic sea ice extent rapidly declined in 2015/16 and exhibits multiple record minima since. This rapid decline has been unexpected and raises the question if global warming has now reached the high-latitude Southern Ocean. In my talk, I will provide evidence that Antarctic sea ice experienced an abrupt transition from a high to low extent state due to a complex interaction with the ocean. I will show that a combination of deep water warming, a signal that is expected from global climate change, and surface ocean destabilization abruptly shifted the ice-ocean system to a new state, with wide implications for the ecosystems and the Antarctic Ice Sheet, and possibly the global climate.

UP 5.2 Wed 11:30 ELP 6: HS 4

Analyzing ^{39}Ar depth profiles in the Arctic Ocean with the new ArTTA measuring technique — •Carl Kindermann[1], Yannis Arck[1], David Wachs[1], Julian Robertz[2], Markus Oberthaler[2], and Werner Aeschbach[1] — [1]Institute of Environmental Physics, Heidelberg University, Heidelberg, Germany — [2]Kirchhoff-Institute for Physics, Heidelberg University, Heidelberg, Germany

Timescales of ventilation of the Arctic Ocean are still only poorly known. The commonly used tracers for ocean ventilation studies like CFCs and SF_6 are limited to young water masses that occur either close to the surface or in highly ventilated deep waters. The radioisotope ^{39}Ar with its half-life of 268 years covers time scales of 50 to 1000 years, perfectly suited for the investigation of ventilation timescales of deep and intermediate water masses. The new measurement technique called Argon Trap Trace Analysis (ArTTA) is based on quantum-optical methods to catch and count single ^{39}Ar atoms. In contrast to the previously used low-level counting method, which required about 1000 liters of water, ArTTA only requires sample sizes of a few liters of ocean water. The benefit of ArTTA for ocean studies is evident by enabling a better resolution of the water column at great depths. This contribution presents results of ^{39}Ar depth profiles analyzed in the project Ventilation and Anthropogenic Carbon in the Arctic Ocean (VACAO), which is part of the Synoptic Arctic Survey carried out in summer 2021 (SAS21). Samples, taken in the Nansen, Amundsen and Makarov Basins, were measured with ArTTA.

UP 5.3 Wed 11:45 ELP 6: HS 4

Snowdepth on Antarctic Sea Ice Retrieved from Microwave Satellite Data — •Christian Melsheimer and Gunnar Spreen — Institute of Environmental Physics, University of Bremen, Bremen, Germany

Snow on sea ice has a large effect on heat and energy fluxes because it is a strong thermal insulator and is very bright; a thick snow layer even influences the freeboard of the underlying ice. Therefore, comprehensive and up-to-date satellite-based data about the variable snow layer on sea ice are very much sought after. Until now, more research has gone into snow on Arctic sea ice, and also the amount of direct snow measurement data from the Arctic is much larger than the amount of data from the Antarctic.

We have applied an existing snow depth retrieval for *Arctic* sea ice without modifications to *Antarctic* sea ice. This retrieval method uses the brightness temperatures at 10 and 17 GHz from the satellite radiometer AMSR2 (Advanced Microwave Scanning Radiometer, on the Japanese Satellite GCOM-W). We have compared snow depth data on Antarctic sea ice thus retrieved with airborne snow depth measurements from two flight campaigns (Operation Ice Bridge, OIB). This showed that the satellite retrieval produces meaningful results but strongly underestimates the snow depth. Therefore, we now train the retrieval method with Antarctic snow depth measurements, preferably from one of the already mentioned OIB flights and compare the results with independent snow depth measurements.

UP 5.4 Wed 12:00 ELP 6: HS 4

Bromine explosions and catalytic ozone depletion in the Arctic spring-time boundary layer — •Stefanie Falk[1,2], Luca Reissig[1], Andreas Richter[3], Hans-Werner Jacobi[4], and Björn-Martin Sinnhuber[1] — [1]Karlsruher Institut für Technologie — [2]Ludwig-Maximilians-Universität München — [3]Institut für Umweltphysik, Universität Bremen — [4]Institute of Environmental Geosciences (IGE), Université Grenoble Alpes / CNRS / Grenoble INP / INRAE / IRD

Ozone depletion in the polar boundary layer is observed frequently during springtime and is related to an enhancement of reactive bromine. Consequently, increased amounts of volume mixing ratio and vertical column densities of BrO have been observed by in situ observation, ground-based and airborne remote sensing, and satellites. Such activated reactive bromine serves as a source of tropospheric BrO at high latitudes, which otherwise is underestimated in global models. We have implemented a treatment of reactive bromine deposition, release, and recycling on sea ice and snow-covered terrestrial surfaces in the global chemistry-climate model ECHAM/MESSy Atmospheric Chemistry (EMAC).

Within the BromoPole project, we will compare EMAC model predictions with bromide concentrations determined in snow samples taken at Spitsbergen (Ny-Ålesund) and BrO observations from satellite (e.g. TROPOMI) and improve the modeled AirSnow mechanism in EMAC. Possible applications in ICON will be explored.

UP 5.5 Wed 12:15 ELP 6: HS 4

Applications of ^{39}Ar-ATTA in Alpine ice samples - surface ages and constraints on diffusion — •Joshua Marks[1], David Wachs[1,2], Pascal Bohleber[3,4], Andrea Fischer[3], Yannis Arck[1], Martin Stocker[3], Susanne Preunkert[1,5], Markus Oberthaler[2], and Werner Aeschbach[1] — [1]Institute of Environmental Physics, Heidelberg, Germany — [2]Kirchhoff-Institute for Physics, Heidelberg, Germany — [3]Institute for Interdisciplinary Mountain Research, Innsbruck, Austria — [4]Ca' Foscari University of Venice, Venice, Italy — [5]Institut des Géosciences de l'Environnement (IGE), Grenoble, France

In the study of alpine ice cores, dating with radiometric methods is an important tool. Common tracers used for dating like ^{3}H, ^{210}Pb and ^{14}C do not cover the important age range of several 100 years. ^{39}Ar with its half-life of 269 years is well suited for dating between 50 and 1000 years. However, due to its low abundance of 10-15 a very selective measurement method is needed. This is implemented by the quantum technology of Argon Trap Trace Analysis (ArTTA) which enables ice dating with samples of only few kg of ice.

This work focuses on the further development of the sampling methods and sample preparation for the ArTTA dating tool. Several alpine glaciers have been investigated with surface age profiles. Furthermore, the possible contamination of samples by diffusion of argon into the ice has been addressed and a first estimation of effective magnitude of diffusion was conducted

UP 6: Other Topics

Time: Wednesday 14:30–15:15 Location: ELP 6: HS 4

UP 6.1 Wed 14:30 ELP 6: HS 4

Resource-aware Research on Universe and Matter: Call-to-Action in Digital Transformation — •Ben Brüers — Deutsches Elektronen Synchrotron DESY, Zeuthen

Given the urgency to reduce fossil fuel energy production to make climate tipping points less likely, we call for resource-aware knowledge gain in the research areas on Universe and Matter with emphasis on the digital transformation. A portfolio of measures is described in detail and then summarized according to the timescales required for their implementation. The measures will both contribute to sustainable research and accelerate scientific progress through increased awareness of resource usage. This talk is based on the publication arXiv:2311.01169, which is the result of a three-days workshop on sustainability in digital transformation held in May 2023.

UP 6.2 Wed 14:45 ELP 6: HS 4

Atmospheric Gravity Wave Spectra: A Study Using Lidar Data — •Mohamed Mossad, Irina Strelnikova, Robin Wing, Gerd Baumgarten, Michael Gerding, Jens Fiedler, and Eframir Franco-Diaz — Leibniz Institute of Atmospheric Physics, Kühlungsborn, Germany.

Gravity waves (GWs) play a crucial role in Earth's atmospheric dynamics. The propagation, breaking and dissipation of GWs drive the general circulation of the atmosphere, redistributing energy and momentum through the different layers of the atmosphere. Changes in wind and temperature measured by lidars and other instruments help us understand the spectral properties of GWs, such as their frequencies, amplitudes, and scales. Better understanding of these parameters and the sources that produce GWs is important to model parameterizations of their impact on the average state of the atmosphere.

In this study, we analyze lidar data from Kühlungsborn (54°N, 12°E) and ALOMAR (69°N, 16°E) to examine the GW spectra in the atmosphere. We present a thorough analysis of GW spectra across various atmospheric conditions, focusing on seasonal and altitudinal variations. This work contributes to a deeper comprehension of energy transfer within the atmosphere, bridging theoretical models with empirical observations and offering insights beneficial for climatological research and environmental forecasting.

UP 6.3 Wed 15:00 ELP 6: HS 4

The occurrence and sources of Ni in ambient air particulates using Synchrotron Radiation Based X-ray Fluorescence and X-ray Absorption Near Edge Structure — •Abdallah Shaltout[1], Messaoud Harfouche[2], and Diane Eichert[3] — [1]Spectroscopy Department, Physics Research Institute, National Research Centre, El Behooth St., 12622 Dokki, Cairo, Egypt — [2]Synchrotron-light for Experimental and Scientific Applications in the Middle East (SESAME), P.O. Box 7, Allan 19252, Jordan — [3]ELETTRA Sincrotrone Trieste, Strada Statale, Science Park 34149 Basovizza, Trieste, Italy

High concentrations of Ni in the ambient air might induce carcinogenic effects. The present work aims at investigating the presence of Ni in ambient air particulates using advanced X-ray synchrotron radiation techniques. Total suspended and fine particulates (TSP, PM2.5) were collected from residential and industrial areas of Cairo, Egypt. Quantitative results indicate remarkable high concentrations of Ni in the ambient air particulates which are higher than the annual allowance thresholds as indicated by the world health organization (WHO). Elemental maps of Ni were acquired to unravel the natural spatial distribution of Ni on the filters carrying the ambient air particulates. Complementary X-ray absorption near edge structure (XANES) spectroscopy at the Ni K-edge (8.331 keV) was used to determine Ni speciation. Our results demonstrate that Ni is predominantly found under its divalent oxidation state in the studied ambient air particulates.

UP 7: Posters

Time: Wednesday 16:30–18:30 Location: ELP 6: Foyer

UP 7.1 Wed 16:30 ELP 6: Foyer

Revisiting the question "Why is the sky blue?" — •Anna Lange[1], Alexei Rozanov[2], and Christian von Savigny[1] — [1]Institute of Physics, University of Greifswald, Germany — [2]Institute of Environmental Physics, University of Bremen, Germany

The common answer to the question "Why is the sky blue" is usually Rayleigh scattering. In 1953 Edward Hulburt demonstrated, that the blue colour of the zenith sky at sunset is to 1/3 caused by Rayleigh scattering and to 2/3 caused by ozone absorption. In this study, an approach to quantify the contribution of ozone to the blue colour of the sky for different viewing geometries is implemented using the radiative transfer model SCIATRAN and the CIE XYZ colour system. The influence of ozone on the blue colour of the sky is calculated for solar zenith angles of 10°-90° and a wide range of viewing geometries. For small solar zenith angles, the influence of ozone on the blue colour of the sky is minor, as expected. However, the effect of ozone increases with increasing solar zenith angle. The calculations for the Sun at the horizon confirm Hulburt's estimation with remarkably good agreement. More stratospheric aerosols reduce the ozone contribution at and near the zenith for the Sun at the horizon. The exact contribution of ozone depends strongly on the assumed total ozone column. The calculations also show that the contribution of ozone increases with increasing viewing zenith angle and total ozone column. Variations in surface albedo as well as full treatment of polarised radiative transfer were found to have only minor effects on the contribution of ozone to the blue colour of the sky.

UP 7.2 Wed 16:30 ELP 6: Foyer

Langzeitmessungen von Halogenoxiden in der Arktis: Projektübersicht und erste Ergebnisse — •Bianca Lauster[1,2], Sebastian Donner[1], Udo Friess[2], Ulrich Platt[2], Lucas Reischmann[1], William Simpson[3], Steffen Ziegler[1] und Thomas Wagner[1,2] — [1]Max-Planck-Institut für Chemie, Mainz — [2]Universität Heidelberg — [3]University of Alaska Fairbanks

Die Halogenchemie ist ein zentrales Element des troposphärischen Ozonabbaus im polaren Frühjahr. Entstehungsmechanismen reaktiver Halogene, ihr Transport und deren Wechselwirkungen sind jedoch nicht vollständig verstanden. Darüber hinaus hat das sich ändernde arktische Klima potentiell einen starken Einfluss auf die Halogenaktivierung.

Im Dezember 2023 wurde ein LP-DOAS (Lang-Pfad Differentielle Optische AbsorptionsSpektroskopie) Instrument in Utqiagvik (Barrow), Alaska, für Langzeitmessungen aufgebaut. Das Instrument wurde speziell für seinen vorherigen Einsatz an der deutschen Forschungsstation Neumayer in der Antarktis konzipiert, wo es über zwei Jahre lang erfolgreich betrieben wurde (Nasse, 2019). Mit

den jetzigen Messungen in der Arktis sollen die komplexen Wechselwirkungen zwischen Halogenen und anderen Spurengasen, wie z.B. NO2, auch unter dem Einfluss anthropogener Luftverschmutzung näher untersucht werden.

Um die Datenqualität zu verbessern, wurde der Instrumentenaufbau vorab basierend auf den Erkenntnissen aus der vorangegangenen Messkampagne optimiert. Hier werden die Instrumenteneigenschaften sowie die Zielsetzung des Projekts präsentiert und erste Ergebnisse der LP-DOAS Daten mit Fokus auf Datenqualität und -analyse gezeigt.

UP 7.3 Wed 16:30 ELP 6: Foyer

Characterisation and deployment of a Pandora DOAS instrument in Heidelberg — •Johannes Hägele, Karolin Voss, Ralph Kleinschek, and André Butz — Institute of Environmental Physics, Heidelberg University, Germany

Over the past five decades, Differential Optical Absorption Spectroscopy (DOAS) has been used successfully for the measurement of various atmospheric trace gases such as O_3 and NO_2. In order to establish a global network of DOAS measurements, NASA and ESA collaborate on the Pandonia Global Network using their custom-built Pandora instruments.

Here, we report on our progress in deploying a Pandora setup at the Institute of Environmental Physics in Heidelberg. The instrument is suitable for both direct sun and moon as well as sky scanning measurements and uses 2 Czerny-Turner spectrometers with a wavelength range of 280-530 nm and 380-900 nm, respectively. It will be set up at the institute's roof close to the city centre. So far, we have optically and electronically characterized the spectrometers using a set of different lamp and dark measurements. For spectrometer 1, the electronic readout induces a spatially oscillatory signal of unknown origin which influences the instrument noise.

UP 7.4 Wed 16:30 ELP 6: Foyer

Single particle polarimetry of volcanic ash in a plasma traps — •Franko Greiner[1], Alexander Schmitz[1], Thor Hansteen[2], and Christian von Savigny[3] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Dynamics of the Ocean Floor, GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany — [3]Institute of Physics, University of Greifswald, Greifswald, Germany

Numerous aspects of volcanic effects on the atmosphere and climate remain poorly understood. A significant but often overlooked factor is the presence of volcanic ash in aerosol plumes, which is typically ignored in satellite observations in the optical spectral range due to limited data on the ash's complex refractive index (CRI). Accurate identification of volcanic ash in these observations requires understanding both the CRI and its variability among different eruptions.

We propose a new, less assumption-dependent laboratory method for measuring the CRI of volcanic ash. Using a plasma trap and assessing angle-resolved Mie scattering of single ash particles, this approach aims to provide high-precision CRIs. The project's main goal is to explore whether the CRI of a specific volcanic event may be determined based on ash amorphicity and chemical composition.

UP 7.5 Wed 16:30 ELP 6: Foyer

Determination of radioactivity levels and radiological hazards of soils from the Bitola region — •Irena Zlatanovska[1], Trajče Stafilov[2], Robert Šajn[3], Bojana Dimovska Gonovska[4], Snežana Dimovska[5], Jovan Janusheski[5], and Lambe Barandovski[1] — [1]Institute of Physics, Faculty of Natural Sciences and Mathematics, Ss Cyril and Methodius University in Skopje, POB 162, 1000 Skopje, Macedonia — [2]Institute of Chemistry, Faculty of Natural Sciences and Mathematics, Ss Cyril and Methodius University in Skopje, POB 162, 1000 Skopje, Macedonia — [3]Geological Survey of Slovenia, Dimičeva ul. 14, 1000 Ljubljana, Slovenia — [4]Scientific Tobacco Institute, St. Kliment Ohridski University, Kičevska bb, 7500 Prilep, Macedonia — [5]Republic Institute for Health Protection, 50 Divizija 6, 1000 Skopje, Macedonia

To determine the radioactivity levels in soil and evaluate the associated radiological impact, 58 topsoil samples from the town of Bitola and its environs were collected. Gamma spectrometry measurements indicated significant variability in activity concentrations, with median values for 40K, 226Ra, and 232Th exceeding global medians. Calculations for the absorbed dose rate and annual effective dose rate were performed to assess radiological health hazards for the residents. The obtained results were statistically processed, and maps of spatial distribution were prepared, clearly indicating the combined influence of geology and human activities on the outcomes.

UP 7.6 Wed 16:30 ELP 6: Foyer

Investigating the size distribution of stratospheric aerosols following volcanic eruptions during the SAGE-I mission from 1979 to 1981 — •Christian Löns, Felix Wrana, and Christian von Savigny — University of Greifswald

As part of my master's thesis, I retrieved particle size information from satellite solar occultation measurements of SAGE-I, which collected data from February 1979 to 1981. The particle size was derived with a fixed distribution width using a Mie code via two aerosol extinction coefficients at 450 nm and 1000 nm. To verify the results, they were compared with in situ particle counter measurements from Laramie. At altitudes of 15 km to 25 km, a good usability of the data set is observed, which improves with an increase in aerosol extinction and thus a lower influence of NO_2 on the 450 nm channel. While the volcanic eruptions of Mt. St. Helens (1980) and Alaid (1981) in the northern mid-latitudes tended to increase the average aerosol size, the tropical volcanic eruptions of Sierra Negra (1979) and Ulawun (1980) led to a reduction in the median radius.

UP 7.7 Wed 16:30 ELP 6: Foyer

Ground-based Hyperspectral Imaging of Greenhouse Gases Using a Physics Inversion Algorithm — •Helge Haveresch, Marvin Knapp, Benedikt Löw, Leon Scheidweiler, Felix Külheim, Ralph Kleinschek, and André Butz — Institute of Environmental Physics, Heidelberg University, Im Neuenheimer Feld 229, 69120 Heidelberg

Emissions of carbon dioxide (CO_2) and methane (CH_4) drive anthropogenic climate change significantly. Monitoring point sources of greenhouse gas emissions is crucial for validating mitigation strategies. We present the results of imaging CH_4 emission plumes from a coal mine in Silesia using a NEO HySpex SWIR-384 hyperspectral camera in a ground-based geometry. The camera is positioned at a distance of kilometres from the source, capturing images in the shortwave infrared (1-2.5 μm) approximately every minute. Methods like the matched filter technique only work well for CO_2 and CH_4 analysis given homogeneous backgrounds. However, based on statistical analysis, this method fails in heterogeneous scenes, as seen at passively degassing volcanoes like Mount Etna, where aerosols accompany gases. To overcome this, we developed a physics-based inversion routine based on the single scattering solution of atmospheric radiative transfer, which retrieves aerosol parameters and measures CO_2 and CH_4 columns. The method shows promising agreement with previous results obtained by the matched filter analysis for homogeneous scenes at the coal mine. For measurements of volcanic CO_2 emission under heterogeneous conditions at Mt. Etna, we discuss implications and challenges.

Working Group on Equal Opportunities
Arbeitskreis Chancengleichheit (AKC)

Agnes Sandner
Sprecherin des AKC
sandner@akc.dpg-physik.de

Overview of Invited Talks and Sessions

(Lecture hall ELP 6: HS 2)

Invited Talks

AKC 1.1	Tue	11:30–12:30	ELP 6: HS 2	**The tragic destiny of Mileva Marić Einstein** — •Pauline Gagnon

Sessions

AKC 1.1–1.1	Tue	11:30–12:30	ELP 6: HS 2	**AKC**
AKC 2	Tue	12:30–13:30	ELP 6: HS 2	**Women in Physics Lunch**

Sessions

– Invited Talks –

AKC 1: AKC

Time: Tuesday 11:30–12:30 Location: ELP 6: HS 2

Invited Talk AKC 1.1 Tue 11:30 ELP 6: HS 2

The tragic destiny of Mileva Marić Einstein — •Pauline Gagnon — CERN, Geneva

What were Albert Einstein's first wife's contributions to his extraordinary productivity in the first years of his career? A first biography of Mileva Marić Einstein was published in Serbian in 1969 but remained largely unknown despite being translated first in German, then in French in the 1990's. The publication of Mileva and Albert's love letters in 1987 revealed how they lived together while two recent publications shed more light on Mileva Marić's life and work. I will review this evidence in its social and historical context to give a better idea of her contributions. In this presentation, I avoid all type of speculation and do not attack Albert Einstein personally, but rather strictly stick to facts. The audience will be able to appreciate why such a talented physicist has been so unkindly treated by history.

AKC 2: Women in Physics Lunch

Time: Tuesday 12:30–13:30 Location: ELP 6: HS 2

Female physicists of all career stages are cordially invited to join our meet-and-greet networking lunch. Diverse and all kinds of interested colleagues are also welcome!

Index of Exhibitors

Exhibition venue
Universität Greifswald, Building ELP 6, 1st Floor, Campus Loefflerstraße, 17489 Greifswald

Exhibition opening hours

Tuesday, February 27	10:30 – 18:00
Wednesday, February 28	10:30 – 18:00
Thursday, February 29	10:30 – 18:00

The entrance is free!

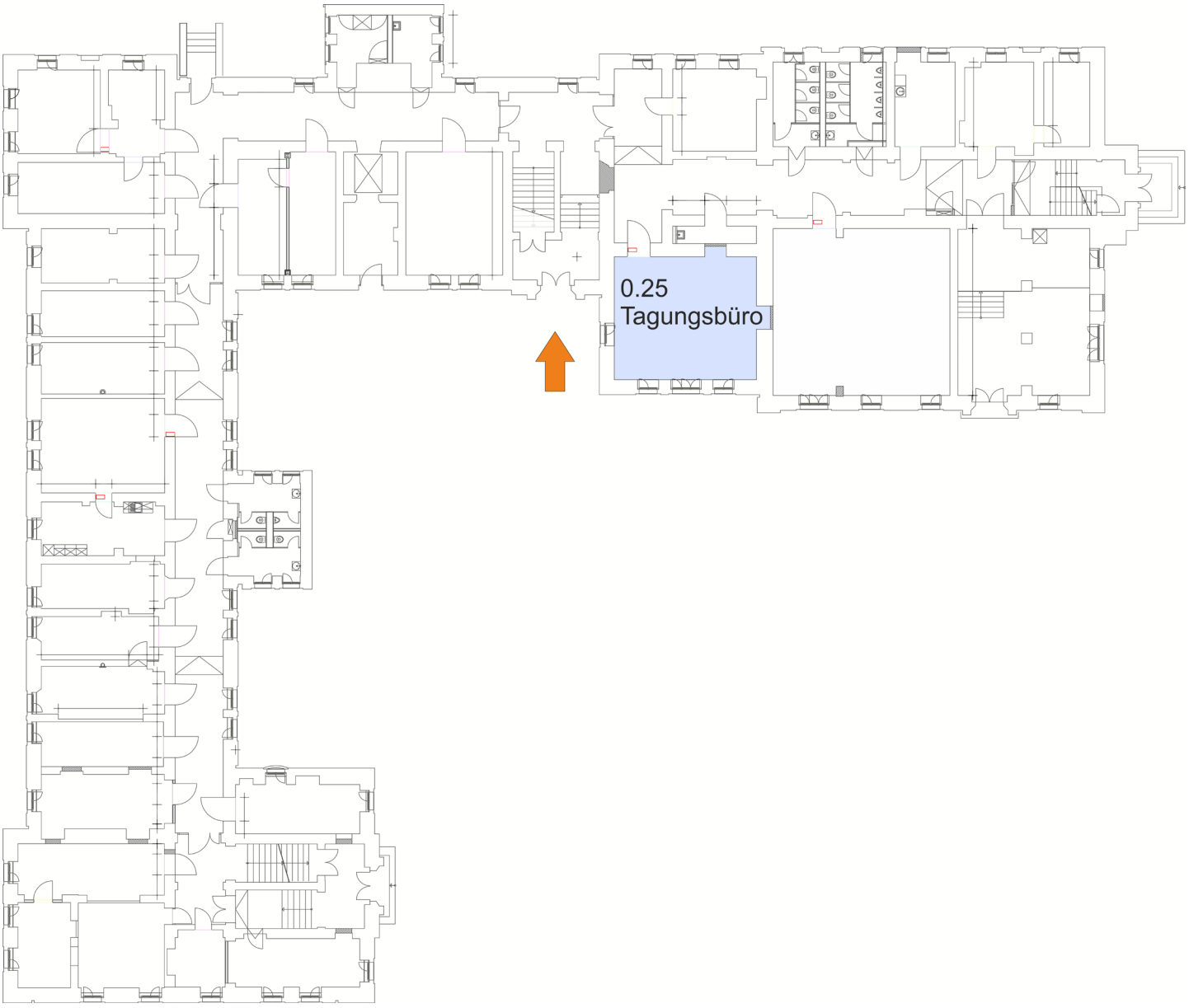
Company — **Booth No.**

Hamamatsu Photonics Deutschland GmbH — **01**
Arzbergerstraße 10, 82211 Herrsching
Our mission is to benefit society through the development of technologies that capture, measure, and generate various types of light.

Wolff Grundlagenforschung mit Muntalin Verlag — **02**
Landstraße 21, Itaslen, 8362 Balterswil, Switzerland
Erstes Buch des Muntalin Verlages (2023): „Neue Physik“ mit Gravodynamik ohne Krummräume, die die lokale ART ersetzt, und mit Weltpotentialtheorie mit statischer Müdlichtkosmologie und „MOND-Brücke“.

THORLABS GmbH — **03**
Münchner Weg 1, 85232 Bergkirchen
Optische & optomechanische Komponenten, Test & Measurement Systeme, optische Tische und Vibrationskontrolle, Nanopositionierungen, Lichtquellen sowie Imaging, Mikroskopie und Life Science Komponenten.

ELP1 Ground Floor (0)



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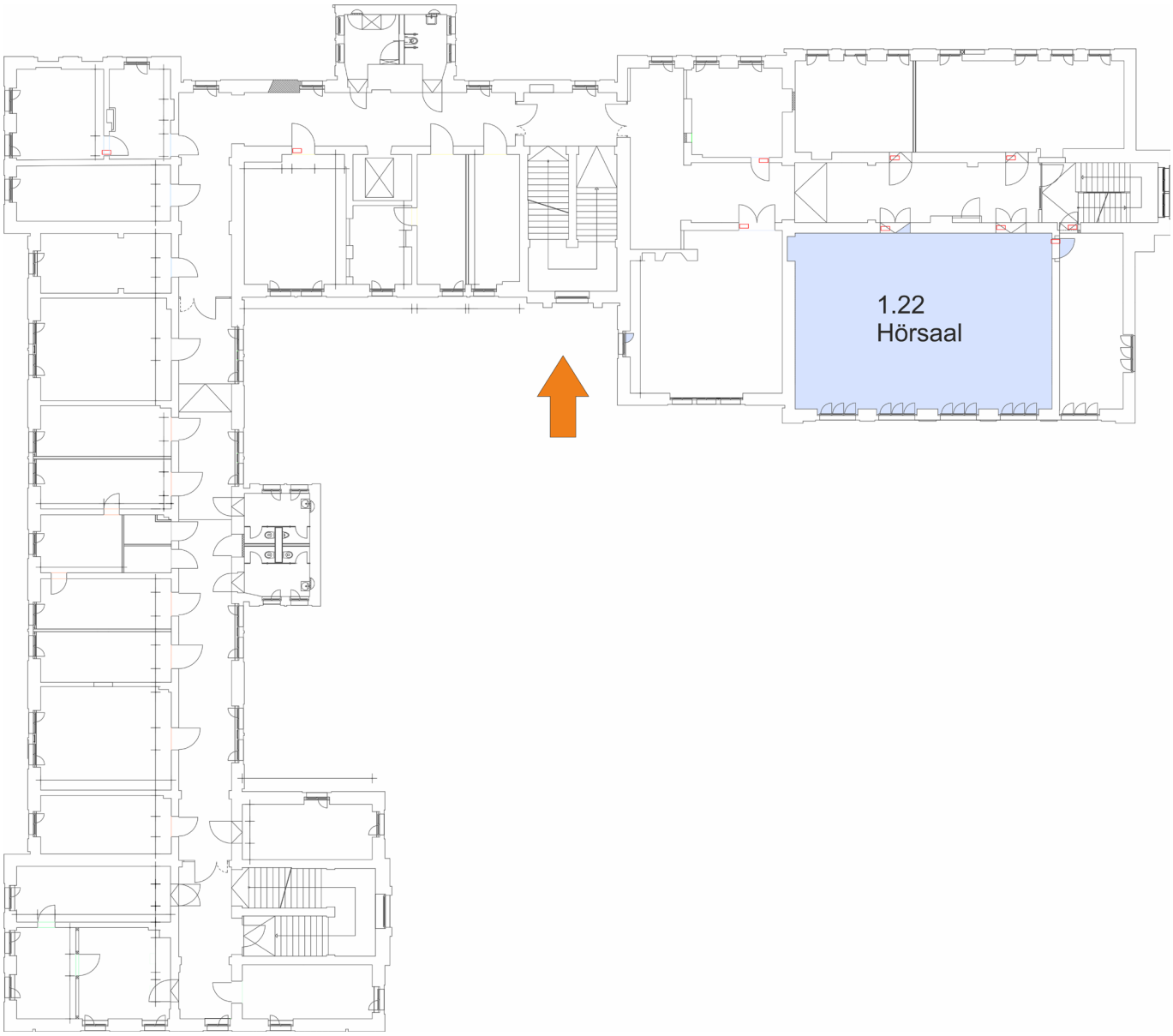

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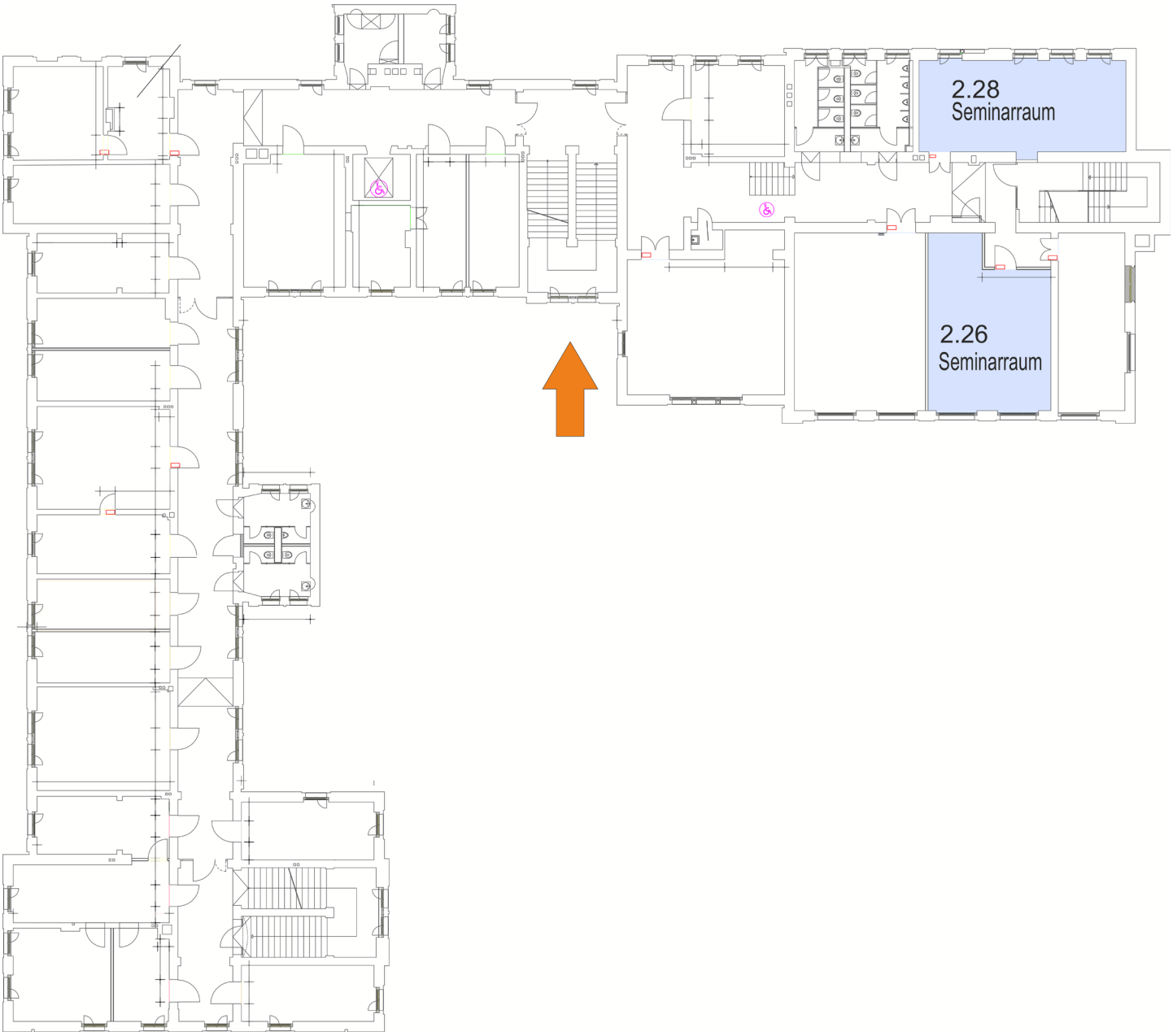

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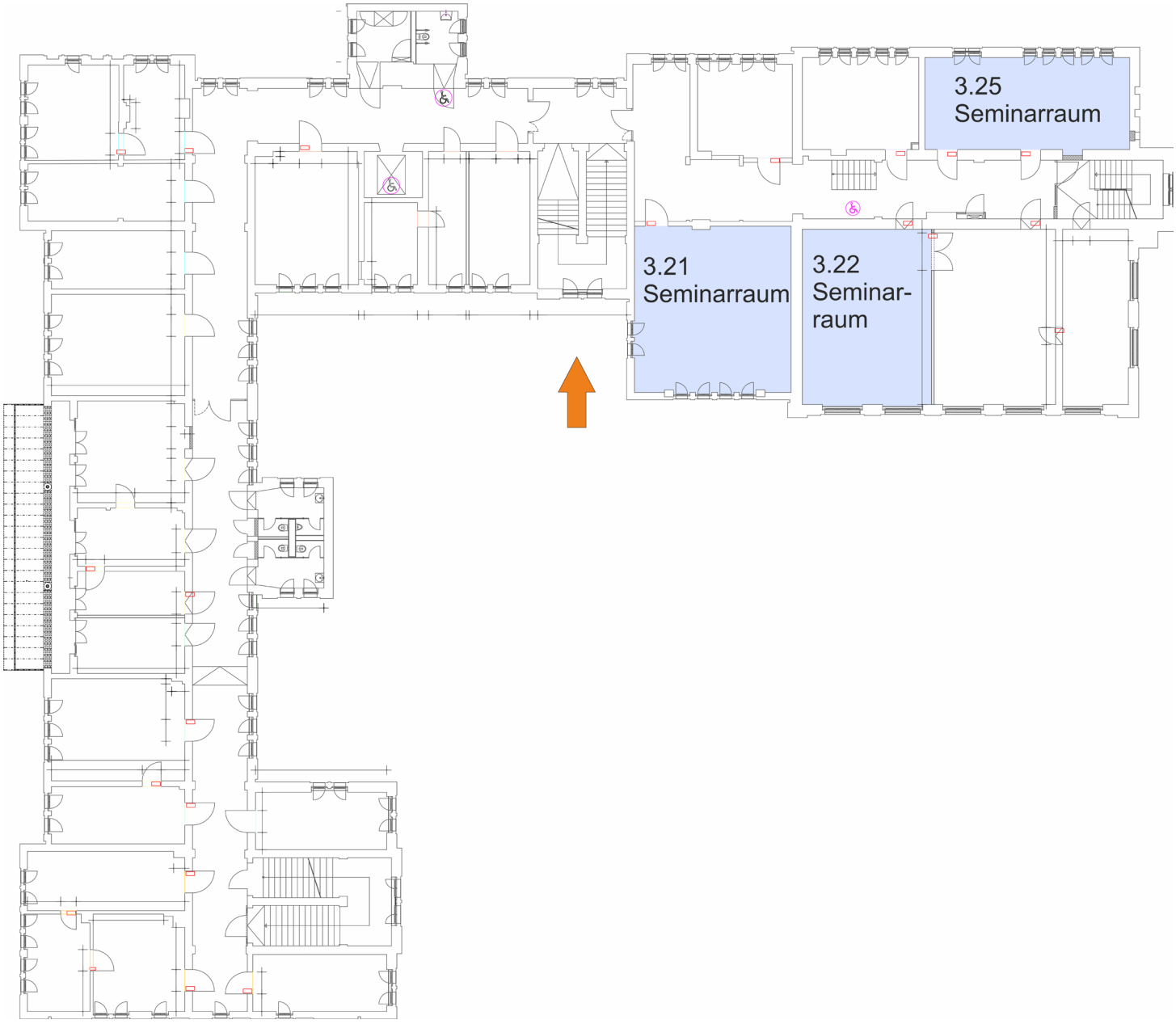
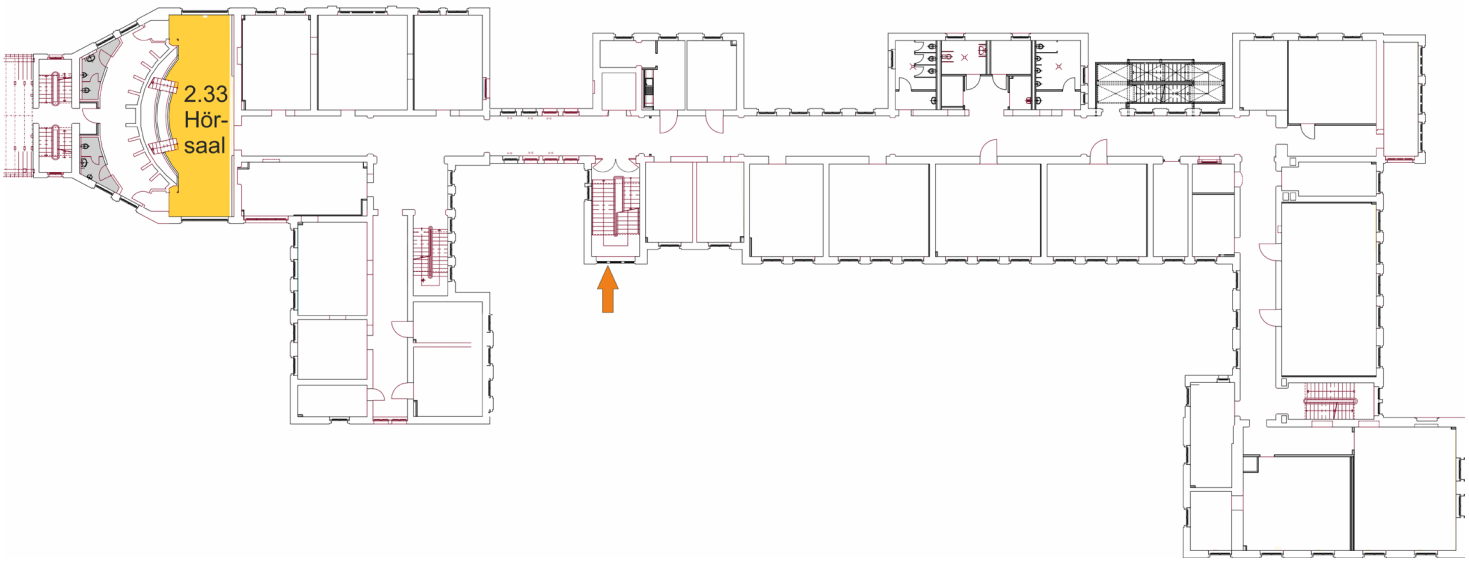
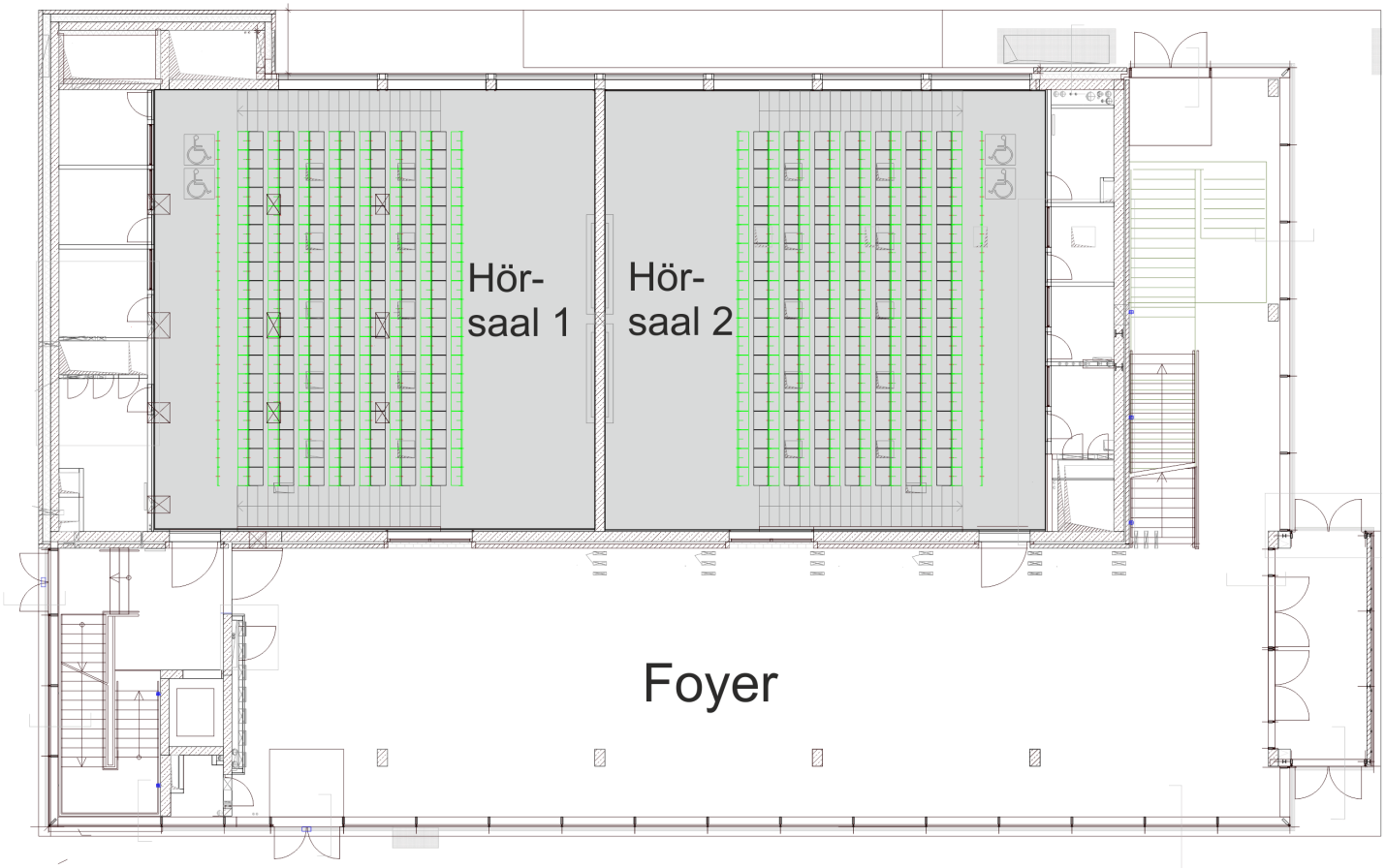


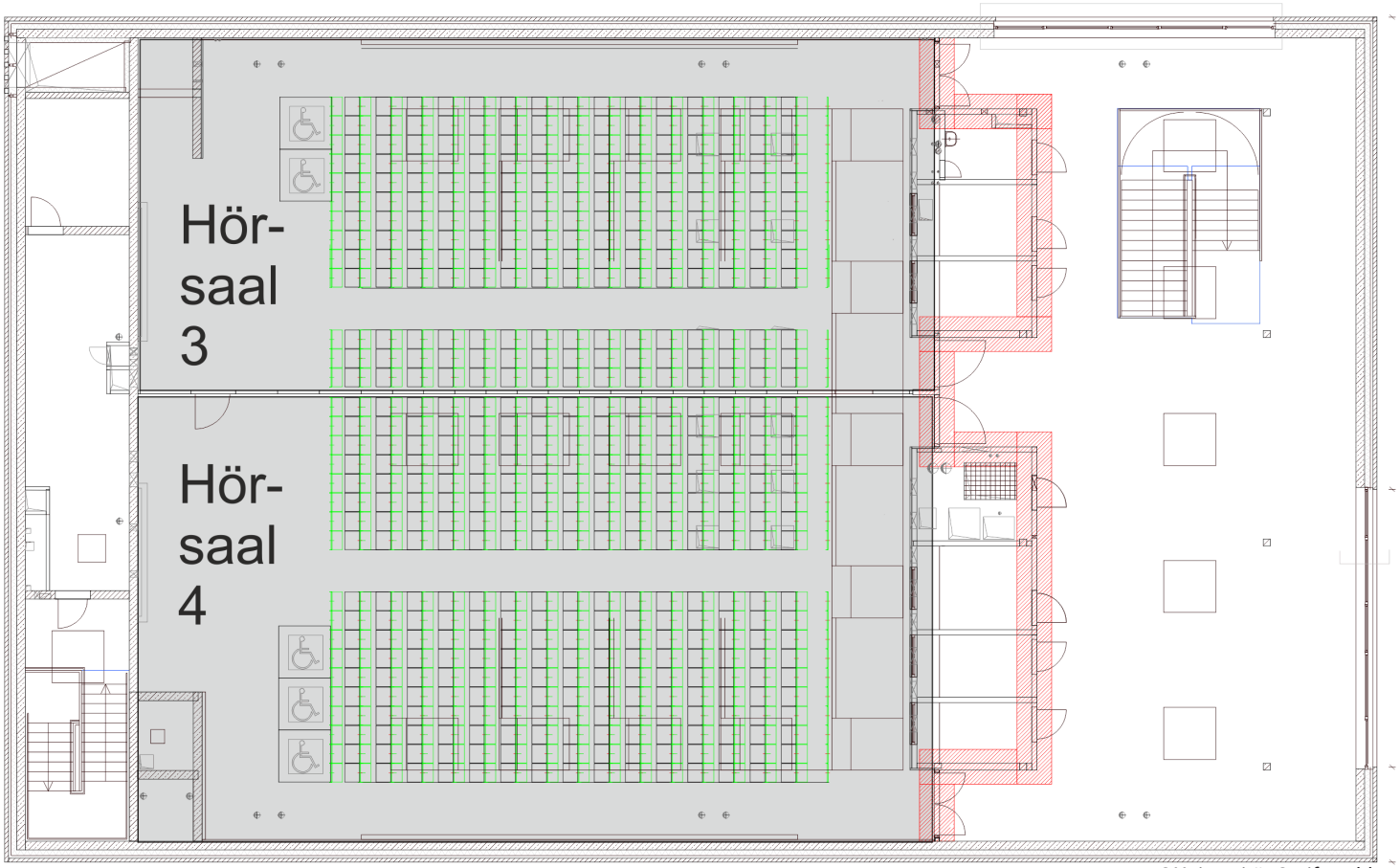
ELP3 2nd Floor (2)



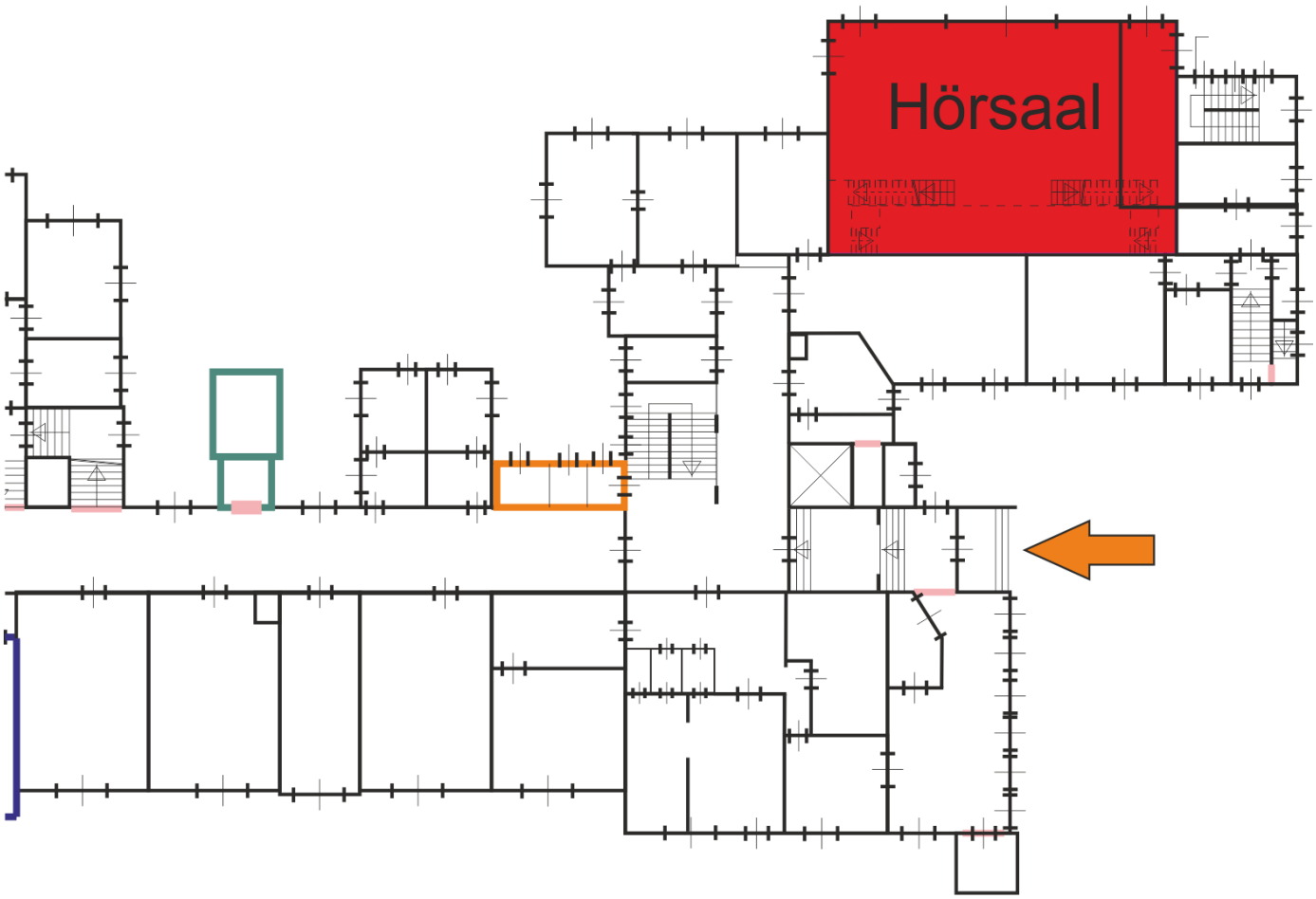
ELP6 Ground Floor (0)



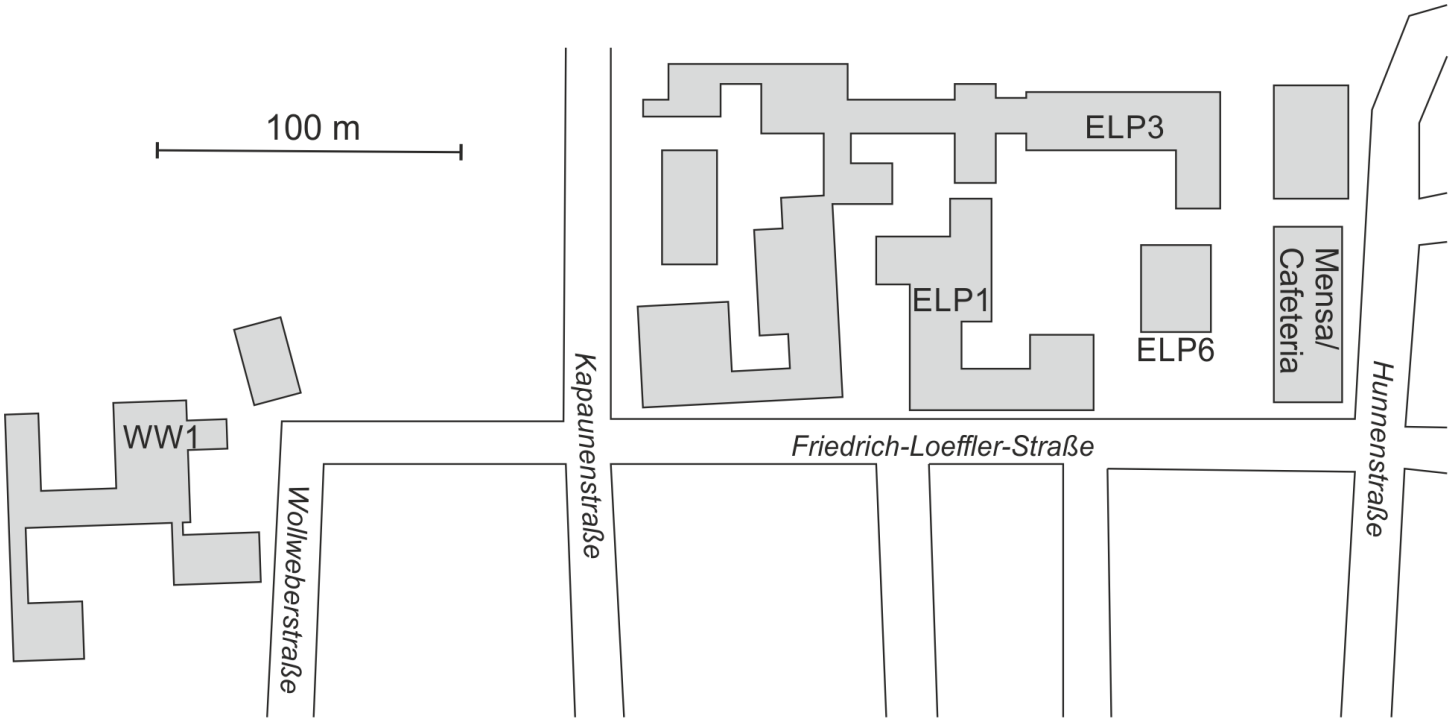
ELP6 1st Floor (1)



WW Ground Floor (0)



Campus Overview



ELP = Ernst-Lohmeyer-Platz
WW = Wollweberstraße

Mensa Beitzplatz
Welcome Evening
(2 km)