Plasma Physics Division
Fachverband Plasmaphysik (P)

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Overview of Invited Talks and Sessions

(Lecture halls ZHG102 and ZHG006; Poster: ZHG Foyer 1. OG)

Plenary Talk of the Plasma Physics Division

PV IX	Thu	9:45–10:30	ZHG011	**Negative hydrogen ion sources - utilizing low temperature plasmas in ITER's neutral beam systems** — •Ursel Fantz, IPP NNBI Team

Invited Talks

P 1.1	Mon	13:45–14:15	ZHG102	**On the way to a fusion power plant** — •Felix Warmer
P 2.1	Mon	13:45–14:15	ZHG006	**Nanosecond pulse generators for gas discharges** — •Tom Huiskamp, Jeroen Van Oorschot, Chiel Ton, Guus Pemen
P 2.4	Mon	14:45–15:15	ZHG006	**Multimodal Diagnostic Approaches and Interactive Analysis of Mode Transitions in the kINPen Plasma Jet Interacting with Surfaces** — •Torsten Gerling, Hans Höft, Sander Bekeschus, Markus M. Becker, Klaus-Dieter Weltmann, Philipp Mattern
P 3.1	Mon	16:15–16:45	ZHG102	**Flux Pumping for High Performance Tokamak Scenarios** — •A. Bock, A. Burckhart, G. Pucella, F. Auriemma, D. Keeling, D. King, C. Challis, V. Igochine, R. Schramm, J. Stober, T. Pütterich, R. Fischer, J. Hobirk, N. Hawkes, H. Zhang, E. Joffrin, M. Baruzzo, C. Piron, P. Jacquet, JET Contributors, the ASDEX Upgrade Team
P 4.1	Mon	16:15–16:45	ZHG006	**Plasma wind tunnel and plasma propulsion** — •Georg Herdrich, Hendrik Burghaus, Clemens Kaiser, Johannes Oswald, Adam Pagan, Alexander Schlitzer, Martin Eberhart, Stefan Löhle, Constantin Traub, Marcel Pfeiffer, Stefanos Fasoulas
P 4.3	Mon	17:00–17:30	ZHG006	**Force profile and charge estimation of a single particle in the sheath of a dual-frequency CCP** — •Jessica Niemann, Viktor Schneider, Holger Kersten
P 5.1	Tue	11:00–11:30	ZHG102	**Mode activity at the Wendelstein 7-X stellarator - Turbulence driven Alfvén modes** — •S. Vaz Mendes, K. Rahbarnia, H. Thomsen, C. Büschel, J. Riemann, C. Slaby, R. Kleiber, A. Könies, M. Borchardt, J.P. Bähner, A. von Stechow, Wendelstein 7-X Team
P 6.1	Tue	11:00–11:30	ZHG006	**Spatially and temporally resolved electric fields in an RF-APPJ measured by E-FISH** — •Inna Orel, Nikita Lepikhin, Zoltan Donko, Dirk Luggenhölscher, Uwe Czarnetzki
P 7.1	Tue	13:45–14:15	ZHG102	**Impurity Transport in Wendelstein 7-X: Basics and Experimental Observations** — •Birger Buttenschön, Thomas Wegner, Thilo Romba, Daihong Zhang, Felix Reimold, Alice Bonciarelli, the W7-X Team
P 8.1	Tue	13:45–14:15	ZHG006	**Status and outlook for CO_2 conversion with microwave plasmas** — •Ante Hecimovic, Christian K. Kiefer, Arne Meindl, Rodrigo Antunes, Ursel Fantz
P 8.4	Tue	14:45–15:15	ZHG006	**Plasma activation of low-energy molecules using the example of nitrogen** — •Mariagrazia Troia, Katharina Wiegers, Andreas Schulz, Matthias Walker

P 9.1	Tue	16:15–16:45	ZHG102	**In-vessel and depth-resolved hydrogen isotope composition analysis in JET by LIBS operated on a remote handling arm** — •Rongxing Yi, Rahul Rayaprolu, Gennady Sergienko, Erik Wuest, Marc Sackers, Timo Dittmar, Sebastijan Brezinsek
P 11.1	Wed	11:00–11:30	ZHG102	**Ab initio path integral Monte Carlo simulation of warm dense matter** — •Tobias Dornheim
P 12.1	Wed	11:00–11:30	ZHG006	**Using dusty plasmas to measure low-electron sticking coefficients of dielectric materials** — •Armin Mengel, Isabel König, Lorin S. Matthews, Franz X. Bronold, Franko Greiner
P 14.1	Wed	13:45–14:15	ZHG006	**Carbon Dioxide Splitting in Dielectric Barrier Discharges: Power Dissipation and Plasma Chemistry** — •Ronny Brandenburg, Milko Schiorlin, Volker Brüser
P 14.4	Wed	14:45–15:15	ZHG006	**Insights into Mode Transitions and Reactive Species Densities in a Micro Cavity Plasma Array** — •David Steuer, Henrik van Impel, Volker Schulz-von der Gathen, Marc Böke, Judith Golda
P 18.1	Thu	11:00–11:30	ZHG102	**Simulating W erosion, transport, and deposition in Ne-seeded discharges in ITER with full-W wall** — •Christoph Baumann, Juri Romazanov, Sebastian Rode, Andreas Kirschner, Sebastijan Brezinsek, Tom Wauters, Richard Pitts
P 19.1	Thu	11:00–11:30	ZHG006	**A plasma process model for high power impulse magnetron sputtering discharges** — •Martin Rudolph, Daniel Lundin, Jon Tomas Gudmundsson
P 20.1	Thu	13:45–14:15	ZHG102	**First applications of the kinetic ion transport module in the EMC3-EIRENE code package** — •Derek Harting, Dirk Reiser, Christoph Baumann, Sebastian Rode, Juri Romazanov, Sebastijan Brezinsek, Heinke Frerichs, Alexander Knieps, Yuhe Feng
P 20.3	Thu	14:40–15:10	ZHG102	**Simulating boundary turbulence in fusion reactors in different confinement, ELM and detachment regimes** — •Wladimir Zholobenko, Andreas Stegmeir, Kaiyu Zhang, Konrad Eder, Jan Pfennig, Christoph Pitzal, Philipp Ulbl, Matthias Bernert, Michael Griener, the ASDEX Upgrade Team
P 21.1	Thu	13:45–14:15	ZHG006	**Vacuum UV spectroscopy at atmospheric pressure plasmas utilizing silicon nitride membranes** — •Luka Hansen, Görkem Bilgin, Hendrik Kersten, Jan Benedikt
P 21.4	Thu	14:45–15:15	ZHG006	**Hybrid fluid/MC simulations of radio-frequency atmospheric pressure plasma jets** — •Mate Vass, Peter Hartmann, Zoltan Donko, Ihor Korolov, Thomas Mussenbrock, Julian Schulze
P 22.1	Thu	16:15–16:45	ZHG102	**High-resolution optical emission spectroscopy of neutral W lines: comparing near-threshold sputtering of W with different crystal orientation in PSI-2** — •Marc Sackers, Oleksandr Marchuk, Stephan Ertmer, Sebastijan Brezinsek, Fredric Granberg, Arkadi Kreter
P 23.1	Thu	16:15–16:45	ZHG006	**Electric Field Determination for Fundamental and Applied Discharge Physics** — •Tomas Hoder

Invited Talks of the joint Symposium Turbulence in Space and Fusion Plasmas (SYSF)

See SYSF for the full program of the symposium.

SYSF 1.1	Wed	13:45–14:15	ZHG101	**Addressing turbulence questions in the Wendelstein 7-X stellarator device - a combined experimental and theoretical approach** — •Josefine Proll, Paul Mulholland, MJ Pueschel, Maikel Morren, Gavin Weir, Ksenia Aleynikova, Adrian von Stechow, Pavlos Xanthopoulos, Gabriel Plunk, the W7-X Team
SYSF 1.2	Wed	14:15–14:45	ZHG101	**Particle acceleration and transport in astrophysical, magnetized turbulent plasmas** — •Martin Lemoine
SYSF 1.3	Wed	14:45–15:15	ZHG101	**Turbulence in the young solar wind, results from Solar Orbiter and Parker Solar Probe** — •Robert Wicks, Utsav Panchal, Julia Stawarz, Stefan Lotz, Du Toit Strauss, Amore Nel
SYSF 1.4	Wed	15:15–15:45	ZHG101	**Digital Solutions for EUROfusion** — •Volker Naulin

Sessions

P 1.1–1.5	Mon	13:45–15:55	ZHG102	**Magnetic Confinment Fusion/HEPP I**
P 2.1–2.6	Mon	13:45–15:45	ZHG006	**Atmospheric Plasmas and their Applications I**
P 3.1–3.4	Mon	16:15–18:00	ZHG102	**Magnetic Confinment Fusion/HEPP II**
P 4.1–4.4	Mon	16:15–17:45	ZHG006	**Low Pressure Plasmas and their Applications I**
P 5.1–5.4	Tue	11:00–12:35	ZHG102	**Magnetic Confinment Fusion/HEPP III**
P 6.1–6.5	Tue	11:00–12:30	ZHG006	**Atmospheric Plasmas and their Applications II**
P 7.1–7.5	Tue	13:45–15:55	ZHG102	**Magnetic Confinment Fusion/HEPP IV**
P 8.1–8.6	Tue	13:45–15:45	ZHG006	**Atmospheric Plasmas and their Applications III**
P 9.1–9.3	Tue	16:15–17:15	ZHG102	**Plasma Wall Interaction**
P 10.1–10.54	Tue	16:15–18:15	ZHG Foyer 1. OG	**Poster Session I**
P 11.1–11.4	Wed	11:00–12:15	ZHG102	**Laser Plasmas**
P 12.1–12.4	Wed	11:00–12:15	ZHG006	**Complex Plasmas and Dusty Plasmas I**
P 13	Wed	12:20–13:20	ZHG102	**Members' Assembly**
P 14.1–14.5	Wed	13:45–15:30	ZHG006	**Atmospheric Plasmas and their Applications IV**
P 15.1–15.6	Wed	16:15–17:45	ZHG102	**Astrophysical Plasmas**
P 16.1–16.5	Wed	16:15–17:30	ZHG006	**Complex Plasmas and Dusty Plasmas II**
P 17.1–17.49	Wed	16:15–18:15	ZHG Foyer 1. OG	**Poster Session II**
P 18.1–18.4	Thu	11:00–12:35	ZHG102	**Codes and Modeling/HEPP**
P 19.1–19.5	Thu	11:00–12:30	ZHG006	**Low Pressure Plasmas and their Applications II**
P 20.1–20.5	Thu	13:45–15:50	ZHG102	**Magnetic Confinment Fusion/HEPP V**
P 21.1–21.6	Thu	13:45–15:45	ZHG006	**Atmospheric Plasmas and their Applications V**
P 22.1–22.3	Thu	16:15–17:35	ZHG102	**Plasma Wall Interaction/HEPP**
P 23.1–23.6	Thu	16:15–18:00	ZHG006	**Atmospheric Plasmas and their Applications VI**

Members' Assembly of the Plasma Physics Division

Wednesday 12:20–13:20 ZHG102
Small snack included :-)

- Report
- Election of the new board members
- Miscellaneous

P 1: Magnetic Confinment Fusion/HEPP I

Time: Monday 13:45–15:55 Location: ZHG102

Invited Talk P 1.1 Mon 13:45 ZHG102

On the way to a fusion power plant — •Felix Warmer — Max Planck Institut für Plasmaphysik

The pursuit of controlled nuclear fusion for sustainable energy generation has long been a focal point of scientific research. Recent demonstration of significant energy gain in fusion experiments has triggered a wave of excitement around the world. In particular, a number of large, privately funded fusion startup companies have emerged that aim to bring fusion power to the grid. Is fusion power within our grasp? This talk will discuss the state-of-the-art in fusion reactor design, explore the remaining challenges, and sketch the way forward, focusing on magnetic confinement and the Stellarator concept.

P 1.2 Mon 14:15 ZHG102

Avenues to steady-state turbulence suppression at Wendelstein 7-X — •Markus Wappl, Sergey Bozhenkov, Jürgen Baldzuhn, Sebastian Bannmann, Håkan Smith, Edgardo Villalobos, and Pavlos Xanthopoulos — Max Planck Institute for Plasma Physics, Greifswald, Germany

Plasma scenarios of transient turbulence suppression, featuring improved energy confinement and high ion temperature, are well known at W7-X. By means of injecting neutral beams or frozen hydrogen pellets, the electron density gradient can be momentarily increased which suppresses ITG-driven turbulent heat transport in the ion channel to nearly zero. However, collapse of the density gradient and return to conventional turbulent heat transport usually occurs after only a few confinement times.

Recent plasma scenario development suggests paths to steady-state turbulence suppression. A newly commissioned steady-state pellet injector along with careful adjustment of microwave heating power allows to maintain the increased density gradient. In addition, a self-ordering process leading to a similar density gradient and turbulence suppresion is observed in microwave heated plasmas at low power, following boronization of the first wall.

This talk provides an overview of a large turbulent transport database obtained by power balance analysis. Several transient and steady-state turbulence-suppressed plasma scenarios are discussed in detail and compared to gyrokinetic transport simulations. An outlook to future steady-state turbulence-suppressed scenarios is given.

P 1.3 Mon 14:40 ZHG102

Introduction of a 3D global non-linear full-f particle-in-cell model for runaway electrons in JOREK — •Hannes Bergstroem[1], Shi-Jie Liu[1], Vindoh Bandaru[2], and Matthias Hoelzl[1] — [1]Max Planck Institute for Plasma Physics, Garching b. M. — [2]Indian Institute of Technology Guwahati, Assam

Disruptions are a major challenge for ensuring reliable tokamak operation. The acceleration of electrons to relativistic energies, so-called *runaway electrons* (REs), being a significant concern for future large scale devices like ITER. Accurately predicting the formation and deposition of REs is critical for optimizing machine design and implementing effective disruption mitigation systems. This requires advanced modeling that captures the interplay between REs and the plasma, including the large-scale MHD activity characteristic of disruptions. The non-linear 3D extended MHD code JOREK provides a powerful framework for investigating disruption and RE dynamics. This talk introduces recent enhancements to JOREK, incorporating a hybrid fluid-kinetic model where REs are represented kinetically and coupled to the non-linear MHD equations through a full-f particle-in-cell approach. The model offers precise insight into the phase space distributions, drift dynamics, and transport and losses of REs in stochastic magnetic fields. Benchmarks are conducted for both 2D and 3D configurations, with results showing good agreement with analytical predictions. Additionally, a particularly challenging non-linear case with high relevance for large tokamaks is presented: a benign termination of REs triggered by a rapid burst of MHD activity.

P 1.4 Mon 15:05 ZHG102

Gyrokinetic instabilities and turbulence in stellarators — •Linda Podavini, Per Helander, Gabriel G Plunk, and Alessandro Zocco — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald, Germany

The stellarator Wendelstein 7-X (W7-X) is designed to achieve reduced neoclassical transport through magnetic field optimization. Its confinement properties are thus predominantly determined by turbulence, which arises from instabilities active at kinetic scales. The stability of these turbulence-driving modes depends on various plasma parameters, such as the strength of temperature and density gradients, the mirror ratio, and the rotational transform of the confining magnetic field, for instance. Adjusting these parameters offers a pathway to optimising performance in W7-X and future stellarators alike. In this contribution, we present numerical investigations of kinetic plasma turbulence in W7-X within the context of gyrokinetic theory, paying attention to possible improvements in operating scenarios and performance. The high sensitivity of these instabilities on plasma parameters underscores the need for a unified theoretical framework capable of providing rapid stability proxies. The theory of upper bounds on the growth rates of local gyrokinetic instabilities addresses this need by offering results that are independent of magnetic geometry and several plasma parameters. However, comparisons with gyrokinetic simulations highlight the crucial role of magnetic geometry in achieving quantitatively accurate results.

P 1.5 Mon 15:30 ZHG102

Reduced kinetic modelling of shattered pellet injection in ASDEX Upgrade — •Peter Halldestam[1], Paul Heinrich[1], Gergely Papp[1], Mathias Hoppe[2], Matthias Hölzl[1], István Pusztai[3], Oskar Vallhagen[3], Rainer Fischer[1], and Frank Jenko[1] — [1]Max Planck Institute for Plasma Physics, Garching b. München, Germany — [2]Royal Institute of Technology, Stockholm, Sweden — [3]Chalmers University of Technology, Göteborg, Sweden

Plasma-terminating disruptions are a critical outstanding issue for reactor-relevant tokamaks. ITER will use Shattered Pellet Injection (SPI) as its disruption mitigation system to reduce heat loads, vessel forces, and to suppress the formation of runaway electrons. In this work we demonstrate that reduced kinetic modelling of SPI is capable of capturing the major experimental trends in ASDEX Upgrade SPI experiments, such as dependence of the radiated energy fraction on neon content, or the current quench dynamics. Simulations confirm the experimental observation of no runaway electron generation with neon and mixed deuterium-neon pellet composition. We also show that statistical variations in the fragmentation process only have a notable impact on disruption dynamics at intermediate neon doping, as was also observed in experiments.

P 2: Atmospheric Plasmas and their Applications I

Time: Monday 13:45–15:45 Location: ZHG006

Invited Talk P 2.1 Mon 13:45 ZHG006

Nanosecond pulse generators for gas discharges — •Tom Huiskamp, Jeroen Van Oorschot, Chiel Ton, and Guus Pemen — Eindhoven University of Technology, Eindhoven, The Netherlands

Gas discharges generated by nanosecond high-voltage pulses have gained attraction for a number of reasons, but mainly because they are very efficient for a variety of (environmental) plasma applications such as air pollution control, nitrogen fixation, synthesis of chemicals, materials processing, plasma medicine and others. Specifically, researchers have noted that the pulse duration and the rise time of the applied high-voltage pulse have a significant influence on the radical yield of the transient plasmas generated with nanosecond pulses; shorter pulses result in higher yields. With the need to study gas discharges generated by these short pulses comes the need to understand how to generate those pulses and to understand the interaction between the pulse source and the discharge. In this contribution, we will explore the different methods with which to generate nanosecond high-voltage pulses, how the interaction between the pulse source and the discharge may influence the source and the discharge and how to optimize the energy transfer from the pulse source to the discharge.

P 2.2 Mon 14:15 ZHG006

Properties of microarcs in atmospheric pressure air in a presence of metal vapour — •Margarita Baeva[1] and Dirk Uhrlandt[2] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Institute of Electrical Power Engineering, University of Rostock, Rostock, Germany

Electric discharges in presence of metal vapours can be found in various applications, e.g. in switching devices and welding arcs. In low-voltage, low-current switching devices, an electric arc in metal vapours occurs during the early contact opening. A bridge of molten metal can be built and it can break at temperatures close to the boiling temperature of the material so that the gap between the electrodes is filled with metal vapour. The metal atoms are easily ionized due to their low ionization potential and a discharge ignites.
In this contribution, we report results from modelling studies of microarcs in atmospheric pressure air-copper vapour mixtures. The effects of copper metal vapour on the microarc properties and plasma chemistry are studied. Findings demonstrate the spatial structure of the microarc and the behaviour of the plasma parameters for various ratios of the air and metal vapour concentrations, and the length of the inter-electrode gap.
The work is funded by the German Research Foundation (DFG) Project number 524731006.

P 2.3 Mon 14:30 ZHG006

modeling of the ion wind for a surface barrier discharge used for gas conversion — •soad mohsenimehr[1], sebastian wilczek[2], thomas mussenbrock[3], and achim von keudell[1] — [1]Experimental Physics II, Reactive Plasmas, Ruhr University Bochum, D*44780 Bochum, Germany — [2]Technische Hochschule Georg Agricola, Bochum, Germany — [3]Chair of Applied Electrodynamics and Plasma Technology, Ruhr University Bochum, D-44780 Bochum, Germany

The ion wind in a surface dielectric barrier discharge (SDBD) plays a crucial role in generating and manipulating the flow field through its electrohydrodynamic force (EHD). This work employs a twin SDBD consisting of an aluminium oxide plate (190*88*0.63 mm) covered by a nickel grid printed on both sides in a comb-like pattern and generated at atmospheric pressure using damped sinusoidal voltage waveforms at kHz frequency. A Schlieren diagnostic was performed and compared with computational fluid dynamic simulation to investigate the flow pattern. This work presents how the EHD force was calculated from a direct time-dependent plasma simulation by the nonPDPSIM platform and incorporated, after proper scaling, into the steady-state flow simulation by COMSOL. Finally, the comparison between numerical simulation and experimental results is reported. It is shown that the origin of the EHD force is not only given by the streamer propagation dynamics but more importantly by the relaxation phase of the boundary region above the dielectric during the decay of the plasma channel.

Invited Talk P 2.4 Mon 14:45 ZHG006

Multimodal Diagnostic Approaches and Interactive Analysis of Mode Transitions in the kINPen Plasma Jet Interacting with Surfaces — •Torsten Gerling[1], Hans Höft[1], Sander Bekeschus[1,2], Markus M. Becker[1], Klaus-Dieter Weltmann[1], and Philipp Mattern[1] — [1]1Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Department of Dermatology and Venerology, Rostock University Medical Center, Rostock, Germany

The dynamic interactions of the effluent of the cold atmospheric pressure plasma jet kINPen and surfaces is investigated, focusing on the identification and characterization of distinct operational modes: conductive, transient, and free modes. By evaluating the influence of the surface distance on the plasma characteristics, the critical role of multimodal diagnostic techniques in monitoring mode shifts is explored including electrical measurements, high speed imaging, optical emission spectroscopy (OES), and acoustic analysis. Each diagnostic method revealed valuable insights into the discharge modes associated with a specific distance of the kINPen to the surface. The individual response of the detection methods to the mode shifts is compared and discussed. As data management emerges as a new challenge and burden in scientific research, this study highlights how leveraging these demands can inspire innovation and enhance scientific discovery. By providing the evaluated data in an interactive fashion, the results are prepared to support an individual exploration.

P 2.5 Mon 15:15 ZHG006

thermal characteristics of microarray DBD in helium — •Yue Cheng[1], Henrik van Impel[1], David Steuer[1], Judith Golda[1], and Marc Böke[2] — [1]Plasma Interface Physics, Ruhr-University Bochum, D-44801 Bochum, Germany — [2]Experimental Physics II: Physics of Reactive Plasmas, Ruhr-University Bochum, D-44801 Bochum, Germany

The urgent demand for efficient and sustainable chemical processes has driven interest in plasma-assisted catalytic methods, particularly for n-butane conversion, for their ability to promote energy-efficient reactions. Reaction kinetics and conversion rates are highly temperature-dependent, making it critical to investigate the effects of elevated temperatures on plasma chemistry. To address this, we optimized our reactor specifically for high-temperature applications. The reactor incorporates a neodymium magnet embedded in a MACOR carrier as the grounded electrode. A heating system positioned beneath the magnet, capable of reaching up to 350°C. A 40μm zirconium dioxide dielectric layer separates the magnet from a nickel grid, which is cut into two 1*1 cm squares with 1 mm gaps featuring substructures of 100 μm and 150 μm. The entire assembly is stabilized using a quartz frame and cover. Experimental results reveal a significant increase in rotational temperature with rising discharge surface temperature, with larger cavity structures exhibiting higher rotational temperatures. This temperature potentially reduces the activation energy for n-butane reactions, thereby enhancing reaction rates and promoting intermediate formation. This work is supported by DFG within SFB1316 (A6).

P 2.6 Mon 15:30 ZHG006

Tuning plasma chemistry by various excitation mechanisms for the H_2O_2 production of atmospheric pressure plasma jets — •Steffen Schüttler, Niklas Eichstaedt, and Judith Golda — Ruhr-University Bochum, Universitätsstraße 150, 44801 Bochum, Germany

Atmospheric pressure plasmas (APPJs) are widely used in various fields of research and applications. There are plenty of different APPJs designed with various geometries and excitation mechanisms ranging from μs and fast ns pulses pulsed at kHz frequencies to RF-driven waveforms. A direct comparison of these APPJs is challenging as the different excitation mechanisms at different geometries are barely comparable. In this work, a capillary plasma jet was used that is operable at kHz pulsing with a high voltage pulse with μs or ns rise time and a sinusoidal voltage pulse at 13.56 MHz (RF) at the same plasma jet geometry [1]. The effect of the excitation mechanisms on the production of H_2O_2 was investigated by treating liquids and measuring the H_2O_2 concentration in the treated liquid. The plasma jet is operable under all excitation mechanisms up to a plasma power of 1.5 W. An increased humidity admixture and higher plasma powers lead to enhanced H_2O_2 production under all excitation mechanisms. The fast ns pulses and the RF operation show similar results, while the μs operation is less effective.

This work is supported by the DFG within CRC 1316 (Subproject B11, project number 327886311).

[1] S. Schüttler et al 2025 J. Phys. D: Appl. Phys. 58 025203

P 3: Magnetic Confinment Fusion/HEPP II

Time: Monday 16:15–18:00 Location: ZHG102

Invited Talk P 3.1 Mon 16:15 ZHG102
Flux Pumping for High Performance Tokamak Scenarios — •A. Bock[1], A. Burckhart[1], G. Pucella[2], F. Auriemma[2], D. Keeling[3], D. King[3], C. Challis[3], V. Igochine[1], R. Schramm[1], J. Stober[1], T. Pütterich[1], R. Fischer[1], J. Hobirk[1], N. Hawkes[3], H. Zhang[1], E. Joffrin[4], M. Baruzzo[2], C. Piron[2], P. Jacquet[3], JET Contributors[5], and the ASDEX Upgrade Team[6] — [1]MPI for Plasma Physics, Garching, Germany — [2]ENEA, Frascati, Italy — [3]CCFE, Abingdon, United Kingdom — [4]CEA, Saint-Paul-lez-Durance, France — [5]see author list of J. Mailloux et al. 2022 Nucl. Fusion — [6]see author list of H. Zohm et al., 2024 Nucl. Fusion

Viable tokamak fusion power plant scenarios must exhibit high energy confinement and magnetohydrodynamic (MHD) stability. To this end, the anomalous redistribution of magnetic flux caused by a central continuous self-regulating saturated MHD mode ("flux pumping") can be of great benefit: it clamps the central safety factor q to 1, i.e. limits the core magnetic field line helicity, thereby preventing the occurrence of periodic reconnection events known as sawtooth crashes which can take place whenever $q < 1$. This not only avoids the performance-degrading crashes, but can also prevent secondary resistive instabilities and their potentially disastrous consequences. Ultimately, flux pumping can result in a peaked plasma current profile just shy of sawteeth, giving additional stability against ideal MHD instabilities.

This contribution will present recent experimental evidence of flux pumping from the ASDEX Upgrade and JET tokamaks, including initial modelling results.

P 3.2 Mon 16:45 ZHG102
Hybrid kinetic-MHD and gyrokinetic simulations of the fishbone instability with JOREK and ORB5 — •Felix Antlitz[1], Xin Wang[1], Matthias Hoelzl[1], Guido Huijsmans[2,3], Philipp Lauber[1], Thomas Hayward-Schneider[1], and Alexey Mishchenko[4] — [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 — [4]Max Planck Institute for Plasma Physics, Greifswald, Germany

Energetic particles (EPs) will play a central role in future burning plasma experiments, as they can strongly interact with the bulk plasma and drive magnetohydrodynamic (MHD) instabilities. For instance, the so called fishbone instability is the result of an internal kink mode destabilized by EPs in tokamaks. In this contribution, we first describe numerical simulations using the nonlinear extended MHD code JOREK, whose kinetic module is used to include EPs with a particle-in-cell technique. JOREK uses a full-f formulation for the EPs and evolves the MHD equilibrium consistently in time. Second, results from simulations with the global electromagnetic gyrokinetic code ORB5 are presented. This uses a gyrokinetic (or drift-kinetic) description not only for the fast ions, but also for the thermal ions and electrons. The two codes are run in both the linear and nonlinear regimes and the effect of the differences between the two models implemented in the codes are discussed.

P 3.3 Mon 17:10 ZHG102
Progress of Machine Learning-based Real Time Control Applications and SPI Shard Tracking at ASDEX Upgrade — •Johannes Illerhaus[1,2], Wolfgang Treutterer[1], Bernhard Sieglin[1], Alexander Bock[1], Rainer Fischer[1], Matthias Gehring[1], Paul Heinrich[1,2], Ondrej Kudlacek[1], Mohammad Miah[1,2], Gergely Papp[1], Tobias Peherstorfer[3], Thomas Zehetbauer[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 *NF* 62 042006

Machine Learning (ML) is a versatile tool with unique benefits in different applications of magnetic confinement fusion research, particularly in plasma control. This contribution will discuss the progress of integrating ML models into **A**SDEX **U**pgrade's (**AUG**'s) **D**ischarge **C**ontrol **S**ystem (**DCS**) and towards an ML-based automated video analysis of a **S**hattered **P**ellet **I**njection (**SPI**) dataset from a test series in search of the optimal setup configuration for the ITER SPI system. A focus will be put onto the DCS integration, where a generic pipeline for quick integration of different ML models as augmentations to the DCS was constructed using real time GPU inference. The pilot project of this pipeline is a real-time capable high-fidelity electron density profile reconstructor, which now runs in routine operation during the ongoing AUG experimental campaign.

P 3.4 Mon 17:35 ZHG102
Neural Networks as Solution Ansatz for the Ideal Magnetohydrodynamic Equilibrium Problem — •Timo Thun[1], Andrea Merlo[2], and Daniel Böckenhoff[1] — [1]Max-Planck-Institute for Plasma Physics, Wendelsteinstraße 1, 17491 Greifswald, Germany — [2]Proxima Fusion, Am Kartoffelgarten 14, 81671 Munich, Germany

Quick and accurate solvers for the fixed-boundary ideal magnetohydrodynamic (MHD) equilibrium problem in non axisymmetric magnetic fields can accelerate stellarator optimisation, facilitate high-fidelity real-time control and enable other data-driven algorithms. Unfortunately, current MHD equilibrium solvers either require high computational wall-time or suffer from a lack of accuracy. Solvers based on Neural Networks (NN) 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, using a dataset calculated by conventional solvers and the ideal MHD equilibrium force-residual. Training without a dataset removes implicit biases of its solution strategy and avoids computational costs associated with its creation. We present simple NN models trained solely on the physics-based force residual that achieve comparable or better flux surface averaged force residuals than conventional solvers.

P 4: Low Pressure Plasmas and their Applications I

Time: Monday 16:15–17:45 Location: ZHG006

Invited Talk P 4.1 Mon 16:15 ZHG006
Plasma wind tunnel and plasma propulsion — •Georg Herdrich, Hendrik Burghaus, Clemens Kaiser, Johannes Oswald, Adam Pagan, Alexander Schlitzer, Martin Eberhart, Stefan Löhle, Constantin Traub, Marcel Pfeiffer, and Stefanos Fasoulas — Institut für Raumfahrtsysteme, Pfaffenwaldring 29, 70569 Stuttgart

More than 4 decades of experience have been gained in the field of electric propulsion (EP). Respective developments are summarized and foremost results are highlighted. The types of EP systems are not considered as to be competitive as it is shown by system analyses. Correspondingly, ion thrusters, Hall thrusters, thermal arcjets, or magnetoplasmadynamics (MPD) thrusters are preferable depending on the mission. Several advanced plasma propulsion designs have been developed and characterized. Among them are TIHTUS, steady state applied field MPD thrusters, PPTs, IEC-based thrusters and advanced Helicons. These devices have been characterized and show potential for future missions. With the heritage in high-power EP it was a train of thought to modify these such that they could be operated e.g. with air to emulate high enthalpy flows. Four plasma wind tunnels are in operation enabling modeling verification, the characterization and qualification of materials and the development of instrumentations (flight). The talk will also highlight the CRC ATLAS assessing VLEO. E.g. advanced Helicon-based thrusters are candidates for air breathing EP. ATLAS is far beyond: There are aspects as material characterization, modeling, enabling technologies and mission application.

P 4.2 Mon 16:45 ZHG006

Characterization of E- to H-mode transition in inductively coupled argon-hydrogen plasma — •Marimel Mayer, Mikhail Pustylnik, Hubertus Thomas, and Daniela Zander — DLR Institut für Materialphysik im Weltraum, Cologne, Germany

Hydrogen-containing plasma is a promising alternative for CO_2 emission-free iron ore reduction [1]. In many applications, operation of inductively coupled plasma in the H-mode is favorable for higher process rates [2]. A low-temperature inductively coupled argon-hydrogen plasma is characterized at the transition from E- to H-mode to determine plasma parameters for iron ore reduction processes.

A modified Gaseous Electronics Conference reference cell with a radio-frequency antenna powered at 13.56 Hz serves as plasma reactor [3]. Operating pressures are in the range of 5 Pa to 50 Pa in an argon-hydrogen (9:1) gas mixture. The plasma is monitored during the mode transition by an inline voltage, current and phase measurement, optical emission spectroscopy and microwave interferometry. Consequently, transition threshold powers, plasma densities, hydrogen dissociation degrees and electron temperatures are evaluated.

[1] Sabat, K.; Murphy, A. doi: 10.1007/s11663-017-0957-1 (2017)
[2] Ahr, P. et al. doi: 10.1088/0963-0252/24/4/044006 (2015)
[3] Miller, P. et al. doi: 10.6028/jres.100.032 (1995)

Invited Talk P 4.3 Mon 17:00 ZHG006

Force profile and charge estimation of a single particle in the sheath of a dual-frequency CCP — •Jessica Niemann, Viktor Schneider, and Holger Kersten — Institute of Experimental and Applied Physics, Christian-Albrechts-University, Kiel, Germany

Optically trapped microparticles have emerged as valuable non-invasive probes for exploring plasma environments. Using optical tweezers, particle probes can be positioned in regions such as the sheath, which are often inaccessible by conventional diagnostics, enabling precise investigations of local plasma properties. In this study, force profiles acting on trapped microparticles are measured in the sheath of a dual-frequency capacitively coupled plasma (CCP). The discharge is generated by the superposition of two harmonics (13.56 MHz and 27.12 MHz) with a variable phase angle between them. By systematically varying the phase angle, parameters such as the sheath edge position, the maximum electric field force, and the evolution of the particle charge are determined. Additionally, the averaged particle charge is independently estimated by calculating the mechanical work required to move the particle through the sheath, providing a benchmark for evaluating electric field models. Comparisons with models, including matrix sheath theory and Child-Langmuir law, as well as simulation results, reveal good agreement and validate the potential of this approach as suitable diagnostic.

P 4.4 Mon 17:30 ZHG006

Plasma spectroscopy with a mid-infrared optical frequency comb — Ibrahim Sadiek[1,2], Norbert Lang[1], and •Jean-Pierre H. van Helden[1,2] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Faculty of Physics and Astronomy, Ruhr University Bochum, Bochum, Germany

Non-thermal molecular plasmas play a crucial role in numerous industrial processes and hold significant potential for driving essential chemical transformations. Precise information on the molecular composition of the plasma, on the absolute concentrations and temperatures of the reactive species in the plasma, their population distribution among the quantum states and their reaction kinetics is essential for understanding and optimizing plasma processes. We develop and apply frequency comb-based spectroscopy techniques, offering a unique combination of broad bandwidth and high spectral resolution, enabling the simultaneous detection of multiple species in the plasma. We report on an air-spaced virtually imaged phased array (VIPA) spectrometer that resolves the modes of a mid-infrared frequency comb with a repetition rate of 250 MHz [1]. We demonstrate its capabilities by measuring high-resolution spectra of molecular species generated in plasmas containing hydrogen, nitrogen, and methane at a pressure of 1.5 mbar. The compact and practical air-spaced VIPA spectrometer exploits the full potential of a stabilized frequency comb, making it suitable for a wide range of spectroscopic applications in plasmas. This work is funded by the DFG - project number 499280974

P 5: Magnetic Confinment Fusion/HEPP III

Time: Tuesday 11:00–12:35 Location: ZHG102

Invited Talk P 5.1 Tue 11:00 ZHG102

Mode activity at the Wendelstein 7-X stellarator - Turbulence driven Alfvén modes — •S. Vaz Mendes[1], K. Rahbarnia[1], H. Thomsen[1], C. Büschel[1], J. Riemann[1], C. Slaby[1], R. Kleiber[1], A. Könies[1], M. Borchardt[1], J.P. Bähner[2], A. von Stechow[1], and Wendelstein 7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]MIT Plasma Science and Fusion Center, MA 02139, USA

In the optimized stellarator Wendelstein 7-X, magnetic fluctuation measurements reveal the excitation of Alfvén eigenmodes (AEs) in electron cyclotron resonance heated plasmas, despite the absence of a normal fast-particle driving source. This work presents an explanation for AE excitation via ion-temperature-gradient (ITG) turbulence. The detected AEs (Mirnov-measurements) in the range $50 < f < 450$ kHz are consistent with ellipticity, toroidicity, and non-circularity induced AEs. Density fluctuations (Phase Contrast Imaging measurements) indicated dominant ITG turbulence in these plasmas. The amplitudes of AEs and density fluctuations show a correlation for different magnetic field configurations. Moreover, in turbulence-reduced regimes, caused by peaking of the density profile via pellet injection, a reduction in the AE amplitude is found. Non-linear gyrokinetic simulations using the EUTERPE code revealed simultaneous excitation of zonal flow activity and generation of AEs driven by ITG turbulence. They also show that ITG modes are necessary to excite AEs above their initial low level.

P 5.2 Tue 11:30 ZHG102

Characterization of low frequency electromagnetic modes in the W7-X core and scrape-off layer plasma — •Dario Cipciar[1], Carsten Killer[1], Jiri Adamek[2], Kian Rahbarnia[1], Christian Brandt[1], Olaf Grulke[1,3], Neha Chaudhary[1], Henning Thomsen[1], and W7-X Team[1] — [1]Max-Planck-Institut fur Plasmaphysik, Wendelsteinstr. 1, 17491 Greifswald, Deutschland — [2]Institute of Plasma Physics of the CAS, U Slovanky 2525/1a, 18200 Prague 8, Czech Republic — [3]Department of Physics, Technical University of Denmark, Lyngby, Denmark

Global low-frequency electromagnetic oscillations of m=1 type are often observed in the Wendelstein 7-X stellarator. These modes significantly modulate the plasma stored energy and can appear as harmonic oscillations or as intermittent bursts, depending on the magnetic configuration. The bursty mode activity occurs in scenarios with large stationary magnetic islands just inside the last closed flux surface. In this case, a particularly strong effect on the plasma confinement is observed, via the effect of bursts on the density gradient and a gradient-associated temporary suppression of cross-field losses. Further, both continuous and bursty mode activity is observed in the Scrape-Off Layer using electric probes. The fluctuations of the poloidal electric field, electron temperature and density is captured using an array of Langmuir and ball-pen probes and used to calculate the perpendicular transport parameters. A Ball-pen probe in a swept regime (20 kHz) is used to measure the fluctuations of ion temperature, crucial for the material sputtering of the first wall due to transiently high Ti.

P 5.3 Tue 11:55 ZHG102

Turbulent magnetic fluctuations in plasma edge — •Kaiyu Zhang, Wladimir Zholobenko, Andreas Stegmeir, and Frank Jenko — Max Planck Institute for Plasma Physics, Garching, Germany

Small magnetic fluctuations are inherently present in a magnetic confinement plasma due to turbulent currents. These fluctuations flutter the background field lines, thereby reshaping the turbulence, which is investigated with GRILLIX, a global full-f fluid turbulence code using a locally field-aligned scheme. This study introduces a real-time high-pass filter to screen the magnetic fluctuations in turbulence, based on which the magnetic flutter effect is implemented. The implementation is verified by the method of manufactured solution and validated in the full-size simulations for the edge and scrap-off layer of Asdex Upgrade tokamak. The magnetic flutter in the drift-Alfvén-wave is found to reduce ExB transports by decreasing the phase shift between potential and density fluctuations, imparting stabilizing factors of 2 in the low confinement conditions and up to 100 in high confinement conditions. These findings establish the flutter stabilization as a fundamental aspect of edge turbulence. In reactor-relevant small edge-localized-modes (ELMs) regimes, the magnetic fluctuations form substantial Maxwell stresses, which flatten the radial electric field and weaken the associated flow shear near the separatrix. This facilitates the growth of the quasi-coherent mode driven by the kinetic-ballooning-mode, ultimately contributing to increased flutter transport of particles, conducive to avoiding Type-I ELMs and alleviating the heat exhaust challenge.

P 5.4 Tue 12:20 ZHG102

Investigation of Density-Potential Coupling as Agent for the Interplay of Particle and Momentum Transport in Drift Wave Turbulence — •Ralph Sarkis, Bernhard Schmid, Günter Tovar, and Mirko Ramisch — IGVP, University of Stuttgart, Germany

The experimental investigation of turbulent transport dynamics in the edge of magnetically confined plasmas highlights the coupling of density and potential fluctuations in the interplay of particle and momentum transport. At the TJ-K stellarator, a poloidal Langmuir-probe array is set up to simultaneously measure density and potential fluctuations, providing spatiotemporal observations of particle transports and Reynolds stress. While both transport phenomena rely on conflicting density-potential coupling conditions, experimental measurements exhibit a shared local region of maximum levels. Dynamics investigations reveal an inverse temporal relation of particle and momentum transport, substantiated by their strong correlation and anticorrelation with the density-potential decoupling, respectively. The spectral decomposition of the coupling parameter emphasizes the role of small-scale contributions in the drift-wave dominated transports' formation. Furthermore, the occurrence of zonal flows appears to alter the transports' dependence on the coupling. Both particle and momentum transport appear to be decorrelated from the density-potential coupling during zonal flows. This phenomenon is elucidated by analyses of spectral energy transfer between small-scale fluctuations in density and potential and meso-scale shear flows.

P 6: Atmospheric Plasmas and their Applications II

Time: Tuesday 11:00–12:30 Location: ZHG006

Invited Talk P 6.1 Tue 11:00 ZHG006

Spatially and temporally resolved electric fields in an RF-APPJ measured by E-FISH — •Inna Orel[1], Nikita Lepikhin[1], Zoltan Donko[2], Dirk Luggenhölscher[1], and Uwe Czarnetzki[1] — [1]Ruhr University Bochum, Institute for Plasma and Atomic Physics, Bochum, Germany — [2]Institute for Solid State Physics and Optics HUN REN Wigner Research Centre for Physics, Budapest, Hungary

Spatially and temporally resolved electric fields in a self-sustained radio frequency atmospheric plasma jet (RF-APPJ) in a helium:nitrogen mixture are measured by electric field induced second harmonic generation (E-FISH). It is shown that the electric field in the bulk of the RF-APPJ is unexpectedly high, having an amplitude of about 1.6 kV/cm, and that it exhibits a phase shift of approximately -0.2π relative to the voltage waveform [1]. The electron density in the bulk is estimated from the measured phase shift between the electric field and the applied voltage by using an equivalent RC-circuit model for the discharge. Comparison of the measured electric field with the results of ab initio Particle-in-Cell/Monte Carlo collisions (PIC/MCC) simulations reveals excellent agreement. Special attention is paid to the calibration of the E-FISH measurement which includes removal of polarity sensitive artifacts.

The work is supported by the DFG funded SFB1316 Project "Transient atmospheric plasmas - from plasmas to liquids to solids".

[1] I Orel et al 2025, submitted to Plasma Sources Sci. Technol.

P 6.2 Tue 11:30 ZHG006

Applied machine learning for electron density measurements of an atmospheric plasma torch — •Christos Vagkidis, Alf Köhn-Seemann, Stefan Merli, Mirko Ramisch, Andreas Schulz, and Günter Tovar — IGVP, University of Stuttgart, Germany

Atmospheric plasma torches are considered a promising approach for the decomposition of waste gases. In order to enhance their performance, it is crucial to accurately measure the plasma properties. One of the most important properties of the plasma is the electron density.

In this work, a deep neural network is used to predict the electron density distribution of an atmospheric plasma torch. The neural network is trained on data obtained from 3D simulations, carried out with the COMSOL Multiphysics software. In the simulation domain, a microwave beam is propagating through the plasma and the beam power is monitored after the interaction with the plasma. A 1D cut of this power, calculated perpendicularly to the direction of propagation, is used as training data for the neural network.

Experimental data are obtained through a similar set-up. A network analyzer is used to measure the microwave beam power. By moving the detecting antenna of the network analyzer perpendicularly to the plasma torch the beam power is measured. The beam power profile is then fed into the neural network, which in turn estimates the electron density of the torch with very good accuracy.

P 6.3 Tue 11:45 ZHG006

The role of metastable atoms on the dissociation of CO_2 in the COST Reference Microplasma Jet — •Alexander Schicke, Amira Nouira, Sebastian Burhenn, Marc Böke, and Judith Golda — Plasma Interface Physics, Ruhr-Universität Bochum, 44801 Bochum, Germany

The dissociation of CO_2 has become a growing topic in recent years. There are many applications, including decarbonising the atmosphere and producing carbon for chemicals and fuels. When adding CO_2 to an rf plasma, the dissociation can nearly double using argon instead of helium as a feed gas, because of the lower excitation and ionisation energies. Consequently, the assumption was made that the dissociation of CO_2 is dominated by electron impact dissociation and dissociation via Penning collisions with metastable atoms.

Therefore, to quantify which part the metastable atoms play in the COST Reference Microplasma Jet, the respective densities of helium and argon metastable atoms were measured while changing the ratio of He/Ar in the feed gas. The metastable atom densities were measured via tunable diode laser absorption spectroscopy (TDLAS), which allows the simultaneous measurement of both densities with high spatial resolution. With this 2D maps of the discharge channel can be created, which gives us in-depth information on the dissociation of CO_2.

This work is funded by the projects A3 and B2 of the CRC 1316.

P 6.4 Tue 12:00 ZHG006

Open-source tools for interactive preselection and analysis of large image datasets — •Philipp Mattern[1], Richard Krieg[2], Hans Höft[1], Torsten Gerling[1], and Markus M. Becker[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]University of Greifswald, Greifswald, Germany

To gain a holistic understanding of complex phenomena in plasma processes, it is often necessary to combine several high-resolution diagnostics and extensive parameter variations. This results in large data sets that are difficult to access using conventional methods and analysis tools. This contribution introduces two open-source tools developed at INP Greifswald for efficient data handling and image analysis: WOLKE and BLITZ. BLITZ enables rapid loading, visualization, and statistical evaluation of large image collections—handling more than 20,000 images (exceeding 20 GB) in under a minute—without requiring specialized hardware. Its matrix-based approach allows swift calculation of key parameters even for massive datasets. WOLKE provides a web-oriented layout and filtering framework for interactively preselecting image data based on user-defined criteria (e.g., mean, entropy, sharpness, operation parameter combinations, timestamps, EXIF information or any pre-calculated value). Filtered subsets identified in WOLKE can be seamlessly examined and further analyzed within BLITZ. This combination creates a highly adaptable workflow for data exploration, evaluation, and presentation, effectively responding to evolving research demands in plasma physics and beyond.

P 6.5 Tue 12:15 ZHG006

Laser Optical Loop for highly repetitive laser measurements by a single laser pulse — •Nikita Lepikhin, Dirk Luggenhölscher, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany

A Laser Optical Loop (LOL) approach is proposed to achieve high repetition rates of laser pulses by using each single laser shot several times. As a result, measurement speed of laser based experimental techniques can be accelerated significantly, e.g. Electric Field Induced Second Harmonic generation (E-FISH), Two-Photon Absorption Laser Induced Fluorescence (TALIF), Thomson scattering, etc. Several optical schemes are proposed to form the optical loop and to trap the laser emission. The feasibility of the suggested method is demonstrated using the example of the E-FISH technique.

Acknowledgements: The work is supported by the DFG funded SFB1316 Project "Transient atmospheric plasmas - from plasmas to liquids to solids".

P 7: Magnetic Confinment Fusion/HEPP IV

Time: Tuesday 13:45–15:55 Location: ZHG102

Invited Talk P 7.1 Tue 13:45 ZHG102

Impurity Transport in Wendelstein 7-X: Basics and Experimental Observations — •Birger Buttenschön[1], Thomas Wegner[1], Thilo Romba[1], Daihong Zhang[1], Felix Reimold[1], Alice Bonciarelli[1,2], and the W7-X Team[1] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]Politecnico di Milano, Italy

The presence of impurities in a fusion plasma can have significant influence on the plasma performance. While impurities generally dilute the fuel and thus reduce fusion efficiency, their line radiation is often used in the boundary plasma to reduce power fluxes to plasma-facing components. A high concentration of impurities in the confined plasma and the resulting radiation, however, is a critical loss channel for plasma energy and can lead to a radiative collapse of the plasma.

In the optimized stellarator Wendelstein 7-X, plasma scenarios featuring high energy and particle confinement inherently tend to accumulate impurities in the plasma center due to inwards directed neoclassical convective transport in the turbulence reduced ion-root regime. Understanding the (impurity) transport mechanisms is therefore a crucial step on the path to maintaining plasma performance by adjusting the impurity content and radiation within tolerable ranges.

This talk will give an overview on impurity transport in stellarators, introducing both theoretically expected transport mechanisms and suitable impurity transport diagnostics. Recent findings on the impurity transport in W7-X will be presented.

P 7.2 Tue 14:15 ZHG102

Characterizing scenarios of suppressed anomalous impurity transport in W7-X — •Thilo Romba[1], Felix Reimold[1], Sebastian Bannmann[1], Alejandro Banon Navarro[2], Hugo Cu Castillo[2], Oliver Ford[1], Peter Zsolt Poloskei[1], Markus Wappl[1], Thomas Klinger[1], and the W7-X team[3] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]Max Planck Institute for Plasma Physics, Garching, Germany — [3]O. Grulke et al 2024 Nucl. Fusion 64 112002

In view of dilution and radiative losses, the understanding and subsequent tailoring of impurity transport in fusion plasmas depicts a crucial step towards self-sustained burn. While the impurity transport in the Wendelstein 7-X stellarator is typically benign [Geiger19], certain experimental scenarios exhibit a central accumulation of impurities with transport of impurities reducing to neoclassical level [Romba23].

This work aims to characterize such scenarios. While a high density is identified as a necessary condition for impurity peaking to occur, no fundamental dependence on magnetic field configuration is identified. In addition to high density, a local normalized density gradient a/L_{n_e} above unity is identified as a necessary, yet not sufficient, condition for impurity accumulation to occur. Transport simulations across impurity species with different charges Z are found to match with neoclassical transport predictions, indicating a suppression of anomalous transport across impurities.

P 7.3 Tue 14:40 ZHG102

Prototype Coils and Engineering Design for the EPOS Stellarator — •Paul Huslage[1], Tristan Schuler[2], Pedro Gil[1], Dylan Schmeling[1,3], Diego A. R. Orona[1,4], Elisabeth von Schoenberg[1,5], Robert Luerbke[1], Jason Smoniewski[1], and Eve V. Stenson[1] — [1]Max-Planck Institut für Plasmaphysik — [2]SchulerTec — [3]Columbia University — [4]Massachusetts Institute of Technology — [5]Concordia University

The EPOS stellarator (a tabletop device to confine electron positron plasmas) will use high-temperature superconductors (HTS) to generate its quasi-axisymmetric magnetic field. Non-planar, non-insulated coils made from rare-earth barium copper oxide (ReBCO) tapes will be used to create a 2 T magnetic field on axis and enable a plasma volume of ~10 L.

In this contribution, we present the results of the hardware test campaign in preparation of the EPOS experiment design and assembly. During this effort, we are designing, manufacturing, and testing a series of coils from planar manufacturing demonstrators to a full-size, full-current coil.

Results from the coils tests inform the design of the EPOS stellarator. We will present the current state of the engineering design, as well as the road map for manufacturing and assembly.

P 7.4 Tue 15:05 ZHG102

Exploration of Instabilities in Weakly Magnetized Plasmas: A Hybrid Gyrokinetic Approach. — •Sreenivasa chary Thatikonda[1], Felipe nathan De Oliveira lopes[1], Aleks Mustonen[2], Karen Pommois[2], Rainer Grauer[2], Daniel Told[1], and Frank Jenko[1] — [1]Max planck institute for plasma physics, Garching, Germany — [2]Ruhr-Universität Bochum, Germany

Instabilities, turbulence, and reconnection in weakly magnetized plasmas, such as those encountered in the solar wind, present significant challenges to our understanding of plasma dynamics. High-frequency dynamics of space plasmas challenge the foundational assumptions of Gyrokinetic theory, especially for ions. To overcome these constraints, we developed a hybrid gyrokinetic model that preserves Gyro/Drift kinetic physics for electrons while integrating full kinetic physics for ions. The hybrid gyrokinetic model was incorporated into the Super Simple Vlasov (ssV) code. The code was verified against standard benchmark configurations after numerical diffusion, oscillations, and Ampere cancellation issues were effectively resolved. In particular, this study uses the hybrid-gyrokinetic framework in the ssV code to investigate the dynamics of Lower Hybrid Drift Instabilities (LHDIs) in reconnecting current sheets. Temperature, mass ratio, and plasma beta are among the parameters that are methodically investigated. Among the important findings are the analyses of growth rate dependences on temperature ratios, mass ratios, plasma beta, and the temporal development of electric field amplitudes. Future work will validate these results through comparisons with in-situ reconnection data from MMS.

P 7.5 Tue 15:30 ZHG102

Dependence of turbulent transport on the divertor flux expansion in ASDEX Upgrade — •Jan Pfennig, Wladimir Zholobenko, Andreas Stegmeir, Konrad Eder, Kaiyu Zhang, 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, and thus economic viability. Previously, extensive validation efforts for the locally field-aligned fluid turbulence code GRILLIX against ASDEX Upgrade attached L-Mode have been performed and resulted in good agreement with both mean-field and turbulence diagnostics. As a successive step, simulations with similar physical parameters but in the geometry of the new AUG upper divertor are performed for different levels of low-field side divertor flux expansion. Due to the global, full-f capabilities of GRILLIX it is possible to connect the effect of local changes in magnetic geometry to both local and global changes in the turbulent transport. By these means it is possible to disentangle the purely geometrical gain in exhaust performance by poloidal flux expansion from that of turbulent cross-field transport. The simulation results show a strong influence of the flux expansion on divertor heat flux peaking while global properties such as input power, edge confinement time, outboard mid-plane profiles and in fact the turbulence in the complete plasma edge remain nearly unchanged.

P 8: Atmospheric Plasmas and their Applications III

Time: Tuesday 13:45–15:45 Location: ZHG006

Invited Talk P 8.1 Tue 13:45 ZHG006

Status and outlook for CO_2 conversion with microwave plasmas — •Ante Hecimovic, Christian K. Kiefer, Arne Meindl, Rodrigo Antunes, and Ursel Fantz — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, D85748 Garching b. München

Carbon dioxide (CO_2) gas is regarded as a valuable building block in a non-fossil fuel economy, and if captured from the atmosphere it allows creating a closed carbon cycle, leading to net zero emissions. Low temperature plasmas have the potential to contribute to the field of CO_2 utilization through unique reaction pathways that are not accessible by other conversion technologies. The reaction pathways in the plasma can be driven either by electrons, a combination of electron-driven and heavy species driven mechanisms, or by elevated temperatures (2000-6000 K). In this contribution, conversion of CO_2 into CO using the microwave plasmas in large pressure range (1-1000 mbar) is presented, demonstrating effect of these mechanism on the achieved conversions. Relatively high conversion rates obtained in the microwave plasmas could potentially be applied in an industrial process. Two main obstacles towards the application: gas separation in the plasma effluent, and up-scaling towards CO flow rates compatible with the Fischer-Tropsch process are discussed.

P 8.2 Tue 14:15 ZHG006

High power atmospheric microwave plasma torch for CO_2 conversion — •Marc Bresser, Katharina Wiegers, Stefan Merli, Andreas Schulz, Matthias Walker, and Günter Tovar — IGVP, University of Stuttgart, Germany

Due to global warming and the increase in Earth's surface temperature the concentration of CO_2 in the atmosphere and the CO_2 pollution must be reduced. A renewable alternative to the use of fossil fuels in the chemical industry, as one of the largest producers of CO_2, must be found. An attractive way is to utilize CO_2 as a starting chemical to generate a sustainable alternative and close the carbon cycle. An innovative process is a microwave plasma to activate CO_2. The generated CO can then be used together with hydrogen form renewable resources such as electrolysis to produce synthesis gas. This process has the advantage of on-demand operation with fluctuating and intermitted electric energies. In this work, a 2.45 GHz atmospheric microwave plasma torch is used to convert CO_2 into CO. The torch is operated in a reverse vortex flow configuration. A nozzle behind the torch prevents the back reaction of the product gas. To analyze the cold product gas, the conversion was measured using absorption Fourier-transform infrared spectroscopy, mass spectrometry, and a X-Stream gas analyzer from Emerson. The influence of microwave power and CO_2 gas flow on the conversion was investigated. Based on the conversion values, the energy efficiency was determined. The plasma process achieved maximum conversions of up to 21 % and an energy efficiency of over 40 %.

P 8.3 Tue 14:30 ZHG006

Process optimization of iron oxide (in-flight) reduction in a high-performance microwave argon-hydrogen plasma torch — •Jonas Thiel, Simon Kreuznacht, Marc Böke, and Achim von Keudell — Experimental Physics II - Reactive Plasmas, Ruhr University Bochum, Bochum, Germany

Using an argon-hydrogen microwave plasma torch, the experiments aim at advancing nearly climate-neutral iron ore reduction. These atmospheric-pressure hydrogen plasmas provide advantages such as faster reduction rates, lower energy consumption, in-flight treatment, and scalability compared to other methods. The experimental setup can be used in two operation modes: exposing defined sample amounts to the plasma effluent or directly injecting iron oxide powder into the gas flow for in-flight treatment. A swirl-like flow pattern is employed to shield the reactor's quartz tube from the hot core. However, for the latter case, this swirl also leads to particles being adhered to the wall before reaching the collection system. Therefore, an optimization of the process parameters assisted by fluid simulations examining particle trajectories, residence times, and melting/evaporation behavior under varied flow and geometric conditions is crucial for efficient long-term in-flight treatment. In addition, optical emission spectroscopy and X-ray diffraction are employed to analyze on the one hand plasma properties as gas temperature and electron density/temperature, and on the other hand the reduction degree of treated samples.

Invited Talk P 8.4 Tue 14:45 ZHG006

Plasma activation of low-energy molecules using the example of nitrogen — •Mariagrazia Troia, Katharina Wiegers, Andreas Schulz, and Matthias Walker — Institute for Interfacial Engineerinf and Plasma Technology, University of Stuttgart, Stuttgart, Germany

A key chemical in the manufacture of fertilizers is nitric acid, usually produced via the well-established combination of the Ostwald and the Haber-Bosch processes, with an average energy cost that amounts to 2% of the world*s total, and a side production of several greenhouse gases. An ongoing global effort is being currently carried out in order both to achieve climate neutrality and to reduce the overall production costs of raw chemicals. Plasmochemical processes open up attractive alternative routes, thanks to their flexible, on-demand operating mode which allows for an in-loco production of the fertilizers precursor NOx at low costs. In the current work, a commercially available microwave atmospheric plasma torch is used to synthesize NOx from dry air over a wide set of operating parameters. Resulting concentrations, comparable to the current state-of-the-art for plasma processes, have been further improved by optimizing the gas management in the plasma volume and in its after-glow region, by means of a custom-made nozzle with different geometries and operating principles. High-speed camera measurements and characterization via emission spectroscopy further elucidate the chemistry taking place in the plasma phase. Paired with extensive *cold* gas numerical simulations, they offer promising avenues for further improvements of the NOx yield thus obtained.

P 8.5 Tue 15:15 ZHG006

Nanosecond resolved vibrational kinetics of CO_2 in CO_2/N_2 mixtures: experiment and model — •Christian Alexander Busch[1], Tiago Silva[2], Vasco Guerra[2], Nikita Lepikhin[1], Inna Orel[1], Jan Kuhfeld[1], Dirk Luggenhölscher[1], and Uwe Czarnetzki[1] — [1]Ruhr University Bochum, Institute for Plasma and Atomic Physics, Bochum, Germany — [2]Instituto Superior Técnico, Institute for Plasmas and Nuclear Fusion, Portugal

In this work, the vibrational kinetics of CO_2 in a ns-pulsed near-atmospheric pressure plasma jet operated in a CO_2/N_2 mixture is studied experimentally [1] and by modeling using the LisbOn KInetics codes (LoKI). This discharge allows for a temporal separation and thus an independent study of the excitation during the discharge pulse and the V-V and V-T transfer in the afterglow. The densities of individual rovibrationally excited states of CO_2 are measured with ns resolution by absorption spectroscopy using a quantum-cascade laser.

Notably, a short-lived non-equilibrium was observed between the populations of the Fermi resonant states and the bending mode. Additionally, the excitation of the asymmetric stretch mode was found to deviate from a commonly applied scaling law.

The work was supported by the DFG funded SFB1316 project *Transient atmospheric plasmas - from plasmas to liquids to solids*. IPFN activities were supported by FCT - Fundação para a Ciência e Tecnologia under projects UIDB/50010/2020, UIDP/50010/2020, LA/P/0061/202 and PTDC/FIS-PLA/1616/2021.

[1] Christian A Busch et al 2025 *J. Phys. D: Appl. Phys.* **58** 065202

P 8.6 Tue 15:30 ZHG006

Impact of a plasma window arc discharge on the transmission properties of a 48-Ca heavy ion beam — •Andre Michel, Fateme Ghaznavi, Michael Händler, Adem Ates, Marcus Iberler, and Joachim Jacoby — Goethe Universität Frankfurt

With the increase of particle beam energies and intensities in accelerator facilities around the world, a reliable technique for the separation of accelerator vacua to high-pressure targets is needed where conventional techniques such as differential pumping stages or solid membranes might fail. A promising technique that allows the transmission of such ion beams even at short distances is the so-called plasma window [1]. It is based on a cascaded arc discharge that enables the active control of the pressure gradient depending on the selected working gas, flow rate and arc current.

In 2018 the Plasma Physics department of Goethe University Frankfurt developed a prototype of the plasma window, which has since been optimized for its purpose as an active pressure separation component in particle accelerators. As part of its further development, the plasma window has been successfully used to demonstrate the transmission of a heavy ion beam while maintaining the pressure gradient up to 10h in a single run.

This contribution gives an insight into the plasma physical properties as well as the operating parameters of the developed plasma window and highlights its impact on the properties of the transmitted ion beam.

[1] Hershcovitch, A., J. Appl. Phys., AIP Publishing, 1995, 78, 5283

P 9: Plasma Wall Interaction

Time: Tuesday 16:15–17:15 Location: ZHG102

Invited Talk P 9.1 Tue 16:15 ZHG102

In-vessel and depth-resolved hydrogen isotope composition analysis in JET by LIBS operated on a remote handling arm — •Rongxing Yi[1], Rahul Rayaprolu[1], Gennady Sergienko[1], Erik Wuest[1], Marc Sackers[1], Timo Dittmar[1], and Sebastijan Brezinsek[1,2] — [1]Forschungszentrum Jülich GmbH, IFN-1 Plasmaphysics, Jülich, GERMANY — [2]HHU Düsseldorf, Faculty of Mathematics and Natural Sciences, Düsseldorf, GERMANY

As the world's most successful Tokamak, JET achieved a groundbreaking milestone in nuclear fusion during its final deuterium-tritium experimental campaign (DTE-3) last year by setting a new world energy record. However, one critical safety aspect, the fuel retention distribution within the vessel walls after DTE-3, remains an unresolved challenge. To resolve it, a laser-induced breakdown spectroscopy (LIBS) system has been deployed. Compactly integrated into a laptop-sized box, the setup is mounted on a remote handling arm inside the JET vessel. Spectral data collected through this system is transmitted via long optical fibers to multiple spectrometers for analysis. The laser achieves a surface and depth resolution of 130 μm and 180 nm on tungsten, respectively. Additionally, a high-flux Littrow spectrometer gives high sensitivity for detecting hydrogen isotopes. By utilizing the remote handling arm with the LIBS setup, over 800 positions were analyzed within the vessel, providing both global distribution and depth profiles of retained hydrogen isotopes.This approach represents a method in understanding fuel retention, crucial for improving the safety and wall material design of future fusion reactors.

P 9.2 Tue 16:45 ZHG102

Experimental Investigations of the Hydrogen Isotopes Retention and Permeation in Boron Coatings — •Eduard Warkentin[1,2], Anne Houben[1], Marcin Rasinski[1], Hans Rudolf Koslowski[1], Timo Dittmar[1], Bernhard Unterberg[1,2], and Christian Linsmeier[1,2] — [1]Forschungszentrum Jülich GmbH, Institut of Fusion Energy and Nuclear Waste Managment - Plasmaphysics (IFN-1), Jülich 52425, Germany — [2]Ruhr-Universität Bochum, Faculty of Physics and Astronomy, Bochum 44801, Germany

Fuel permeation and retention in fusion reactor wall materials are important issues for plasma operation and safety reasons in ITER. The loss of the hydrogen isotope tritium, which will be used as fuel, has to be estimated and prevented. Due to the change of the ITER first wall material from Be to W, oxygen and other impurities in the vessel are not sufficiently gettered by a W wall. A thin boron layer which is applied during the regular wall conditioning phase can solve the problem and a more efficient plasma operation can be obtained. In order to investigate hydrogen retention and permeation of boron coatings, pure boron layers were fabricated by magnetron sputter deposition on W and steel substrates. After characterization, the deuterium permeation flux was measured and the layer permeation was obtained. Boron coated samples were exposed to different deuterium plasma and ion loadings in order to investigate retention via nuclear reaction analyis (NRA) and thermal desorptions spectroscopy (TDS).

P 9.3 Tue 17:00 ZHG102

Depth-resolved deuterium retention profiles in displacement-damaged tungsten with laser-induced ablation quadrupole mass spectrometry — •Christoph Kawan[1,2], Sebastijan Brezinsek[1,2], Timo Dittmar[1], Erik Wüst[1,2], Thomas Schwarz-Selinger[3], Liang Gao[1], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich GmbH, IFN-1 Plasmaphysics, 52425 Jülich, GER — [2]Mathematisch- Naturwissenschaftliche Fakultät, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany — [3]Max-Planck-Institut für Plasmaphysik, Boltzmannstrasse 2, 85748 Garching, Germany

Future fusion devices will operate with the hydrogen isotopes deuterium (D) and tritium (T) as fuel gases and tungsten (W) as wall material. The released high energetic neutrons from DT fusion reactions cause displacement damage in the W lattice and increase fuel retention by trapping and diffusion, leading to decreased reactor performance. Therefore, diagnostics are required to quantify the D and T content. Laser-induced ablation quadrupole mass spectrometry (LIA-QMS) is a promising method with good depth resolution and absolute quantification and can be combined with traditional diagnostics, such as laser-induced breakdown spectroscopy (LIBS). This study compares LIA-QMS D profiles with LIBS and nuclear reaction analysis (NRA) on self-damaged W samples. LIA-QMS shows a higher sensitivity (< 0.1 at% D at 75 nm average ablation) than LIBS. Qualitatively, LIA-QMS can reproduce the NRA depth profiles, but quantitatively, LIA-QMS underestimates the total content by a factor of ~ 3.

P 10: Poster Session I

Time: Tuesday 16:15–18:15 Location: ZHG Foyer 1. OG

P 10.1 Tue 16:15 ZHG Foyer 1. OG

Development of a planar dielectric barrier discharge for plasma and surface studies — •A.A. Ben Yaala[1], R. Antunes[1], T. Höschen[1], S. Buchberger[1], A. Meindl[1], A. Hecimovic[1], and U. Fantz[1,2] — [1]Max Planck Institute for Plasma Physics (IPP), 85748 Garching b. München, Germany — [2]University of Augsburg, 86149 Augsburg, Germany

The growing demand for ammonia in fertilizers, chemical industry and energy storage drives the need for production methods compatible with an electrified energy system. Plasma-catalysis offers a promising alternative to the traditional Haber-Bosch process, with potential for decentralization and renewable energy integration. The Dielectric Barrier Discharge (DBD) is the most extensively studied plasma discharge for ammonia synthesis due to its operating temperatures, which facilitate catalyst activation and improve reaction selectivity. While plasma-catalysis synergism in DBD has been demonstrated in several works, the detailed plasma-surface interactions remain an underexplored area. In this contribution, a newly developed planar DBD reactor, which permits an easier access to plasma and surface diagnostics, will be presented. This planar DBD is assembled in a setup with in-vacuo access to X-ray Photoelectron Spectroscopy (XPS), whereby surface characterization of a catalytic material deposited on the ground electrode can be done without breaking the vacuum. Preliminary work on formation of NH_3 in N_2-H_2 plasmas as well as surface analysis of the exposed electrode will be presented.

P 10.2 Tue 16:15 ZHG Foyer 1. OG

Hybrid FTIR setup for gas sampling and in-situ analysis for low-temperature, high-pressure plasmas — •Francesco Franco[1,2], Arne Meindl[1], Ante Hecimovic[1], Rodrigo Antunes[1], and Ursel Fantz[1,2] — [1]Max Planck Institute for plasma physics, Boltzmannstr. 2, D-85748 Garching b. München — [2]University of Augsburg, Universitätsstr. 1, D-86159 Augsburg

Fourier Transform InfraRed (FTIR) spectroscopy is a flexible, fast and sensitive diagnostic based on the absorption of broadband infrared light from molecules with net electric dipole. This technique can be applied to the qualitative and quantitative analysis of cold gas products and in-plasma reactive species, here in the context of low-temperature, high-pressure plasma reactors for gas conversion (e.g. NH_3, CO_2 and CH_4 into N_xH_y, CO and C_xH_y). Important plasma parameters, such as chemical composition and vibrational state distributions, can be derived with FTIR. In this contribution, the development and calibration steps of a new FTIR apparatus are presented, featuring a commercial interferometer and an external and movable detector for both in-situ and gas sampling experimental operation. This configuration deviates from the standard application of these instruments and requires custom hardware implementations. Since FTIR is very sensitive to moisture and environmental contaminants, solutions for atmosphere control along the beamline, between the interferometer and the detector, are outlined, together with technical features of the setup. To carry out quantitative analysis from infrared absorption spectra, the challenges and approaches to calibration of the instrument are discussed.

P 10.3 Tue 16:15 ZHG Foyer 1. OG

Characterization of different DCSBD designs using plasma diagnostics — •Henry von Wichert[1], Jianyu Feng[2], Tobias Hahn[1], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics, Christian-Albrechts-University, Kiel, Germany — [2]Department of Plasma Physics and Technology, Masaryk University, Brno, Czech Republic

Atmospheric pressure plasma jets are effective for treating surfaces. To modify larger areas efficiently, a curtain-shaped jet can be used by positioning two surface barrier discharges (DCSBDs) facing each other. Here, we characterize different designs of the jets and the DCSBD units themselves by various diagnostics.

The energy flux from the discharge to the substrate was measured at different distances and power levels using passive thermal probes. These were compared with the total electrical power consumed by the discharge, estimating the energy efficiency of the setup.

Spectral profiles of the DCSBDs were measured by OES to check for variations within the plasma, and high-resolution brightness profiles were captured. These optical measurements are compared with the energy flux data to better understand the relationship between the total power used, the area covered by the discharge, and the intensity of the plasma in the illuminated region.

Using a high-speed-camera, the short-term behavior of the filaments of the discharge could be compared with the average distribution of the plasma on the surface, as measured by long-exposure photographs.

P 10.4 Tue 16:15 ZHG Foyer 1. OG

Electrochemical investigation of microsecond plasma-in-liquid treated copper surfaces — •Neil Dominik Unteregge, Pia Victoria Pottkämper, and Achim von Keudell — Ruhr-Universität Bochum, Bochum, Deutschland

The aim of this project is to investigate the production of hydrogen peroxide and its effects on copper oxide surfaces. This interaction leads to the growth of copper oxide nanocrystals, which are valuable catalysts for the electrochemical reduction of CO2. However, the catalysts activity decreases during operation in an electrochemical cell. In this project an in-liquid plasma is ignited in distilled water, which creates many reactive species with varying lifetimes, such as hydrogen peroxide, molecular oxygen and hydrogen, as well as solvated electrons. This plasma is powered using high voltages and microsecond pulses. The energy dissipated in each pulse triggers the phase transition to water vapor and allows dissociation in the plasma state. As a result, so-called plasma activated water (PAW) is obtained. The concentration of hydrogen peroxide in PAW is determined by absorption spectroscopy using the reaction of hydrogen peroxide with ammonium vanadate as sensor. PAW is then brought into contact with the copper oxide surfaces to induce the nanocrystal growth. The copper oxide surfaces are analyzed by SEM and cyclic voltammetry.

P 10.5 Tue 16:15 ZHG Foyer 1. OG

Investigation of a microwave plasma torch for conversion of CO_2 and CH_4 molecules — •Clemens Kranig[1], Christian K. Kiefer[1], Arne Meindl[1], Ante Hecimovic[1], and Ursel Fantz[1,2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, D85748 Garching b. München — [2]University of Augsburg, Universitätsstr. 1, D-86159 Augsburg

Using a microwave plasma for converting various gaseous molecules, e.g. CO_2 or CH_4, into value-added molecules like CO and H_2, is a promising technology. For the case of CO_2 high conversion rates have been demonstrated as well as comparably short start-up times, which synergizes well with fluctuating renewable energy supplies. The microwave torch generates a low-temperature plasma in the pressure range from several millibars to atmospheric pressure. The plasma is characterized by gas temperatures ranging from 2000-6000 K, which enable endothermic reactions, such as CO_2 conversion ($CO_2 \rightarrow CO + \frac{1}{2}O_2$), methane pyrolysis ($CH_4 \rightarrow 2H_2 + C_s$), and dry reforming of methane ($CO_2 + CH_4 \rightarrow 2CO + 2H_2$). Due to the high temperature in the effluent, one key challenge is the reduction of recombination. Other challenges are the desired selectivity accompanied by sufficient energy efficiency, as well as the deposition of carbon black at critical locations in the reactor. This contribution will focus on using pure CH_4 or a gas mixture of CO_2 and CH_4 for the production of H_2 or syngas. The analysis of the composition of the product gases is challenging, as e.g. solid carbon and condensed water are not detected using the gas analysis techniques (gas chromatography or mass spectrometry).

P 10.6 Tue 16:15 ZHG Foyer 1. OG

Nitrogen fixation and H_2O_2 production by an atmospheric pressure plasma jet — •Jannis Kaufmann, Steffen Schüttler, and Judith Golda — Plasma Interface Physics, Ruhr University Bochum, Bochum, Germany

Atmospheric pressure plasmas are widely used for nitration fixation. Atmospheric pressure plasma jets are suitable sources of reactive species delivered into liquids. The addition of H_2O leads, for example, to the production of H_2O_2 as shown by a capillary plasma jet. Adding nitrogen to the humidified feed gas, nitrogen fixation can be performed by the capillary plasma jet investigated in this work [1]. We used various diagnostics for measuring the concentration of different species in plasma-treated liquid: spectrophotometry (hydrogen peroxide, nitrite), fluorometry (ammonia) and amperometry (hydrogen peroxide). We show that a small admixture of nitrogen (between 0.1 and 1 %) already leads to a lower concentration of hydrogen peroxide. Instead, the plasma produced nitrogen-containing species such as nitride and ammonia. Low frequency pulsing of the RF signal can be used to tune plasma chemistry in our system. Given an additional admixture of oxygen to the system, the hydrogen peroxide production can be increased, while no ammonia is generated. Furthermore the production via hydroxyl radicals was shown to be the main production channel for hydrogen peroxide and nitrite.

This work is supported by the DFG within CRC1316 Project B11

[1] S. Schüttler, J. Kaufmann, J. Golda, Plasma Process. Polym. 2024; 21:e2300233. https://doi.org/10.1002/ppap.202300233

P 10.7 Tue 16:15 ZHG Foyer 1. OG

Formation of stable species in atmospheric-pressure coaxial DBDs in argon-tetramethylsilane mixtures — •Marjan Stankov[1], Lars Bröcker[2], Nickolas Steppan[2], Claus-Peter Klages[2], Markus M. Becker[1], and Detlef Loffhagen[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Institute for Surface Technology, Technische Universität Braunschweig, Braunschweig, Germany

The formation of stable species in atmospheric-pressure dielectric barrier discharges (DBDs) operated in argon with small admixtures of tetramethylsilane (TMS) has been investigated with the help of modelling and experiment for gas residence times up to 8 ms. The DBD reactor studied consists of two borosilicate glass tubes in a coaxial configuration with a gap of 1 mm. It is powered by a 4 kV sinusoidal voltage at 86.2 kHz. The modelling study employs a time-dependent, spatially one-dimensional fluid-Poisson method including a complex plasma chemistry for Ar-TMS mixtures considering about 90 species and 700 reactions. It is accompanied by measurements using Fourier-transform infrared (FTIR) spectroscopy for the analysis of stable molecules in the effluent gas. Satisfactory agreement between calculated and measured number densities of several stable species is generally found. In particular, the analysis for admixtures of up to 100 ppm TMS reveals that trimethylsilane is the primary silicon-containing species generated and that methane becomes the predominant hydrocarbon. The work has

been funded by the Deutsche Forschungsgemeinschaft (DFG) - project number 504701852.

P 10.8 Tue 16:15 ZHG Foyer 1. OG

Spatially resolved optical emission spectroscopy on a dielectric barrier discharge for plasma-assisted catalysis — •Kerstin Sgonina[1], Alexander Quack[1], and Jan Benedikt[1,2] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Kiel Nano, Surface and Interface Science (KiNSIS), Kiel University, Germany

Energy efficient and decentralized performance of catalytic reactions for the means of converting excess energy into chemicals is one of the important research topics nowadays. Plasma-assisted catalysis could provide one possible solution as it is available on demand and works even without external heating. Non-equilibrium atmospheric pressure plasmas are used to dissociate and excite gaseous molecules, which can then react at the surface of the catalyst to form the desired products. For efficient plasma-assisted catalysis reactions, the fast product removal is crucial, which can be achieved by specific reactor designs or tailored materials. A reactor was designed aiming the fast product removal and enabling testing powder-like and porous materials for their catalytic effect. Spatially resolved optical emission spectroscopy was used to analyze the discharge properties and structure, and to study the role of the catalyst in the process. The dielectric barrier discharge is operated at different frequencies and voltage amplitudes. By using CO_2 and H_2, the methane formation is investigated via mass spectrometry.

P 10.9 Tue 16:15 ZHG Foyer 1. OG

Diagnostic capabilities of Setup for Imaging of Radicials Interacting with Surfaces (IRIS) — •Robin Minke[1], Robin Labenski[1], Marc Böke[2], Achim von Keudell[2], and Judith Golda[1] — [1]Plasma Interface Physics, Ruhr-University Bochum — [2]Experimental Physics II, Ruhr-University Bochum

The novel field of plasma catalysis involves complex chemistry, making it difficult to identify the underlying causes and effects between catalysts and plasma. Methods are needed to isolate specific processes to understand their contribution in the overall chemistry. To enhance the insight of how plasma-generated molecules interact with surfaces, a low-pressure chamber setup for Imaging of Radicals Interacting with Surfaces (IRIS) has been developed. In this setup, radicals produced by an ECR discharge are accelerated through a differential chamber into the main chamber, forming a molecular particle beam that collides with a substrate surface. Spatially resolved Laser-Induced Fluorescence (LIF) is employed to monitor the density of a chosen radical species in the incoming and outgoing beam, revealing insights into its surface chemistry. The substrate temperature can be controlled between 300 and over 1000 K, making this setup ideal for studying the interplay between molecules and temperature-driven catalysts. Providing the diagnostic capabilities of the setup, using OH molecules is a starting point for the study of other molecules and their interactions with different substrate surfaces.

P 10.10 Tue 16:15 ZHG Foyer 1. OG

Untersuchungen der Plasmareduktion von Mangan in wässriger Lösung — •Daniel Tasche[1,2], Kai Bröking[1,2,3], Mirco Weber[1], Christoph Gerhard[1,4] und Wolfgang Viöl[1,5] — [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]Max-Planck-Institut für Multidisziplinäre Naturwissenschaften, Göttingen, Deutschland — [4]Politecnico di Milano, School of Industrial and Information Engineering, Mailand, Italien — [5]Fraunhofer IST - Anwendungszentrum für Plasma und Photonik, Göttingen, Deutschland

Dieser Beitrag beschäftigt sich mit der plasmainduzierten Reduktion des Manganions in wässriger Lösung. Ein Atmosphärendruckplasma wird über einer manganionenhaltigen Lösung gezündet, wodurch sich die Oxidationsstufe des Mangans verändert. Die Reduktion findet innerhalb der Plasma-Flüssigkeit-Grenzfläche statt. Zusätzlich wird eine Strömung durch das Plasma in der Lösung induziert, wodurch es zu einer Durchmischung der flüssigen Phase kommt. Die Ausbreitung sowie die chemischen und physikalischen Eigenschaften des Prozesses werden durch die hyperspektrale Bildgebung orts-, zeit- und spektralaufgelöst beobachtet. Dadurch sind hochauflösende Analysen der charakteristischen Absorptionsbanden unterschiedlicher Oxidationsstufen des Manganions und der Lichtemission des Plasmas möglich. Durch die Untersuchungen ergeben sich Prozessparameter wie Reduktionsraten und Bestandteile im Plasma.

P 10.11 Tue 16:15 ZHG Foyer 1. OG

Stereoscopic observation of the interaction of fast particle agglomerates with a dusty plasma — •Daniel Maier, Christina Knapek, André Melzer, Daniel Mohr, and Stefan Schütt — Institute of Physics, University of Greifswald, Germany

Fast objects moving through a dispersive medium can interact in various ways and create a variety of phenomena (e.g. Mach cones). The investigation of this interaction has been a topic of research for long times.

Such interactions were observed in experiments with a dusty plasma under microgravity using the "Zyflex" chamber. A cloud of micron sized particles in a low temperature plasma was disturbed by fast particle agglomerates that were unintentionally accelerated to high velocities during the experiments. This disturbance leads to dust-free cavities behind the agglomerates that vary in form and size due to the velocity of the agglomerate and the angle of its moving direction in relation to the plane of the plasma that is illuminated by the laser. Using a stereoscopic camera set-up consisting of four high-speed cameras with a resolution of 2.1 MP at a frame rate of 200 fps it is possible to calculate the spatial position of the dust particles and their movements during the interaction with the fast agglomerates in three dimensions.

In this contribution observations of the described interaction for agglomerates with different velocities and moving angles will be shown focussing on the velocities and density of the surrounding dust particle as well as the spatial characteristics of the the dust-free cavity.

This project has been funded under the DLR grant 50WM2161.

P 10.12 Tue 16:15 ZHG Foyer 1. OG

Microwave cavity resonance spectroscopy (MCRS) and double probe (DP) measurements as nanodusty plasma diagnostic tools — •Andreas Petersen[1], Johanna Vogt[2], Michael Friedrichs[2], Jens Oberrath[2], and Franko Greiner[1,3] — [1]Institute of Experimental and Applied Physics, Kiel University, 24118 Kiel, Germany — [2]South Westphalia University of Applied Sciences, 59494 Soest, Germany — [3]KiNSIS, 24118 Kiel, Germany

Measuring plasma parameters like n_e and T_e in a nanodusty plasma is still a challenge as it requires a non-invasive diagnostic method. An excellent candidate for this purpose is MCRS. Only electrons are affected, as the probing microwave frequency is $\omega > \omega_p$. The approach can be described well for a sealed cavity with N ports. However, analysing nanodusty plasmas requires additional access to the cavity (holes, slits). A theoretical model of the cavity modes and the coupling of the ports is required. We present a suitable experimental cavity design and compare to numerical models. Furthermore, double probe measurements in an argon plasma inside the cavity are considered, as they are a good stepping stone for the diagnosis of nanodusty plasmas.

We gratefully acknowledge funding by Deutsche Forschungsgemeinschaft (DFG), Project No. 531667910

P 10.13 Tue 16:15 ZHG Foyer 1. OG

COMPACT: Project Status and Research Data Managment — •Daniel P. Mohr[1], Christina A. Knapek[1], Stefan Schütt[1], Daniel Maier[1], Andre 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).

COMPACT is a project with international scientific contributions, funded by space agencies (DLR, NASA). The industry phase B is currently underway and will be finished in 2025.

Data generated by experiments on the ISS are of significant importance, as repeating an experiment can be extremely challenging and time-consuming. Therefore, it is crucial to design data management and handling strategies at an early stage to ensure efficient and reliable data processing.

We will present the objectives of COMPACT, the project status, and first concepts for the handling of research data acquired with COMPACT following the FAIR principles.

This work is funded by DLR/BMWi (FKZ 50WM2161).

P 10.14 Tue 16:15 ZHG Foyer 1. OG

3D EM-simulation of the influence of non-ideal cavities on their resonance behaviour to be applied in microwave cavity resonance spectroscopy — •Johanna Vogt[1], Michael Friedrichs[1], Andreas Petersen[2], Franko Greiner[2], and Jens Oberrath[1] — [1]South Westphalia University of Applied Sciences, 59494 Soest, Germany — [2]Institute of Experimental and Applied Physics, Kiel University, 24118 Kiel, Germany

To extract plasma parameters from a plasma, active plasma resonance spectroscopy (APRS) was developed, which works by measuring the frequency response of a plasma subjected to a wide-band radio frequency signal. The resulting spectrum is analysed, and with the use of a model, the electron plasma frequency is calculated. This in turn is used for determining the plasma electron density. A specific version of APRS is microwave cavity resonance spectroscopy (MCRS), in which an electromagnetic (EM) wave is coupled into a resonant cavity containing a plasma. Due to its non-invasive character, MCRS is a good candidate to be applied in nanodusty plasma.

The spectrum of a cavity is influenced by its geometry and materials. To determine plasma parameters from these spectra, detailed knowledge of this influence is necessary. To this extent, the results of a 3D EM simulation of the influence of several non-ideal alterations on the resonance spectrum is investigated and compared to an ideal cylindrical cavity.

This project was funded by Deutsche Forschungsgemeinschaft (DFG), Project No. 531667910, which we gratefully acknowledge.

P 10.15 Tue 16:15 ZHG Foyer 1. OG

Towards automated processing and re-use of open-access content in LTP research — •Markus M. Becker[1], Hans Höft[1], Ihda Chaerony Siffa[1], Muhammad Haris[2], Sarah Dellmann[2], and Markus Stocker[2] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]TIB – Leibniz Information Centre for Science and Technology, Hanover, Germany

In research on low-temperature plasmas (LTP), a wide range of devices, methods and materials are mainly used in table-top experiments. Model-based simulations are often used in conjunction with laboratory experiments to investigate, optimise or develop new plasma processes and applications. This leads to a large number of widely spread, heterogeneous research results, which are difficult to compare and can hardly be brought together. However, this is essential to form a robust overall understanding of the very complex mechanisms and effects in LTP. This contribution deals with modern techniques and exploits the advantages of Open Access (OA) to meet these challenges. OA publications from LTP research are collected in the central public repository "Renate" and converted into a machine-readable format. This enables machine learning-based processing and interpretation of OA publications on the used devices, methods, materials, etc., and ultimately their structured storage in the "Open Research Knowledge Graph" (ORKG). In future, the knowledge extracted and semantically described in this way will be easier to find and aggregate and can therefore be re-used to gain new research insights using data-driven methods.

Funded by the BMBF, projects 16KOA013A and 16KOA013B.

P 10.16 Tue 16:15 ZHG Foyer 1. OG

Exploration of modern techniques for optimising plasma modelling procedures — Aleksandar P. Jovanović[1], Marjan Stankov[1], Robert Wagner[1], Ihda Chaerony Siffa[1], Aleksandar Trokicić[2], Marko D. Petković[2], and •Markus M. Becker[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Faculty of Sciences and Mathematics, University of Niš, Niš, Serbia

Understanding the physical and chemical processes relevant to plasma generation is particularly important due to its broad technological potential. To gain a deeper understanding of these processes, numerical modelling is often applied. Plasma models often need to account for many particle species and reactions, leading to a large system of partial differential equations, which needs to be solved numerically. In addition, fine meshes are required to resolve the sheath regions, which further increases the number of degrees of freedom and prolongs calculation time. Therefore, a big challenge in plasma modelling is to find an efficient way to solve these equations. To tackle this challenge, modern techniques for simplification and optimisation of plasma modelling procedures are investigated and discussed. The studied approaches include automating geometry and refined mesh generation supported by image processing, a reinforcement learning-based time-stepping and the use of tailored preconditioners for iterative solvers. The results of applying these techniques to model a positive streamer in air and an RF discharge in argon at low pressure are presented and discussed.

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P 10.17 Tue 16:15 ZHG Foyer 1. OG

Electrons interacting with dielectric slabs — •Franz Xaver Bronold and Felix Willert — Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany

As a preparatory step for computing secondary electron emission probabilities for dielectrically coated electrodes used in dielectric barrier discharges, we investigate–from a microscopic solid-state physics point of view–the interaction of electrons with dielectric slabs of finite thickness. Whereas for a halfspace geometry, only electron backscattering (including secondary emission) has to be considered, it is now also required to quantify electron transmission through the slab. Leaving aside the interaction of the transmitted electrons with the metal supporting the dielectric layer,we describe in this contribution how the slab's energy and angle-resolved transmission and backscattering functions can be obtained from the invariant embedding principle used by us so far for modeling secondary emission from halfspaces [1]. Both functions enter the equation determining electron backscattering from the dielectric-metal heterostructure comprising the barrier discharge's electrode. Representative data for SiO_2, described by a semiempirical randium-jellium model, are shown as a function of layer thickness, in addition to the Möbius scheme used for numerically integrating the set of matrix Riccati/Sylvester differential equations, arising in slab geometry, in contrast to their algebraic counterparts appearing in the modeling of halfspaces. [1] F. X. Bronold and F. Willert, Phys. Rev. E **110**, 035207 (2024). Supported by Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)–495729137.

P 10.18 Tue 16:15 ZHG Foyer 1. OG

Solving the Spatially Dependent Boltzmann Equation for Electrons with 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), Felix-Hausdorff-Straße 2, 17489 Greifswald, Germany — [2]Kiel University, Kaiserstraße 2, 24143 Kiel, Germany

Physics-informed neural networks (PINNs) are an exciting new research area in the field of scientific machine learning. They offer an alternative approach to numerically solving partial differential equations (PDEs) in both forward and inverse problem settings with great flexibility. This study investigates the application of PINNs to solve the spatially one-dimensional electron Boltzmann equation in two-term approximation, which is relevant for the study of non-local effects in weakly ionized, non-thermal plasmas. An attention-based neural network architecture is developed to prevent the convergence to incorrect or trivial solutions of the PDEs as encountered by other architectures in solving this kinetic equation. Numerical experiments are conducted for argon plasmas considering homogeneous electric fields with varying values using a conventional numerical method and the PINN approach. The results from PINNs show good agreement with the reference solutions (obtained from the conventional approach) for the considered cases, which further strengthens PINNs' position as an alternative to solve this type of equation, paving a way for more efficient and accurate fluid-Poisson plasma simulations.

P 10.19 Tue 16:15 ZHG Foyer 1. OG

Local projectors for sparse storage of Basis Projection Operators. — •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, we developed a custom set of commuting local projection operators for the De-rham complex based on a new set of quasi-interpolation points. These new local projectors maintain the same convergence rate of the global projectors, replicate the basis functions, and have an execution time in the same order of magnitude as the global projectors if run in parallel (the local projectors are about twice as slow as the global projectors). All while having the added advantage of producing a significantly sparser matrix for the Basis Projection Operators (even when compared with other Local Projectors), which allow us to store said operators in the PSYDAC Stencil-matrix format.

P 10.20 Tue 16:15 ZHG Foyer 1. OG

Development and validation of optimized grids for sim-

ulations of erosion and impurity transport — •Lukas Maximilian Ellerbrock[1,2], Christoph Baumann[1], Andreas Kirschner[1], Henri Kumpulainen[1], Berkant Palazoglu[1], Juri Romazanov[1], Sebastijan Brezinsek[1,2], and Christian Linsmeier[1,3] — [1]Forschungszentrum Jülich IFN-1, Jülich, Germany — [2]Heinrich-Heine-Universität, Düsseldorf, Germany — [3]Ruhr-Universität, Bochum, Germany

Fusion reactors require precise numerical predictions of plasma-wall interactions and impurity transport. Such predictions can be provided by numerical tools like the 3D Monte-Carlo simulation code ERO2.0. The present work deals with improvements of the ERO2.0 code regarding the numerical grid layout with the goal to optimize precision and computing power.

Until recently, simple rectangular grids were used to store the input distributions of plasma parameters like density and temperature coming from codes like SOLPS. However, the spatial resolution of these rectangular grids is limited due to memory reasons. This limitation can lead to artefacts in the simulation results. Therefore, a new code version introduced flexible field-aligned grids to improve the spatial resolution.

To verify the development, test simulations are applied for tungsten erosion in the future DEMO reactor and further improvements are made to optimize the precision of the code.

P 10.21 Tue 16:15 ZHG Foyer 1. OG

Calculating non-axisymmetric heat loads on plasma-facing components from infrared measurements in W7-X — •Sebastian Thiede[1], Marcin Jakubowski[1], Yu Gao[1], and Peter Manz[2] — [1]Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald, Germany — [2]Institut für Physik, Universität Greifswald, Greifswald, Germany

The edge topology of the Wendelstein 7-X stellarator has a complicated 3D structure. This is also true in particular for the deposited heat on plasma-facing components (PFCs). Local heat flux patterns are a valuable source of information for edge physics. The C++ code DELVER was newly developed to infer the surface heat flux distribution on PFCs from infrared measurements. For cuboid divertor tiles, consisting of multiple material layers, it uses an implicit finite-difference approach and an operator splitting technique to calculate this heat flux. It features arbitrary problem dimension, orthotropic material properties that can be arbitrary functions of temperature, non-equidistant orthogonal grids and flexible boundary conditions. A python interface was also developed for more convenient usage. DELVER has been tested against a simple analytical case, other codes, and was assessed on experimental data from W7-X.

P 10.22 Tue 16:15 ZHG Foyer 1. OG

Towards Implementing a Hirshman-Sigmar Type Collision Operator in the Gyrokinetic Code GENE-X — •Andrew Ivan Sulimro, Philipp Ulbl, and Frank Jenko — Max Planck Institute for Plasma Physics

The performance of future magnetic confinement fusion power plants is primarily influenced by the turbulence-driven quality of plasma confinement and heat exhaust. High-fidelity gyrokinetic simulations are key tools to investigate turbulence in fusion devices. The `GENE-X` gyrokinetic code is designed to simulate such situations in the complex geometry of the edge and scrape-off layer regions.

One of the important aspects influencing the accuracy of a gyrokinetic solver is the physics realism of the collision model. In the current state, the gyrokinetic code `GENE-X` is equipped with the Lenard-Bernstein/Dougherty (LBD) operator which is a lightweight alternative to the Fokker-Planck operator. However, the LBD operator lacks the accuracy to study different plasma components, such as impurities. As the collision frequency is proportional to the square of the ion charge, a realistic collision operator is especially crucial for studying high-Z impurities.

In this work, a more accurate collision operator of Hirshman-Sigmar type is implemented into `GENE-X`. This new operator can capture additional effects, such as an accurate pitch-angle scattering and the velocity dependence of the collision frequency, which are not accounted for by the LBD operator. The models involved and the numerical aspects of the implementation will be presented and discussed.

P 10.23 Tue 16:15 ZHG Foyer 1. OG

Inclusion of MHD effects in the transport description of tokamak plasmas — •Federico Stefanelli, Emiliano Fable, Clemente Angioni, and Hartmut Zohm — Max-Planck-Institute for Plasma Physics, 85748 Garching, Germany

This project aims to include MHD effects in the transport description of tokamak plasmas, in particular Sawtooth Cycles, Magnetic Flux Pumping and Neoclassical Tearing Modes (NTMs). Including such effects is relevant for a comprehensive transport description, as solving the transport equations provides the drive for MHD instabilities, and the non-linear evolution of such instabilities affects transport. Furthermore, many MHD effects, such as the Sawtooth Cycles or the NTMs, must be avoided or controlled, as they could lead to a loss of performance or disruptions. On the other hand, Magnetic Flux Pumping can provide a desirable operational regime for future machines, with a sawtooth-free core and an optimal redistribution of the core current. Reduced models for such effects would be then relevant for tokamak control applications. The approach followed in this work will be to implement reduced models for the triggering and evolution of such effects in the ASTRA transport code, to be validated on ASDEX Upgrade discharge. For the Sawtooth Cycles and the NTMs, these models will be taken from the literature, while for magnetic flux pumping it will be necessary to develop the reduced model as well.

P 10.24 Tue 16:15 ZHG Foyer 1. OG

Full-wave Simulations of Helicon Waves for Plasma Wakefield Accelerators — •Luis Carlos Herrera Quesada[1], Nils Fahrenkamp[2], Stefan Knauer[2], Peter Manz[2], Günter E.M. Tovar[1], and Alf Köhn-Seemann[1] — [1]IGVP, Universität Stuttgart, Stuttgart, Germany — [2]Universität Greifswald, Greifswald, Germany

This study aims to understand the propagation and dissipation of helicon waves in plasma wakefield systems and to investigate the influence of different antenna geometries on the efficiency of helicon wave excitation. Furthermore, the evolution of the radial plasma density gradient on the efficiency of coupling to the helicon wave is investigated.

The 3D finite-difference time-domain (FDTD) code FOCAL enables full-wave simulations and theoretical analysis, which is used to solve Maxwell's equations coupled to the fluid equation of motion for electrons in a cold magnetized plasma. In parallel, a Finite Element Method (FEM) analysis is carried out using the COMSOL Multiphysics code package. As a first step for simulation scenarios, the device parameters and the geometry of VINETA.75, located at the University of Greifswald, are implemented in the numerical model. In addition, external cooperation with the teams of the MAP device at the University of Wisconsin-Madison, and the PROMETHEUS-A and AWAKE experiments at CERN is planned.

Funding of this research by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - project number 517709182 is gratefully acknowledge.

P 10.25 Tue 16:15 ZHG Foyer 1. OG

3D full-wave simulation of the O-SX mode conversion process — •Alf Köhn-Seemann[1], Bengt Eliasson[2], Simon Freethy[3], Roddy Vann[4], and Thomas Wilson[3,4] — [1]IGVP, University of Stuttgart, Germany — [2]SUPA, Department of Physics, University of Strathclyde, Glasgow, U.K. — [3]Culham Centre of Fusion Energy, Culham, U.K. — [4]York Plasma Institute, University of York, U.K.

Electron Bernstein waves (EBWs) provide a method to heat over-dense plasmas, whose electron plasma density exceeds the cut-off density of an injected electromagnetic wave. EBWs are very well absorbed at the electron cyclotron resonance frequency and its harmonics, even for low electron temperatures. They can furthermore drive significant toroidal net currents. This makes them particularly interesting for spherical tokamaks which often have only a small or no central solenoid and rely therefore on non-inductive current drive. EBWs are electrostatic waves, requiring them to be coupled to externally injected electromagnetic waves. Here we present 3D numerical simulations of the coupling process with the novel finite-difference time-domain code FOCAL. Simulation results from a feasibility study for the spherical tokamak MAST Upgrade are presented and related numerical challenges are discussed.

P 10.26 Tue 16:15 ZHG Foyer 1. OG

Study of Quasi-Symmetry in Stellarator Designs: Impact of Coil Parameters on Device Robustness — •Elisa Buglione-Ceresa, Pedro Gil, and Eve Stenson — Max Planck Institute for Plasma Physics, Garching

This study investigates the role of quasi-symmetry (QS) in stellarators, focusing on its sensitivity to various design parameters. QS is crucial for confining trapped charged particles and plasma in toroidal magnetic fields. In a quasi-symmetric stellarator the magnetic field strength can exhibit symmetry along a specific coordinate, providing the confinement of guiding center trajectories. The research examines three stellarator configurations, analyzing the impact of coil number, coil separation, coil complexity (λ), and manufacturing imperfections (simulated as Gaussian perturbations with amplitude σ and characteristic length L) on QS. The studied equilibria include the APEX-EPOS configuration and reactor-sized designs with quasiaxisymmetry and quasihelical symmetry for precise plasma confinement. Using REGCOIL for coil design optimization and SIMSOPT for perturbations, we applied Gaussian perturbations to simulate realistic manufacturing conditions. Results show that QS decreases with increasing perturbations, highlighting its sensitivity to manufacturing tolerances. This study also investigates how QS changes with varying coil numbers, separation, and complexity. These findings provide critical insights into optimizing coil design, including performance of the field accuracy at reactor relevant dimensions, offering valuable guidelines for designing stellarators that balance high performance with practical feasibility.

P 10.27 Tue 16:15 ZHG Foyer 1. OG

Coupling of fluid neutrals with gyrokinetic plasma in the edge turbulence code GENE-X — •Sabine Ogier-Collin, Philipp Ulbl, Wladimir Zholobenko, and Frank Jenko — Max-Planck Institute for Plasma Physics, Garching bei München, Germany

Understanding turbulent transport in the plasma edge and scrape-off layer (SOL) is essential for managing heat and particle exhaust while maintaining effective core confinement in magnetic confinement fusion (MCF) reactors. In these regions, the abundance of neutral particles and their interactions with the plasma significantly influence radial profiles and thus gradient-driven instabilities, particle transport across the separatrix, and blob dynamics in the SOL.

`GENE-X` is a first-principles code designed to simulate edge and SOL turbulent transport in realistic magnetic geometries, including X-points. We present the first coupling of a continuum full-f gyrokinetic model with a fluid model for neutrals. The evolution of the neutrals density is captured by a pressure-diffusion equation, where the diffusion is driven by charge exchange collisions. Plasma-neutral interactions - such as ionisation, recombination and associated radiation - are included via special Krook operators.

Following verification, relaxation studies have been carried out to assess the impact of inelastic plasma-neutrals reactions on plasma distribution functions and equilibration dynamics. In addition, a first case study in divertor geometry is presented, demonstrating the potential of the coupled model for turbulence simulations in MCF devices.

P 10.28 Tue 16:15 ZHG Foyer 1. OG

Characterization of pure-electron plasmas in APEX-LD — •Veronika C. Bayer, Adam Deller, Alex Card, and E. V. Stenson — Max Planck Institute for Plasma Physics, Garching b. München, Deutschland

We describe the development of diagnostics for studying stably confined pure-electron plasmas in a compact levitating dipole trap (APEX-LD). The existing diagnostics confirm collective behaviour. However, they provide incomplete means to analyse the plasma potential or the density profiles. New diagnostics, an electron beam probe and a retractable target probe, will collect the data necessary to analyse these properties. Further insights into collective behaviour from these new diagnostics will be used to prepare APEX-LD for pulsed positron injection and the trapping of pair plasmas.

P 10.29 Tue 16:15 ZHG Foyer 1. OG

Generation and diagnostics of an inverted fireball (IFB) discharge in an rf plasma — •Viktor Schneider[1], Jan Krieger[1], Johannes Grünwald[2], Gerhard Eichenhofer[3], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics (IEAP), Kiel University — [2]Gruenwald Laboratories GmbH — [3]4A-Plasma

In this work, an inverted fireball (IFB) [1,2], i.e. a secondary plasma within a hollow grid anode cage, was generated and investigated in a radio frequency plasma. IFBs have a significantly increased plasma density, a homogeneous plasma potential and are, therefore, potentially interesting for application in PECVD processes [3-4]. The ignition conditions for the IFB plasma were determined and special features regarding the influence of the rf plasma on the IFB, in particular the bias voltage of the rf electrode, were studied. The IFB plasma was investigated using a Langmuir probe, optical emission spectroscopy (OES) and a passive thermal probe (PTP) [5]. Good agreement was obtained between the diagnostics for the behavior of the IFB with parameter variation using OES and PTP.

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[3] J. Gruenwald et al., Surface & Coatings Technology, (422), (2021)
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P 10.30 Tue 16:15 ZHG Foyer 1. OG

Characterization of Reflected Light Properties in PIC Simulations — •Vidisha Rana[1,2], Milenko Vescovi[1,2], Marvin E.P. Umlandt[1,2], Franziska Paschke-Brühl[1,2], Richard Pausch[1], Pengjie Wang[1], Tim Ziegler[1,2], Karl Zeil[1], Ulrich Schramm[1,2], and Thomas Kluge[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Technische Universität Dresden

Laser-driven ion accelerators offer several advantages over the conventional ones due to their potential of achieving high accelerating gradients over small distances. Recent experiments have demonstrated that one can achieve significantly high proton energies by modifying the temporal profile and controlling the spectral phase of laser pulses, specifically using Group Velocity Dispersion (GVD). However, the entire mechanism still needs to be understood.

Reflected light properties provide a powerful diagnostic tool for understanding these interactions and optimizing proton energies. Experiments involving high-intensity ultrashort laser pulses interacting with thin foils reveal prominent spectral shifts across changing Group Velocity Dispersion (GVD) values. These shifts can offer valuable insights into plasma dynamics, relativistic surface motion, and laser contrast effects, which have a direct impact on proton energies but remains difficult to interpret solely through experiments. This challenge can be addressed by employing PIC codes to simulate these interactions to analyze the underlying mechanisms. By bridging this gap, this work aims to advance our understanding of laser-plasma interactions.

P 10.31 Tue 16:15 ZHG Foyer 1. OG

Radiation emission from relativistic electron bunches interacting with plasma density gratings — •Sophie Opara and Götz Lehmann — Heinrich-Heine-Universität Düsseldorf

The interaction between high-intensity light waves and transient periodic density modulations of underdense plasma has been proven to be a fruitful concept for plasma-based optics in the context of high-power lasers. The plasma density gratings, driven by the ponderomotive force of overlapping laser pulses, can have substantial amplitudes, up to more than 100% in the nonlinear regime. The modulations then subsequently can act e.g. as Bragg-type mirror, polarizer or wave-plate for probe pulses of high intensity. Their holographic nature allows even to convert between different types of laser beams, e.g. from Gaussian to Gauss-Laguerre type. Even concepts for plasma-based pulse compressors for chirped-pulse amplification have been developed. The interaction of density modulated plasma with highly energetic particle beams on the other hand is less well studied, mostly in the context of beam transport through plasmas. In our present work we study the interaction of beams in strongly density modulated systems in the context of radiation generation.

P 10.32 Tue 16:15 ZHG Foyer 1. OG

Plasma-based volume holograms for creation of relativistic Gauss-Laguerre laser beams — •Götz Lehmann and Karl-Heinz Spatschek — Heinrich-Heine-Universität Düsseldorf

Gauss-Laguerre (GL) laser beams have received growing interest in the field of high-intensity laser-plasma interactions over the past years due to their particular doughnut-like intensity distribution, their particular field configuration in the focal region and also for their orbital angular momentum. At moderate intensites, i.e. far away from the ionization-threshold of any material and thus even further away from the (relativistic) intensities discussed in literature, GL beams are obtained e.g. by passing a Gaussian beam through a spiral phase plate, imprinting a helical structure on the phase distribution within the beam. For relativistic focal intensities such solid-state material solutions are not feasible. Plasma-based holograms offer an alternative route to mode conversion. In our work, we show how to write transient plasma density gratings into underdense plasma that then subsequently will act as a hologram and convert Gaussian laser pulses into LG pulses of relativistic intensities.

P 10.33 Tue 16:15 ZHG Foyer 1. OG

Turbulence in Molecular Clouds - A laboratory for understanding waves in partially ionized media — •Christian

Heppe[1], Alexei Ivlev[2], and Frank Jenko[1] — [1]IPP, Garching (DE) — [2]MPE, Garching (DE)

Plasma in space are are found in a partially ionized state only. Thus, we need to consider the interaction between ionized and neutral gases. Since the coupling between both gases is modelled via collisions we expect, on scales smaller than their collision frequencies, the gases to increasingly decouple while on larger scales the gases to move in unison. This has immediate consequences for MHD waves in the medium requiring a deviation from a single-fluid treatment, i.e. two-fluid MHD (2FMHD). Although 2FMHD predicts "decoupling gaps" for MHD modes in which propagation is prohibited or strongly damped, simulations of 2FMHD turbulence do not show such a gap. This suggests that within the framework of ideal 2FMHD an as of yet unknown process that mediates energy through this gap is present. As Molecular Clouds (MCs) are of generally high interest in Astrophysics and Astronomy due to their role in star formation and Cosmic Ray (CR) propagation, while covering a vast variety of plasma conditions under turbulent conditions over a wide range of scales, they pose as an ideal "laboratory" to empirically improve current understanding of MHD waves in partially ionized media.

P 10.34 Tue 16:15 ZHG Foyer 1. OG

Thermal and DC Electrical Conductivities of Hydrogen at the Insulator-to-Metal Phase Transition from Ab Initio Calculations — •Martin Preising[1], Ronald Redmer[1], and Marcus Knudson[2] — [1]University of Rostock — [2]Sandia National Labs, USA

The metallisation of fluid hydrogen under high pressures has a profound impact on planetary science [1]. While most experimental campaigns report transition pressures between 100 and 225GPa, a 2015 campaign reports significantly higher pressures around 300GPa [2].

Understanding and resolving this discrepancy requires calculations of thermal conductivities of shocked hydrogen in the vicinity of the metallisation, including ionic thermal conductivities [3].

We report on DC electrical conductivities, thermal electronic and thermal ionic heat conductivities from ab initio simulations. We employ the vdW-DF1 and vdW-DF2 exchange-correlation functional due their superior ability to predict experimental conductivities of dense hydrogen [4].

Electronic contributions show an increase of several orders of magnitude across the metallisation transition. The ionic thermal conductivities do not significantly change but provide the main contribution to the total thermal conductivity in the non-metallic and a significant contribution in the metallic regime.

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P 10.35 Tue 16:15 ZHG Foyer 1. OG

Particle acceleration in core-collapse supernova remnant — •Samata Das[1,2], Robert Brose[2], Dominique M.-A. Meyer Meyer[3], Martin Pohl[2,4], and Iurii Sushch[5] — [1]Theoretische Physik IV, Fakultät für Physik Astronomie, Ruhr-Universität Bochum, 44780 Bochum, Germany — [2]University of Potsdam, 14476 Potsdam, Germany — [3]Institute of Space Sciences , 08193 Barcelona, Spain — [4]DESY, 15738 Zeuthen, Germany — [5]Gran Sasso Science Institute, 67100 L'Aquila, Italy

The complex environments around core-collapse supernova remnants (SNRs) from their massive progenitors, shape spectra and morphology of non-thermal emissions from remnants. We study the effects of hydrodynamics and magnetic field of circumstellar medium on particle acceleration and emission from remnants. We use RATPaC and PLUTO code where hydrodynamic equations with transport equation for CRs and scattering magnetic turbulence, induction equation for magnetic field evolution solved in 1-D spherical symmetry. Our study shows the SNR propagation through hot bubble, for example, bubble by $60M_{\odot}$, reduce significantly the sonic Mach number of SNR shock that persistently softens the particle spectra with spectral index 2.5, and steepens the radio spectra. SNR with 20 $M_{\odot}$ Red-Super giant progenitor produces steep radio spectra, and soft pion-decay gamma-ray spectra, briefly during the interaction of the SNR shock with the dense RSG shell. For old remnants inside shocked ISM, we got softer pion-decay emission, consistent with the observed gamma-ray emission

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P 10.36 Tue 16:15 ZHG Foyer 1. OG

Particle Acceleration and Emission Signatures in Relativistic AGN Jets — •Nikita Nikita[1], Frank Rieger[1], Bhargav Vaidya[2], and Frank Jenko[1] — [1]Max Planck Institute for Plasma Physics (IPP), Boltzmannstraße 2, 85748 Garching, Germany — [2]DAASE, IIT Indore, Simrol, 453552, India

Relativistic outflows from AGNs can extend up to kilo-parsec scales, exhibiting complex morphologies. Using 3D relativistic magnetohydrodynamic (RMHD) simulations of rotating jet using PLUTO, we explore the role of dynamical instabilities in shaping complex jet morphologies and their synchrotron emission. Our analysis based on simulations of a continuously injected jet suggests that current-driven instabilities, notably the |m| = 1 mode, generate ribs-like structures that are seen in some of the recent radio galaxies using MeerKat. In the simulations of the restarted jet, the kink-instability driven ribs-like structures were formed closer to the nozzle. In both cases, the jet dissipates its magnetic energy through these instabilities, transitioning to a more kinetic energy dominant state. The synchrotron emission modeled in these simulations considers only diffusive shock acceleration. Stochastic acceleration, however, can become relevant in large-scale jets at sufficient magnetization, where strong shocks are absent, and turbulent magnetic fields dominate. As a next step, we aim to incorporate stochastic turbulent acceleration into PLUTO using a semi-analytical approach. These findings will contribute to a deeper understanding of the multi-scale processes driving particle acceleration and emission in AGN jets, bridging numerical simulations with observations.

P 10.37 Tue 16:15 ZHG Foyer 1. OG

Understanding the Role of Plasma Instabilities in Blazar-Induced Pair Beams: Laboratory Simulations and Astrophysical Implications — •Suman Dey and Günter Sigl — II. Institut für Theoretische Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The interaction of TeV photons from blazars with the extragalactic background produces a relativistic beam of electron-positron 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. We employed particle-in-cell (PIC) simulations to study the plasma instabilities of ultra-relativistic pair beams propagating in a denser background plasma, using the parameters designed to replicate astrophysical jets under laboratory conditions. We have investigated the parameter regime where the electromagnetic modes are suppressed, aligning with the physically relevant criteria of Blazar-induced beams. We have used an astrophysically realistic non-Maxwellian distribution for the beam particles, improving upon previous studies. We investigated the interplay between the magnetic field forming from localized currents and transverse beam momentum spread. We calculated the physical limit of density contrast at which the beam achieves optimal suppression of electromagnetic instabilities in laboratory experiments. We extrapolated the non-linear feedback of instability where the beam is energetically broadened. We observed that the instability generates a negligible angular broadening for Blazar-Induced beams.

P 10.38 Tue 16:15 ZHG Foyer 1. OG

Influence of ELMs on O-X mode conversion efficiency — •Shibangi Majumder, Christos Vagkidis, and Alf Köhn-Seemann — IGVP, University of Stuttgart, Germany

Edge Localized Modes (ELMs) constitute a continuous relaxation of the edge plasma pressure gradient. The respective perturbation of the electron plasma density profile can perturb microwaves injected into the plasma for heating purposes. This is particularly true for mode coupling processes like the O-SX-B mode conversion, where an injected O-mode couples to an SX-mode near the cut-off layer. The SX-mode is then reflected and propagates to the upper-hybrid resonance, where it can couple to electron Bernstein waves, which are electrostatic waves that are very well absorbed at the electron cyclotron resonance. The efficiency of the O-SX coupling depends strongly on the injection angle with respect to the background magnetic field. In this work, we explore the effect of ELMs on the O-SX coupling with an FDTD code, providing thus insights into the interplay between ELM-induced edge conditions and microwave heating performance. This further can contribute to a deeper understanding of plasma heating and confinement mechanisms in fusion experiments.

P 10.39 Tue 16:15 ZHG Foyer 1. OG

Study on Fast Electrons Generated in the Stellarator Experiment TJ-K — •José Ignacio Fernández Gómez, Alf Köhn-Seemann, and Mirko Ramisch — IGVP, University of Stuttgart,

Germany

The TJ-K stellarator is equipped with a microwave heating system capable of delivering power at three frequencies: 3 kW at 2.45 GHz, 3 kW at around 8 GHz, and 6 kW at around 14 GHz. While the bulk electron temperature is typically around 10 eV, fast electrons with energies ranging from several 100 eV to 100 keV are found in various experimental scenarios. In this work, the trajectories of these fast electrons are simulated in the 3D magnetic field geometry of TJ-K. It is found that these particles, when comparing movement parallel and anti-parallel to the magnetic field, can result in toroidal net currents if the drift surfaces differ sufficiently. Configurations resulting in toroidal net currents are identified and the underlying physics processes are discussed. Selected scenarios are experimentally analyzed to measure the toroidal net current, providing a basis for validating the simulation outcomes.

P 10.40 Tue 16:15 ZHG Foyer 1. OG

Self-consistent eddy and halo current coupling of a 3D non-linear MHD plasma with 3D realistic wall structures — •Raffaele Sparago[1,2], Javier Artola[2], Matthias Hoelzl[1], Nicola Isernia[3], Guglielmo Rubinacci[4], Nina Schwarz[2], Salvatore Ventre[5], and Fabio Villone[3] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]ITER Organization, 13067 St. Paul Lez Durance Cedex, France — [3]Università degli Studi di Napoli Federico II, Via Claudio 21, 80125 Napoli, Italy — [4]CREATE Consortium, Via Claudio 21, 80125 Napoli, Italy — [5]Università di Cassino e del Lazio Meridionale, Via Gaetano di Biasio 43, 03043 Cassino, Italy

An adequate modeling of the electromagnetic interaction of a magnetized plasma with the surrounding machine's conductors is paramount for the correct replication of 3D plasma dynamics. Reproductions of the latter provide useful predictions regarding the evolution of MHD modes and the electromagnetic forces acting on the vacuum vessel when said modes trigger disruptions. The here presented modeling efforts involving the 3D FEM non-linear MHD code JOREK have accomplished the self-consistent coupling of eddy currents in a full MHD physics scenario, with the related validation and simulation, employing the wall code STARWALL. This contribution also features the latest progress concerning the self-consistent coupling of halo currents (which flow from the plasma to the wall and viceversa) with the 3D wall code CARIDDI; this is essential for the prediction of the related rotating sideways forces that could pose a serious threat to future machines.

P 10.41 Tue 16:15 ZHG Foyer 1. OG

Density and Temperature Profiles from Upper Divertor Spectroscopy — •Hannah Lindl[1], Ralph Dux[1], and The ASDEX Upgrade Team[2] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]See author list of H. Zohm et al, 2024 Nucl. Fusion

Reducing the power load on material surfaces is essential for prolonging the lifetime of plasma facing components. The final goal is to reach plasma detachment, resulting in reduced heat and ion fluxes onto the divertor target. We can accomplish this by significantly reducing the electron temperatures T_e near the target plates compared to the upstream values, resulting in effective ion recombination before they make contact with the first wall.

A new measurement technique based on divertor spectroscopy is proposed to determine T_e profiles in the upper divertor region of ASDEX Upgrade (AUG), where we can observe the plasma with high fidelity. This enables us to obtain local data for all spectroscopic accessible quantities by a fit similar to an Abel transform. We aim to calculate $T_e(r)$ in diverted plasmas by measuring local electron densities n_e through Stark broadening of the high-n deuterium Balmer lines D_δ and D_ϵ. Furthermore, we calculate line emissivity profiles $\epsilon_L(r)$ via a deconvolution of the spectral radiance L. Assuming Saha equilibrium is established between high-n and continuum states of deuterium, we estimate $T_e(r)$ by combining $n_e(r)$ with $\epsilon_L(r)$.

In this contribution, the technique is applied to first measurements of the upper divertor spectroscopy in upper single null discharges at AUG and first n_e and T_e profiles in this region are shown.

P 10.42 Tue 16:15 ZHG Foyer 1. OG

Analysis of the electrostatic potential distribution and drifts in island divertor geometries using fluid turbulence simulations — •Tobias Tork[1], Felix Reimold[1], David Bold[1], Brendan Shanahan[1], Sergei Makarov[1], Peter Manz[2], and the W7-X Team[1] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Institute of Physics, University of Greifswald, 17489 Greifswald, Germany

In fusion devices, particle and heat exhaust pose a significant challenge. The island divertor concept was developed to address the exhaust problem. In this concept, the magnetic field is perturbed and forms magnetic islands at rational flux surfaces. These islands are intersected by target plates and divert particle and heat fluxes to the targets. In the island divertor of the stellarator Wendelstein 7-X, large poloidal ExB-velocities have been observed. These velocities are expected to significantly contribute to the transport of particle and energy. Current state of the art stellarator simulations are not incorporating drift effects. There is thus little knowledge about the electrostatic potential distribution and hence the ExB-drifts in an island divertor. To address this issue, the 3D-turbulence model Hermes-2 is used. It is applied to simplified geometries that mimic the island divertor topology. As Hermes-2 is a hot-ion drift reduced fluid model, it contains the electrostatic potential and thus the drift effects. The latter will be analyzed on mean field solutions to understand the electrostatic potential distribution and the impact of drifts and currents on the plasma parameters and the transport in the island.

P 10.43 Tue 16:15 ZHG Foyer 1. OG

A new method to characterize instabilities in fusion plasmas using the soft x-ray multicamera system at Wendelstein 7- X — •Charlotte Büschel, Christian Brandt, Henning Thomsen, Kian Rahbarnia, Sara Vaz Mendes, Edith Victoria Hausten, and Wendelstein 7-X Team — Max Planck Institute for Plasma Physics, Greifswald, Germany

Soft x-ray tomography is widely used in fusion experiments for the reconstruction of two-dimensional density profiles. The soft x-ray multicamera tomography system (XMCTS) installed in Wendelstein 7-X consists of 20 pinhole cameras [C. Brandt et al. 2020]. Each camera has 18 photodiodes, measuring the line-integrated soft x-ray emissivity of the plasma. As the emissivity is strongly related to the plasma density, the fluctuating part of the signal can be used to analyze instabilities propagating in the plasma. Electrostatic and electromagnetic instabilities affect the particle and energy transport within a plasma and are one of the main reasons for particle and energy losses. To control or even prevent instabilities, their characterization regarding amplitude, frequency, radial location, poloidal structure and propagation direction is important. A new method has been developed to analyze the 360 line-integrated signals of the photodiodes to determine the radial location and the poloidal structure of instabilities with poloidal mode numbers up to m=20. The workflow of the analysis is presented based on artificial data.

P 10.44 Tue 16:15 ZHG Foyer 1. OG

The isotope dependence of the ASDEX Upgrade pedestal structure — •Roxána Takács[1], Michael Dunne[1], Benedikt Zimmermann[1,2], and the ASDEX Upgrade Team[3] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Department of Applied Physics and Applied Mathematics, Columbia University, New York, USA — [3]See author list of H. Zohm et al, 2024 Nucl. Fusionhttps://doi.org/10.1088/1741-4326/ad249d

Future fusion devices, such as ITER, will operate with a deuterium-tritium mixture, whereas current experiments use mainly deuterium or hydrogen. Studying the isotope dependence is, therefore, crucial to accurately predict the performance of these future fusion devices. Previous studies have demonstrated positive isotope mass scaling of the thermal energy confinement time in H-mode plasmas. This phenomenon has been observed in several major tokamaks, including JET [C.F. Maggi], JT-60U [H. Urano], ASDEX [M. Bessenrodt-Weberpals] and ASDEX Upgrade [P. A. Schneider]. To further investigate the isotopic dependence, this analysis compares different isotopic plasmas from the ASDEX Upgrade tokamak, focusing on the pedestal region to understand the specific phenomena where isotopes play an important role. Different main isotopic discharges with matched engineering parameters were selected for comparison. The analysis includes comparison of kinetic profiles (temperature, density, and pressure profiles), stability analysis against peeling-ballooning (PB) modes, and investigation of inter-ELM transport differences.

P 10.45 Tue 16:15 ZHG Foyer 1. OG

Bayesian inference of plasma parameters in the island divertor of W7-X — •Linnéa Björk[1], Felix Reimold[1], Sehyun Kwak[1], Daniel Böckenhoff[1], Udo von Toussaint[2], Sebastian Grosinger[3], and The Wendelstein 7-X Team[1] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]Max Planck Institute for Plasma Physics, Garching, Germany — [3]Lund University,

Department of Physics, Lund, Sweden

The W7-X stellarator is a 3D fusion device with a complex geometry, which make diagnostic measurements of the plasma sparse. This is especially true for the boundary region, known as the scrape-off layer (SOL). Here so-called island divertors are located which manage exhaust for particles and heat. In this region, the plasma interacts with toroidally discontinuous divertor plates, which can lead to strongly toroidally localized effects. Assessing the physics and transport phenomena in this region is therefore not trivial. By using a Bayesian analysis approach, datasets from different diagnostics can be combined in order to obtain information about the underlying plasma parameters, such as the electron density and temperature distributions. This knowledge will ultimately help deepen the understanding of transport at the boundary.

In this contribution, first steps into a Bayesian analysis framework focusing on inference of plasma parameters in the boundary region will be presented. This includes outlier-robust 1D profile fits of electron density and temperature and progress on building a 2D framework for parameter regression.

P 10.46 Tue 16:15 ZHG Foyer 1. OG

Commissioning of a dispersion interferometer for disruption studies at ASDEX Upgrade — •Andrew Moreau[1,2], Alexander Bock[1], Kai Jakob Brunner[3], Riccardo Nocentini[1], Emre Sözer[1], Andreas Burckhart[1], Jens Knauer[3], Thomas Pütterich[1,2], and the ASDEX Upgrade team[4] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Ludwig Maximilian University, Munich, Germany — [3]Max Planck Institute for Plasma Physics, Greifswald, Germany — [4]See author list of H. Zohm et al, 2024 Nucl. Fusion

Disruptions are off-normal events where thermal and particle confinement are lost in magnetic confinement plasma devices. Future reactors carry a high risk of unmitigated disruptions causing unacceptable force and heat loads for the health of the devices. It is essential to develop instruments which can reliably track quantities, such as electron density, through the entire phase of disruptions and their mitigation schemes as we learn to characterize and control the plasma state.

At ASDEX Upgrade, two systems have measured line-integrated electron density, a 195μm interferometer and a 10.6μm two-colour interferometer. These interferometers either refract heavily during disruptions or are extremely noisy from incomplete vibration compensation and both suffer from ambiguities in the phase tracking (fringe jumps). We present the commissioning of a dispersion interferometer, probing at 5.3μm, which uses second-harmonic coherence conservation to intrinsically eliminate vibrational noise and is more resilient against refraction and fringe jumps from the shorter wavelength.

P 10.47 Tue 16:15 ZHG Foyer 1. OG

A new imaging diagnostic for ASDEX Upgrade divertor fluctuation studies — •Manuel Herschel[1,2], Michael Griener[1], Tim Happel[1], Tilmann Lunt[1], and The ASDEX Upgrade Team[3] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technical University of Munich, Physics Department, Chair for Plasma Edge and Divertor Physics, 85747 Garching, Germany — [3]see author list of H. Zohm et al, 2024 Nucl. Fusion 64 112001

In magnetic confinement fusion devices, so-called divertors are used to distribute heat loads on the wall and control impurity influxes into the main plasma volume. Recently, the ASDEX Upgrade fusion experiment has been equipped with a new flexible upper divertor to study various power exhaust scenarios.

To investigate the effect of the different divertor configurations in ASDEX Upgrade, powerful diagnostics are necessary. In this work, a novel multi-color gas puff imaging system is presented. The system consists of a fast helium injection valve to excite localized light emission from helium neutrals and an optical setup including an image splitter, spectral filters and a fast camera. The diagnostic is optimized for timescales below 10 μs and a spatial resolution of around 1 cm. The simultaneous imaging of two spectral lines allows compensation of shadowing effects. This enables the observation of fast turbulent structure dynamics in the divertor region.

The final setup and the design choices behind the components are presented, as well as the progress towards first measurements under various plasma conditions.

P 10.48 Tue 16:15 ZHG Foyer 1. OG

Overview of a MANTIS-II installation in AUG for runaway electron studies using synchrotron imaging — •Andres Orduna[1,2], Andreas Burckhart[1], Gergely Papp[1], Tijs Wijkamp[3], Mathias Hoppe[4], Artur Perek[5], Yanis Andrebe[5], Tilmann Lunt[1], Ralph Dux[1], and ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Ludwig-Maximilians-Universitat Munchen — [3]Dutch Institute for Fundamental Energy Research — [4]KTH Royal Institute of Technology, Stockholm, Sweden — [5]Ecole Polytechnique Fédérale de Lausanne, Swiss Plasma Center

Study of energy and pitch angle dynamics of runaway electrons (RE) in present-day tokamak experiments requires the analysis of the RE momentum-space distribution function. Synchrotron radiation (SR) imaging using multispectral systems has proven capable of providing this information in TCV and AUG. As a consequence, the multispectral imaging system MANTIS consisting of 6 filtered cameras is planned to be installed in AUG.

Three of the filters are dedicated to SR imaging to constraint the distribution function. Since the SR is emitted along the velocity vector of the electrons, the view port needs to be carefully selected. Camera images using each filter and view are simulated using the SOFT synthetic diagnostic framework. Finally, the cameras have to be placed at a distance from the toroidal field coils and protected from the neutron flux to avoid malfunction and image noise.

P 10.49 Tue 16:15 ZHG Foyer 1. OG

Investigation of benign edge scenarios with the tokamak design suite DYT — •Fabian Leindecker[1,2], Teobaldo Luda[2], Mike Dunne[2], Emiliano Fable[2], Tom Bleher[2], Matthias Willensdorfer[2], Alexander Bock[2], Elisabeth Wolfrum[1,2], and the ASDEX Upgrade Team[3] — [1]Institute of Applied Physics, TU Wien, Vienna, Austria — [2]Max-Plank-Institut für Plasmaphysik, D-85748 Garching, Germany — [3]See Zohm et al 2024 for the ASDEX Upgrade Team

The Design Your Tokamak (DYT) program suite is a collection of modules aiming to explore different configurations and establish reliable boundaries for possible machine designs. In the presented work DYT was used to examine the minimal in-plane coil-to-coil force acting on poloidal field coils during operation in small ELM regimes. The operation within the small ELM regime is determined using the shaping parameters and the normalized pressure gradient in the pedestal region. By comparing various plasma elongations for ASDEX-Upgrade, JET, ITER, and DEMO scenarios, the study identifies a favorable plasma shape that reduces the maximum force exerted on the coils. Building on this approach and recognizing the importance of impurity seeding for power exhaust in large machines like ITER or DEMO, a module to investigate the radiated power within the separatrix for different impurities will be implemented into the simulation tool. The objective is to generate insights and a tool that may enhance the safe and effective construction of future fusion reactors.

P 10.50 Tue 16:15 ZHG Foyer 1. OG

MHD equilibrium reconstructions for Wendelstein 7-X stellarator including soft x-ray emission data — •Edith Hausten[1], Kian Rahbarnia[1], Henning Thomsen[1], Christian Brandt[1], Charlotte Büschel[1], Sara Vaz Mendes[1], and Samuel Lazerson[2] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Gauss Fusion GmbH, Parkring 29, 85748 Garching bei München, Germany

In fusion experiments such as the Wendelstein 7-X Stellarator, knowledge about the plasmas MHD equilibrium is of crucial importance for the interpretation of measurements and to obtain several quantities that are not measured directly. The equilibrium can be reconstructed from experimental data by using the STELLOPT code [S. Lazerson 2015 Nucl. Fusion 55]. It uses an optimization algorithm to find the equilibrium that best matches measured target values of various diagnostics. Currently, the code is being enhanced to incorporate measurements of the XMCTS camera system, a diagnostic measuring the plasmas soft x-ray emissivity within a poloidal plane. The aim is to improve the quality of reconstructions, especially with respect to the Shafranov shift, which can be inferred from soft x-ray observations as previously demonstrated. The Shafranov shift is the outward shift of the magnetic axis compared to the vacuum field, and is increasing in strength with rising plasma beta. First results of reconstructions employing the new STELLOPT feature are presented with a focus on high energy discharges and the obtained Shafranov shift size is compared to analytical estimations as well as pure experimental measurements.

P 10.51 Tue 16:15 ZHG Foyer 1. OG

Helium transport using gas puff modulation at Wendelstein 7-X — •Sali Beppler, Thilo Romba, Felix Reimold, and The W7-X Team — Max Planck Institute for Plasma Physics, Greifswald, Germany

In fusion plasmas, decreased performance due to impurity dilution is to be minimized. As the fusion ash helium is produced in the core region of the plasma but needs to be pumped at the edge, its transport properties are of great interest.

The helium transport in Wendelstein 7-X plasmas is evaluated. A modulated source is introduced to make use of the time dependent term in the transport equation. This restricts the determined transport coefficients more strongly than a conventional steady state approach. The scenario is modeled using the 1D-transport solver pySTRAHL. In order to analyze the sensitivity of input and fitting-parameters, synthetic data is generated. Following the synthetic assessment, the method is applied to experimental W7-X data, aiming to assess changes in helium transport across different magnetic configurations. Besides no fundamental differences across the configurations, a high sensitivity to misalignments in the line of sight geometry is identified.

P 10.52 Tue 16:15 ZHG Foyer 1. OG

Toward a nonlinear Schrödinger equation description for geodesic-acoustic-modes in tokamaks: Analytic gyrokinetic studies of the nonlinear self-interaction — •David Korger[1,2,3], Emanuele Poli[1], Fulvio Zonca[3], and Matteo Falessi[3] — [1]Max-Planck-Institut für Plasmaphysik, Garching, 85748, Germany — [2]Ulm University, Ulm, 89081, Germany — [3]Center for Nonlinear Plasma Science and C.R. ENEA Frascati, C.P. 65, 00044 Frascati, Italy

The geodesic-acoustic-mode (GAM) is a plasma oscillation observed in fusion reactors with toroidal geometry and is recognized to be the non-stationary branch of the zonal flows (ZFs). Prior studies have established that, as a direct consequence of nonlinear gyrokinetic theory, the GAM dynamics is well described by an equation of Schrödinger type - i. e., an equation whose linear contribution is exactly of the same form as the linear Schrödinger equation, while the nonlinear dynamics necessitates an integro-differential expression.

The presented work takes a closer look into the nonlinear contributions by deriving approximate, but well-defined, analytic expressions from the (exact) integro-differential operators. At the lowest order of accuracy, prior numerical studies anticipate the retrieval of a cubic nonlinear Schrödonger equation. This may come unexpected since nonlinear interactions usually have a quadratic structure, such as e. g. the $E{\times}B$-nonlinearity. The third power is found to stem from an interaction of quadratic structures generated by the GAMs (with oscillation frequencies that are either zero or twice the GAM frequency) with the GAM itself.

P 10.53 Tue 16:15 ZHG Foyer 1. OG

Force optimization for novel stellarator-tokamak hybrid coils — •Annika Zettl[1,2] and Sophia Henneberg[1] — [1]Max Planck Institut für Plasmaphysik — [2]Universität Greifswald

The novel perturbed tokamak concept seeks to leverage the strengths of both tokamaks and stellarators in a hybrid machine for magnetic confinement fusion. In recent work, S. Henneberg and G. Plunk (2024), as well as T. Schuett and S. Henneberg (2024) introduced a quasi-axisymmetric (QA) design that offers several advantages, including a low aspect ratio for a large plasma volume, fast particle confinement, and simple coil geometry. As a proof of principle, they developed an initial coil set using conventional poloidal and toroidal tokamak coils along with on single type of nonplanar stellarator coils. However, engineering constraints beyond simple geometrical measures were not considered in their design. This study focuses on optimizing the coils for different candidate configurations to closely match the plasma boundary and maintain the desired QA properties, while incorporating practical buildability limitations. To achieve this, we successfully employed a two-stage optimization process, utilizing a new method by S. Hurwitz et al. (2024) to calculate the forces acting on the coils.

P 10.54 Tue 16:15 ZHG Foyer 1. OG

Design system identification input or the dynamics of the radiated power in Wendelstein 7-X — •Anastasios Tsikouras, Felix Reimold, Maciej Krytzowiak, and Georg Schlisio — Max Planck Institute IPP, Greifswald, Germany

Heat dissipation from the plasma is critical for safe long-pulse operation and reactor-relevant scenarios in all magnetic confinement fusion devices. Impurity seeding in the edge region of the plasma dissipates a portion of its power in all directions by radiation. This action leads in reduced heat loads carried in the last plasma layer in contact with materials, as well as reduced plasma edge temperature. Efficient control of this radiated power necessitates a feedback control system. In Wendelstein 7-X stellarator we aim to design such a feedback system. The seeding actuator is a fast piezo-electric valve [1]. The recently operating divertor bolometry system will provide the radiated power signal. An effective controller requires identifying the dynamics of the investigated plant. This means how the output reacts to different input signals. The success of this identification depends highly on the input signal. For this purpose, we design a multisinusoidal input signal to excite the plant. We excite chosen frequencies within specified limits and perform system identification. The experimental time and the time constants of our system dictate these limits. Preliminary results show moderate but noticeable excitation of the system, with the quality evaluated by the coherence function. This function provides quantitative assessment of the excitation on a 0 to 1 scale. [1] Griener et al. Rev. Sci. Instrum. 88, 033509 (2017

P 11: Laser Plasmas

Time: Wednesday 11:00–12:15 Location: ZHG102

Invited Talk P 11.1 Wed 11:00 ZHG102

Ab initio path integral Monte Carlo simulation of warm dense matter — •Tobias Dornheim — Center for Advanced Systems Understanding (CASUS), Görlitz, Germany — Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany

Understanding matter at extreme densities, temperatures and pressures is important for the modeling of astrophysical objects (e.g. giant planet interiors) and technological applications (most notably inertial confinement fusion) alike. Yet, the intricate interplay of effects such as Coulomb coupling, quantum degeneracy, and strong thermal excitations renders the rigorous theoretical description of such warm dense matter (WDM) challenging.

Here, I present an overview of a number of recent developments in the ab initio path integral Monte Carlo (PIMC) simulation of WDM. While being computationally demanding, PIMC is exact within the given error bars and, thus, constitutes a valuable benchmark for computationally more efficient but potentially less accurate methods such as density functional theory (DFT). Moreover, these simulations open up new avenues for the interpretation of X-ray Thomson scattering (XRTS) measurements, which is a key method of diagnostics for experiments with extreme states of matter. As a practical example, we consider a recent XRTS experiment on strongly compressed beryllium carried out at the National Ignition Facility (NIF) in Livermore, for which we find a significantly lower density based on both ab initio PIMC and DFT simulations compared to previously used chemical models and radiation hydrodynamics calculations.

P 11.2 Wed 11:30 ZHG102

Utilization of quasi-neutral plasma to enhance coherent light emission in free electron lasers — •Cagri Erciyes, Matteo Tamburini, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Heidelberg

The behavior of relativistic quasi-neutral plasma and the corresponding enhancement of coherent light emission are investigated by examining the free electron laser (FEL) setup. A key characteristic of the lasing mechanism in FELs is microbunching, which leads to the concentration of beam charges into slices shorter than the radiation wavelength, thereby enhancing coherent radiation. We investigate microbunching and coherent emission in FELs when quasi-neutral beams (either electron/positron or electron/proton) rather than a pure-electron bunch are utilized. The possibility of denser beams is expected to lead to an enhancement of power gain via the microbunching mechanism. Due to the sensitivity of the lasing process to initial conditions, both Self-

Amplified Spontaneous Emission (startup from shot noise) and seed laser mechanisms are explored.

P 11.3 Wed 11:45 ZHG102

The 40 mJ, kHz front-end and pre-amplifier of the KALDERA drive laser for plasma-acceleration — •Cora Braun[1,2], Caterina Vidoli[1], Juan B. Gonzalez-Diaz[1], Christian Werle[1], Timo Eichner[1], Thomas Hülsenbusch[1], Lutz Winkelmann[1], Guido Palmer[1], and Andreas R. Maier[1] — [1]Deutsches Elektronen Synchrotron DESY, Hamburg, Germany — [2]Institute for Experimental Physics, University of Hamburg, Hamburg, Germany

Scaling the repetition rate of laser-plasma accelerators from a few Hz towards the kHz range is a crucial step to enable future applications like free-electron lasers or direct synchrotron-injection. Moreover, a laser high-repetition rate enables active stabilization of crucial laser parameters which will support sub-percent energy spread and energy stability from the plasma accelerator. The KALDERA laser system at DESY will drive such a high repetition rate laser-plasma accelerator. The setup and commissioning of the first project phase, aiming for 100 Hz, 0.5 J, <30 fs pulses, is currently being completed. In this contribution the layout and performance of the in-house developed KALDERA kHz front-end and its subsequent cryogenic kHz-Ti:Sa pre-amplifier will be presented. We report on the performance of the individual subsystems and how they are interfaced to generate 40 mJ of pulse energy with sub-percent stability.

P 11.4 Wed 12:00 ZHG102

Towards studying the collective effects of laser driven ion acceleration. — •Erin G. Fitzpatrick, Laura D. Geulig, Maximlian J. Weiser, Runjia Guo, and Peter G. Thirolf — Ludwig-Maximilian-University

The ultra-high ion bunch density offered from laser-driven ion acceleration may affect the stopping behavior in matter via collective effects and ultimately enable to establish new nuclear reaction schemes like the 'fission-fusion' mechanism, aiming to generate extremely neutron-rich isotopes near N=126 [1]. One prerequisite needed for the realization of this mechanism is laser driven heavy ions with extremely high bunch densities(10^{22}-10^{23} cm^{-3})[1]. Experimental campaigns at different PW class lasers resulted in the acceleration of gold ions with bunch densities of about 10^{13} cm^{-3} (10^{16} cm^{-3}) at 1mm (100 μm) from the target [2]. At the Center for Advanced Laser Applications (CALA) we are working towards measuring collective effects in laser-driven ion bunches, like a potential reduction in stopping power. First experiments focused on proton bunch energy deposition in stopping materials downstream (0.1mm) from the ion source and demonstrated that we must consider shot-to-shot fluctuations of the ion bunch properties and damage caused to the stopping material through transmitted laser energy. An overview of the current results and developing experimental design is given.

[1] D. Habs et al., Appl. Phys. B 103, 471-484 (2011)
[2] F.H. Lindner et al., Sci. Rep. 12, 4784 (2022)

P 12: Complex Plasmas and Dusty Plasmas I

Time: Wednesday 11:00–12:15 Location: ZHG006

Invited Talk P 12.1 Wed 11:00 ZHG006

Using dusty plasmas to measure low-electron sticking coefficients of dielectric materials — •Armin Mengel[1], Isabel König[1], Lorin S. Matthews[2], Franz X. Bronold[4], and Franko Greiner[1,3] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Center for Astrophysics, Space Physics, and Engineering Research, Baylor University, Waco, TX, USA — [3]Kiel Nano, Surface and Interface Science KiNSIS, Kiel University, Germany — [4]Institut für Physik, Universität Greifswald, Greifswald, Deutschland

Low-energy electron sticking coefficients are of high technological interest, even though their measurement proves challenging using conventional means. Precision measurements using single dust particles confined in a low-pressure plasma have now been utilized to quantitatively determine the low-energy electron sticking coefficient of silica. The results show that dielectric and metallic surfaces in a plasma differ in charge substantially. To apply this promising measurement scheme to a broader range of materials, charging models for non-spherical particles are needed in place of the spherical capacitor model used for spherical particles. Measurements and simulations of sphere aggregates are compared against the smallest enclosing sphere (SES) model and the orientation averaged equivalent sphere (OAES) model, as well as the numerically calculated capacitance, allowing to extend the sticking measurements to non-spherical grains of dielectrics.

P 12.2 Wed 11:30 ZHG006

Measuring Diffusion in Dusty Plasma Using Differential Dynamic Microscopy — •Yang Liu and Dietmar Block — IEAP, Christian-Albrechts-Universität, D-24098 Kiel, Germany

Differential Dynamic Microscopy (DDM) is an emerging Fourier-space-based measurement technique that extracts dynamic information similarly to light scattering, combining the sensitivity of scattering with the direct visualization advantages of microscopy [1]. In this study, we propose a new method for measuring diffusion in dusty plasma using DDM. We assume that particles interact via a screened Coulomb potential and generate a series of images that allow to extract the particle motion and to quantify the accuracy and effectiveness of DDM analysis. The particle dynamics are obtained from Langevin dynamic simulation [2, 3]. The results show that, due to the micro frictional damping arising from a neutral gas background, the effects of hydrodynamic interactions (HIs) between multiple particles can be neglected. This study extends the applicability of the DDM method to Yukawa systems, thereby enabling accurate characterization of the diffusion behavior of strongly interacting particles.

References [1] R. Cerbino and V. Trappe, Phys. Rev. Lett. 100, 188102 (2008). [2] M. Gu, Y. Luo, Y. He, M. E. Helgeson, and M. T. Valentine, Phys. Rev. E 104, 034610 (2021). [3] Y. Liu and D. Block, Phys. Plasmas 31, 103701 (2024).

P 12.3 Wed 11:45 ZHG006

Bow shock formation in a dusty plasma flowing around an obstacle under microgravity — •Stefan Schütt, Christina Knapek, Daniel Maier, Daniel Mohr, and André Melzer — University of Greifswald, Greifswald, Germany

Dust flows around an obstacle in three-dimensionally extended dust clouds have been investigated on parabolic flights. As the obstacle, a tungsten wire has been installed in the midplane between the electrodes of a parallel plate radio-frequency discharge. A periodic dust motion was generated by superimposing a low-frequency modulation on the electrodes, shifting the dust cloud between the electrodes. Due to the periodic nature of the dust motion, several shocks could be observed at varying dust densities. When the dust flow was transonic or supersonic, bow shocks were formed upstream of the wire and propagated away from it at a constant speed. However, at the dust densities needed for the shock formation, dust-density waves also occurred and the two phenomena often intermingled. The role of the streaming ions in driving the shock is therefore discussed. At carefully chosen parameters, it was possible to observe only the bow shock while suppressing the waves. It is reasoned that the shock is excited independently from dust-density waves by a density increase upstream of the obstacle.

This work was supported by DLR grants 50WM1962 and 50WM2161.

P 12.4 Wed 12:00 ZHG006

Investigation of dust density waves in binary systems — •Natascha Blosczyk and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

The wave dynamics in monodisperse dusty plasmas are quite well understood. Theoretical predictions of dispersion relations have been verified in a number of experiments with self-excited or driven waves. For binary systems the situation is different. In general the wave properties will depend on the system properties like mixing ratio, charge ratios and local order. In this work an approach to evaluate the wave dynamics is presented for binary systems in experiments. The waves are driven with a laser manipulation system which launches plane wave fronts into the binary system. The measured system response in terms of particle trajectories is analyzed with the so-called Hilbert-transform which allows to measure with spatial resolution the wave frequency and wave number. This allows us to investigate the wave dispersion in these binary systems. Further, we are able to test whether the local particle arrangement affects the wave propagation. This contribution will show typical results and discuss prospects and limitations of this approach.

P 13: Members' Assembly

Time: Wednesday 12:20–13:20 Location: ZHG102

All members of the Plasma Physics Division are invited to participate.

P 14: Atmospheric Plasmas and their Applications IV

Time: Wednesday 13:45–15:30 Location: ZHG006

Invited Talk P 14.1 Wed 13:45 ZHG006

Carbon Dioxide Splitting in Dielectric Barrier Discharges: Power Dissipation and Plasma Chemistry — •Ronny Brandenburg[1,2], Milko Schiorlin[1], and Volker Brüser[1] — [1]Leibniz-Institut für Plasmaforschung und Technologie e.V., Greifswald — [2]Universität Rostock, Institut für Physik

The conversion of carbon dioxide to carbon monoxide (CO), oxygen and ozone in planar volume dielectric barrier discharges (DBDs) is studied. The type of the electrodes, the barrier material, the barrier thickness, the discharge gap, the flow rate, the high voltage frequency and amplitude as well as the electrode area are varied systematically. Power dissipation is studied by voltage-charge plots based on an adapted equivalent circuit and the Manley-equation for discharge power is generalized for the occurrence of parasitic capacitances and so-called partial surface discharging. The energy yield of CO (EY) results in similar values of about 25 g/kWh in pure carbon dioxide within the specific input energy (SIE) range 20 - 2000 J/L, independent on the above mentioned parameters. SIE higher than 3000 J/L yield a slightly lower EY. A comparison with various other DBD-reactors is done and the role of SIE as a scaling parameter is discussed. Funded by German Federal Ministry of Education and Research (BMBF) and European Union NextGenerationEU under grant 033RC030D.

P 14.2 Wed 14:15 ZHG006

Multi-PMT System and 0-D Chemical Modeling for Analyzing Atomic Oxygen Production in Micro Cavity Plasma Arrays — •Henrik van Impel, David Steuer, Volker Schulz-von der Gathen, Marc Böke, and Judith Golda — PIP & EP2, Ruhr-University Bochum, D-44801 Bochum

Dielectric barrier discharges (DBDs) have numerous applications, including ozone generation and the treatment of volatile organic compounds, which can be further enhanced by integrating catalysts. Understanding the underlying processes requires fundamental knowledge about the generation of reactive species. In this study, we investigated atomic oxygen production within a micro cavity plasma array, a customized surface DBD confined to micrometer-sized cavities. Using optical emission spectroscopy, we analyzed the plasma chemical processes. The discharge was operated in helium with a 0.25% molecular oxygen admixture at atmospheric pressure, using a 15kHz 600V triangular excitation voltage. High dissociation degrees were observed with helium state enhanced actinometry (SEA). Utilizing a multi-photomultiplier system proved effective for monitoring the discharge, especially following the temporal evolution of the atomic oxygen density or dissociation degree, making it highly suitable for industrial applications. To further confirm the consistency of the measurements, we developed a simple 0-dimensional chemical model.

The project is funded within project A6 of the SFB 1316.

P 14.3 Wed 14:30 ZHG006

In situ XRD and XAS at Plasma Treatment of Ce(IV)-O-Clusters and Ce(IV)-MOFs — •Alexander Quack[1], Diletta Morelli Venturi[2], Hauke Rohr[2], Tim Graupner[2], Anastasia Molokova[3], Kirill Lomachenko[3], Kerstin Sgonina[1], Malte Behrens[2,4], Norbert Stock[2,4], and Jan Benedikt[1,4] — [1]Institute of Experimental and Applied Physics, Kiel University — [2]Institute of Inorganic Chemistry, Kiel University — [3]European Synchrotron Radiation Facility (ESRF), Grenoble — [4]Kiel Nano, Surface and Interface Science (KINSIS), Kiel University

The utilization of non-thermal atmospheric pressure plasmas, to supplement the existing chemical industry by using access renewable resources, allows for the potential usage of less heat resilient catalysts like metal-organic-frameworks (MOFs). While some MOFs are observed to be stable, while other MOFs are not, the exact processes of decomposition of the MOFs has not directly been investigated.

We have developed a dielectric barrier reactor with an open optical axis to allow for in situ x-ray analysis of material within the plasma. The plasma operates with H_2 gas combined with Ar or CO_2 at 20 kHz at 10-15 kV_{pp} and can be externally heated up to 200 °C. This design was employed during the beam-time of CH-7281 at BM-23 at the European Synchrotron Radiation Facility (ESRF) to treat clusters and MOFs containing cerium. The chemical stability of these compounds was analyzed using in situ x-ray diffraction (XRD) and x-ray absorption spectroscopy (XAS).

Invited Talk P 14.4 Wed 14:45 ZHG006

Insights into Mode Transitions and Reactive Species Densities in a Micro Cavity Plasma Array — •David Steuer[1], Henrik van Impel[1], Volker Schulz-von der Gathen[2], Marc Böke[2], and Judith Golda[1] — [1]Plasma Interface Physics, Ruhr-University Bochum, D-44801 Bochum, Germany — [2]Experimental Physics II: Physics of Reactive Plasmas, Ruhr-University Bochum, D-44801 Bochum, Germany

Micro-cavity plasma arrays are promising for plasma-catalytic research due to their ability to ignite plasma in direct contact with catalytic surfaces. A critical aspect of their application lies in the generation of reactive species within the cavities. He/O2 systems are ideal for studying these species, offering reduced complexity while oxygen plays a crucial role in oxidizing target gases or activating surfaces. Optical emission spectroscopy measures O-densities within the cavities, while laser-based methods analyze areas outside the discharge. A diffusion model connects these regions, revealing that atomic oxygen is generated exclusively inside the cavities, with dissociation degrees close to 100%. Transport out of the cavities is governed by diffusion and ozone formation. Varying oxygen admixtures reveals a shift from a homogeneous glow discharge (<1%) to a filamentary discharge at higher oxygen concentrations. This transition, evident in parameters as current, power, and electric field, significantly impacts conversion efficiency. Fine-tuning of the discharge mode provides a pathway to enhance plasma-catalytic performance. This work is supported by DFG within SFB1316 (A6).

P 14.5 Wed 15:15 ZHG006

The Impact of Electrohydrodynamic Forces on Vortex Formation and Flow Behavior in sDBD Systems — •Dominik Filla[1], Alexander Böddecker[1], Mate Vass[1], Ihor Korolov[1], Thomas Mussenbrock[1], and Sebastian Wilczek[2,3] — [1]Department of Electrical Engineering and Information Science, Ruhr-University Bochum, D-44780, Bochum, Germany — [2]TH Georg Agricola University, D-44787, Bochum, Germany — [3]enaDyne GmbH, D-04103, Leipzig, Germany

The efficient conversion of greenhouse gases and volatile organic compounds (VOCs) remains a significant challenge for environmental sustainability and innovative chemical processes. Surface dielectric barrier discharges (sDBDs) driven by nanosecond pulses offer a promising approach to address these challenges by leveraging the complex interplay between discharge and fluid dynamics. This study investigates the coupling between electrohydrodynamic (EHD) forces induced by positive and negative streamers and gas flow in He/N_2 sDBD systems. Using 2D plasma-fluid simulations, we evaluate the impact of EHD forces on vortex formation and flow behavior. Numerical results reveal that streamers produce localized EHD forces, subsequently driving flow dynamics and shaping overall gas flow patterns in the system. The simulations show high qualitative agreement with experimental data, including particle image velocimetry and schlieren measurements. This work highlights the potential of plasma-assisted flow control to advance the understanding and optimization of gas flow processes in dielectric barrier discharge systems. Supported by the DFG via SFB 1316.

P 15: Astrophysical Plasmas

Time: Wednesday 16:15–17:45 Location: ZHG102

P 15.1 Wed 16:15 ZHG102

Can a Compressible Jet Sustain Significant Turbulence in a (Magnetized) Turbulent Environment? — •David Kube[1], Gabriele Camerlengo[2], Wolf-Christian Müller[1,3], and Jörn Sesterhenn[2] — [1]Centre of Astronomy and Astrophysics, Technische Universität Berlin — [2]Chair of Applied Mechanics and Fluid Mechanics, Universität Bayreuth — [3]Max-Planck/Princeton Center for Plasma Physics

The interaction of turbulence and jets is ubiquitous throughout the universe. A particularly intriguing example is the supersonically turbulent ISM, where the underlying driving mechanisms for turbulence remain insufficiently understood. Protostellar jets are promising candidates, as they are seen to impact the interstellar gas dynamics on parsec scales. Therefore, we aim to investigate the universal characteristics of jet-turbulence interactions using a simplified setup to identify fundamental mechanisms of potential importance for more complex configurations like star and structure formation. To address if a compressible jet can sustain turbulence in a decaying turbulent medium, we perform DNS of a jet impacting a turbulent cloud covering various combinations of the jet Mach number M_j and the RMS Mach number of the cloud $M_{t,\mathrm{rms}}$. Furthermore, the influence of the magnetic field is assessed by comparing results from MHD simulations with those obtained by solving the compressible Navier-Stokes equations. In this talk, we discuss the numerical setup being used in the study and show first results demonstrating that for specific combinations of M_j and $M_{t,\mathrm{rms}}$, notable interaction between the jet and the cloud occurs.

P 15.2 Wed 16:30 ZHG102

Nonmetal-to-metal transition in liquid hydrogen using density functional theory and the HSE XC functional — Armin Bergermann, Lucas Kleindienst, and •Ronald Redmer — Institut für Physik, Universität Rostock, D-18051 Rostock

We investigate the first-order liquid-liquid phase transition in fluid hydrogen, which is accompanied by a nonmetal-to-metal transition. We use a combination of density functional theory for the electrons and molecular dynamics simulations for the ions. By employing the nonlocal Heyd-Scuseria-Ernzerhof (HSE) exchange-correlation functional, we accurately determine the equation of state and the corresponding coexistence line. Additionally, we calculate the electrical conductivity using the Kubo-Greenwood formula and find jumps in the coexisting region, which is characteristic of a first-order transition. Our new predictions are compared with previous theoretical results and available experimental data [1]. Thereby, we find that the strongly constrained and appropriately normed (SCAN) exchange-correlation functional provides an excellent balance between computational cost and accuracy. [1] A. Bergermann, L. Kleindienst, R. Redmer, J. Chem. Phys. (accepted).

P 15.3 Wed 16:45 ZHG102

Marginal Role of the Electrostatic Instability in the GeV Scale Cascade Flux from 1ES 0229+200 — •Martin Pohl[1,2] and Mahmoud Alawashra[1] — [1]Deutsches Elektronen-Synchrotron DESY, Platanenallee 6, 15738 Zeuthen, Germany — [2]Institute for Physics and Astronomy, University of Potsdam, D-14476 Potsdam, Germany

TeV gamma rays from blazars spawn relativistic pair beams that should generate detectable GeV-scale cascade emission, yet this component is absent in the observed spectra of some blazars. One interpretation is the deflection of the electron-positron pairs by a weak intergalactic magnetic field. Alternatively, electrostatic beam-plasma instabilities could drain the beam energy before the pairs produce the cascade emission. Recent studies suggest that particle scattering is the primary feedback of these plasma instabilities, rather than energy loss. In this work, we quantitatively assess the arrival time of secondary gamma rays at Earth as a function of the beam scattering by the electrostatic instability. Our findings reveal that the time delay of the GeV secondary cascade arrival due to instability broadening is on the order of a few months, which is insufficient to account for the missing cascade emission in blazar spectra. In this study, we have not yet included linear Landau damping of the plasma oscillations caused by the MeV-band cosmic-ray electrons. The impact of this damping on the nonlinear evolution of the beam-plasma system will be studied in future work.

P 15.4 Wed 17:00 ZHG102

Particle acceleration at oblique high-Mach-Number shocks propagating in a turbulent medium — •Eloise Moore[1], Karol Fulat[2], Michelle Tsirou[3], and Martin Pohl[1,3] — [1]Institute of Physics and Astronomy, University of Potsdam, D-14476 Potsdam, Germany — [2]Department of Astronomy, University of Wisconsin-Madison, Madison, WI 53706, USA — [3]DESY, Platanenallee 6, 15738 Zeuthen, Germany

Astrophysical collisionless shocks are efficient particle accelerators, however, some pre-acceleration mechanism is needed for electrons to participate in diffusive shock acceleration. We investigate how pre-existing turbulence could modify the shock structure, plasma instabilities, and ultimately particle acceleration. The particle-in-cell (PIC) method provides a kinetic description of a system from first principles of collisionless plasma. Using the PIC code THATMPI, we performed novel simulations of oblique non-relativistic high-Mach-number shocks propagating into an upstream with pre-existing turbulence. We consider decaying compressive turbulence with density fluctuations of amplitude around 15%, consistent with measurements of the local interstellar medium. We find that the turbulence was able to modify the properties of the shock-reflected electrons that drive plasma instabilities ahead of the shock front. While we find that the energy spectrum of the downstream electrons shows a non-thermal tail for both homogeneous and turbulent simulated environments, the latter indicates more efficient electron acceleration. We conclude that the presence of turbulence plays a key role in the pre-acceleration mechanisms at play.

P 15.5 Wed 17:15 ZHG102

Measuring the Free-Free Opacity of Hydrogen at Stellar Interior Conditions Using the National Ignition Facility — •Samuel Schumacher[1], Julian Lütgert[1], Ronald Redmer[1], Mandy Bethkenhagen[8], Laurent Masse[7], Dirk Gericke[2], Siegfried Glenzer[5], Tilo Döppner[6], Tina Ebert[6], Gareth Hall[6], Otto Landen[6], Markus Schölmerich[6], Charles Starrett[3], Nathaniel Shaffer[4], Laurent Divol[6], Benjamin Bachmann[6], Steve MacLaren[6], Clement Trosseille[6], Shahab Khan[6], and Dominik Kraus[1] — [1]Universität Rostock — [2]Warwick University — [3]Los Alamos National Laboratory — [4]University of Rochester — [5]SLAC — [6]Lawrence Livermore National Laboratory — [7]CEA — [8]Université Lyon

The opacity of stellar matter is critical for modeling stellar interiors, primarily composed of hydrogen and helium. It determines where convection becomes the dominant energy transport mechanism.

Stellar interior modeling is challenging due to dense plasma conditions, with temperatures of hundreds of eV and densities 800 times that of solid matter. These conditions pose significant computational challenges and remain largely unexplored experimentally.

To address this, we conducted the first hydrogen absorption experiments at stellar interior conditions at the National Ignition Facility, the only facility capable of reproducing such extreme states. We present a modeling approach avoiding costly hydrodynamic simulations and enabling rigorous uncertainty estimates of our measurement through Bayesian analysis.

P 15.6 Wed 17:30 ZHG102

Stereoscopic observations reveal coherent morphology and evolution of solar coronal loops — •B. Ram[1], L. P. Chitta[1], S.

Mandal[1], H. Peter[1], and F. Plaschke[2] — [1]Max-Planck-Institut für Sonnensystemforschung, Göttingen, Germany — [2]Institut für Geophysik und extraterrestrische Physik, Technische Universität Braunschweig, Braunschweig, Germany

Coronal loops are bright, arched structures of magnetically confined, million-Kelvin plasma in the solar corona. The mechanisms responsible for heating these loops remain poorly understood. Investigation of the three-dimensional spatial morphology and temporal evolution of coronal loops will offer better insights into the underlying heating mechanisms. Some studies suggest that coronal loops may be optical illusions, resembling veils created by folds in two-dimensional sheets of plasma. Stereoscopic observations are, therefore, crucial to clarify their true morphology. We used high-resolution observations from the Extreme Ultraviolet Imager (EUI) on the Solar Orbiter and the Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory to stereoscopically analyse coronal loops in an active region. Our analysis reveals that the loops exhibit nearly circular cross-sectional widths and consistent intensity variations along their lengths over a timescale of 30 minutes. These findings suggest that coronal loops are three-dimensional coherent plasma bundles that outline magnetic field lines indicating nanoflare heating rather than emissions caused by randomly aligned wrinkles in two-dimensional plasma sheets along the line of sight, as proposed by the 'coronal veil' hypothesis.

P 16: Complex Plasmas and Dusty Plasmas II

Time: Wednesday 16:15–17:30 Location: ZHG006

P 16.1 Wed 16:15 ZHG006

Plasma surface interaction at objects at floating potential — •Dietmar Block and Sören Wohlfahrt — IEAP der CAU Kiel, Leibnizstr. 15, 24118 Kiel

A plasma as an ionized gas has markedly different properties than a normal gas. Especially the free electrons and ions can be used to trigger and enhance chemical reactions. Therefore, low-temperature plasmas are a working horse of material processing. From etching via deposition to catalytic reactions a huge variety of processes are subject of research or already used in applications. For most of them the plasma surface interaction is strongly influenced by the plasma sheath region, which has significantly different properties than the plasma bulk region. To study the chemical processes in such plasmas is not trivial. The standard approach uses ex-situ diagnostics, i.e. the treated surface is extracted from the plasma device and transferred to a diagnostic device. This approach has some limitations: the surface might change during this process and to resolve the chemical processes temporally is difficult. However, for spherical dust grains it is possible to realize an in-situ Mie-scattering diagnostic which is powerful enough to give detailed information on chemical reaction at the surface and surface modifications. Starting with a brief introduction of the diagnostic itself, this contribution will discuss the surface modification observed in-situ.

P 16.2 Wed 16:30 ZHG006

Dust acoustic wave properties in varying discharge volumes — •Christina A. Knapek[1,2], Mierk Schwabe[2,3], Victoriya Yaroshenko[2,4], Peter Huber[2], Daniel P. Mohr[1,2,3], and Uwe Konopka[5] — [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 — [3]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, 82234 Oberpfaffenhofen, Germany — [4]Institut für Solar-Terrestrische Physik, Deutsches Zentrum für Luft- und Raumfahrt, 17235 Neustrelitz, Germany — [5]Physics Department, Auburn University, Auburn, Alabama 36849, USA

Properties of self-excited dust acoustic waves under the influence of active compression of the dust particle system were experimentally studied in the laboratory and under microgravity conditions (parabolic flight). Ground based laboratory experiments clearly show that wave properties can be manipulated by changing the discharge volume, its aspect ratio, and thus the dust particle density. Complementary experiments under microgravity conditions, performed to exclude the effects of gravity inflicted sedimentation and anisotropic behavior, were less conclusive due to residual fluctuations in the planes acceleration indicating the need for a better microgravity environment. A theoretical model, using plasma parameters obtained from particle-in-cell simulations as input, supports the experimental findings. It shows that the waves can be described as a new observation of the dust acoustic mode, which demonstrates their generic character.

P 16.3 Wed 16:45 ZHG006

Electron sticking coefficients of dusty plasma relevant materials — •Franko Greiner, Isabel König, and Armin Mengel — Institute of Experimental and Applied Physics, Kiel University, 24118 Kiel, Germany

A relative measurement approach [1] was employed to determine the low-energy sticking coefficient $\tilde{s}$ of dielectric materials frequently utilized in "dust in plasma" research, including silica, melamine formaldehyde (MF), and polymethyl methacrylate (PMMA). The new $\tilde{s}$ values offer valuable insights for analyzing experiments involving different materials or their mixtures, facilitating more accurate comparisons and improved experimental design. Additionally, more precise values of $\tilde{s}$ are necessary to enhance the simulation of discharge systems with dielectric electrodes.

[1] A. Mengel et al. PRL 2024,
https://doi.org/10.1103/PhysRevLett.133.185301

P 16.4 Wed 17:00 ZHG006

Three-dimensional FTLE analysis of fluid dusty plasmas under weightlessness — •Andre Melzer, Christina Knapek, Daniel Maier, Daniel Mohr, and Stefan Schütt — Institute of Physics, University of Greifswald

We have performed experiments on dusty plasmas under the weightlessness conditions of parabolic flights where the dust particles form an extended homogeneous dust cloud. The particle trajectories have been recorded using a four-camera stereoscopic camera system. From that, the three-dimensional particle trajectories have been determined using both a machine-learning particle reconstruction technique and the deterministic shake-the-box algorithm. From the trajectories, fluid parameters, flow fields and finite-time Lyapunov exponent (FTLE)-based fluid structures have been calculated and analyzed. The FTLE analysis indicates that the fluid behavior changes during the course of the parabola. Furthermore, it is demonstrated that the machine-learning based approach allows to reliably characterize the dynamic states by comparison with the shake-the-box algorithm.

P 16.5 Wed 17:15 ZHG006

Modern imaging polarimetry as diagnostics for plasma-grown nanoparticles: Challenges and first results — •Alexander Schmitz, Andreas Petersen, and Franko Greiner — IEAP, Kiel University, Kiel, Germany

Full-Stokes Mie polarimetry is an established diagnostic technique for plasma-grown nanoparticles. It enables the in situ measurement and monitoring of the particle size and complex refractive index. Both parameters are also essential for other diagnostics, such as dust density measurements via extinction. Expanding prior 1D measuring techniques to an imaging polarimeter system presents a number of challenges, such as precise alignment and impurities and aberrations in commercially available polarization optics.

To solve this, a calibration method based on the null-space method for the device's transfer matrix has been applied to a new high-resolution, imaging polarimeter. First 2D polarisation measurements on a dust cloud have been conducted and the spatial and temporal evolution of the particle size evaluated.

P 17: Poster Session II

Time: Wednesday 16:15–18:15 Location: ZHG Foyer 1. OG

P 17.1 Wed 16:15 ZHG Foyer 1. OG

Assessing the validity of simplified models to describe the island divertor — •Nassim Maaziz, Felix Reimold, Vicoria Winters, David Bold, Sergei Makarov, Yühe Feng, and The W7-X Team — Max Planck Institute for Plasma Physics, 17491 Greifswald

In a nuclear fusion reactor power and particle exhaust is crucial. In stellarators the island divertor concept has been proposed as an exhaust solution. In essence a resonant component of the magnetic field creates a chain of magnetic islands around the core. These islands divert heat and particles towards the material interface. This concept is utilized in the W7-X stellarator and shows promising performance [1]. However, particle exhaust is less efficient in stellarators than in tokamaks. Increasing the plasma density at the target (plasma-surface-interaction zone) is required to improve it. The density in the divertor depends on the particle, energy, and momentum transport. Understanding the transport in the 3D island divertor is challenging. Hence, simplified models have been developed to describe the island divertor. This work assesses the validity of a simplified model: the stellarator two-point model [2]. Model predictions are compared to simulations of an island divertor geometry performed with the 3D self-consistent fluid code EMC3- EIRENE. Past comparisons claim that the simplified model is able to describe EMC3-EIRENE simulations [3], but our results indicate that the applied simplifications are not valid. In particular, we have identified that momentum losses are more complex, and that parallel heat convection and explicit particle sources cannot be neglected. [1]NF611060032021 [2]NF468072006 [3]PPCF530240092011

P 17.2 Wed 16:15 ZHG Foyer 1. OG

Implementation and exploitation of new bolometer electronics at ASDEX Upgrade — •Alessandro Mancini and Matthias Bernert — Max Planck Institute for Plasma Physics, Garching, Germany

Bolometry is a diagnostic technique employed in magnetic confinement nuclear fusion machines, like tokamaks and stellarators. It measures the full electromagnetic power (visible to soft X rays, without spectral information) radiated by fusion plasmas. This measure is essential for the global power balance of a fusion reactor. Foil ('resistive') bolometers are a type of bolometer which use thin metallic foils that heat up upon radiation absorption. The foils are connected to resistors, arranged as Wheatstone bridge, whose electrical resistance varies according to their temperature. The bolometer cameras are connected to an electronic system that provides an excitation voltage waveform and measures the bridges response voltage, from which the incident radiation power can be inferred. An amplitude demodulation algorithm is used to obtain the real time incident power. So far only a square waveform has been used for the ASDEX Upgrade foil bolometers. New electronics have been designed at ASDEX Upgrade, capable of driving different excitation waveforms. With this contribution an amplitude demodulation technique for sinusoidal waveforms, which is implemented on an FPGA, is presented, with the goal of improving the signal quality and time resolution of foil bolometers. The new system has been tested in the laboratory and in the current ASDEX Upgrade experimental campaign.

P 17.3 Wed 16:15 ZHG Foyer 1. OG

3D nonlinear MHD simulations with kinetic neutrals and impurities — •Mate Szucs[1], Matthias Hoelzl[1], Andrés Cathey[1], Yu-Chih Liang[1], and Sven Q. Korving[2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching b. M., Germany — [2]ITER Organization, 13067 St. Paul Lez Durance Cedex, France

In reactor-scale tokamaks like ITER, both transient and stationary heat and particle fluxes pose significant threats to plasma-facing components and the safe operation of the machine. Stationary fluxes can be mitigated by "detaching" the divertor using neutral or impurity atoms, which effectively act as a neutral cushion. This detached state can be disrupted by transient heat fluxes originating from MHD edge instabilities, such as type-I or even small ELM, a phenomenon known as burn-through. Therefore, predicting such transients under realistic scrape-off layer (SOL) conditions, which enable the modeling of detachment, is crucial.

The JOREK nonlinear MHD code is routinely used to predict large and small ELM regimes, among other phenomena. The base fluid model has been coupled with kinetic neutral and impurity extensions, allowing for the simultaneous simulation of transient MHD and SOL processes. In this contribution, the first 3D simulations of small ELM burn-through and X-point Radiator Regime (XPR) are presented.

P 17.4 Wed 16:15 ZHG Foyer 1. OG

Towards Modeling Pellet-Produced Plasmoid Dynamics in Stellarators with JOREK — •Carl Wilhelm Rogge[1], Ksenia Aleynikova[1], Pavel Aleynikov[1], Rohan Ramasamy[2], Matthias Hoelzl[2], and Nikita Nikulsin[3] — [1]Max-Planck-Institut, 17491 Greifswald, Germany — [2]Max-Planck-Institut, 85748 Garching, Germany — [3]Dept. of Astrophysical Sciences, Princeton University

Pellet injection will be vital for refueling future tokamak and stellarator reactors. While pellet plasmoid physics has been extensively studied in tokamak magnetic geometries, understanding it in stellarator geometries remains less comprehensive. In particular, the non-axisymmetry of the equilibrium field in stellarators increases the complexity of numerical analysis.

However, recent advancements in the stellarator extension [Nikulsin 2022] of the JOREK non-linear 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 deepen the understanding of pellet plasmoid dynamics, with a particular focus on perpendicular drifts in stellarators.

We benchmark computed plasmoid dynamics with the expected analytical solutions [Aleynikov 2019, 2024]. A good agreement is demonstrated when the plasmoid expands predominately along the field line using an appropriate heating model. Different heating models for the pellet-plasmoid are implemented in JOREK and compared.

P 17.5 Wed 16:15 ZHG Foyer 1. OG

A novel optimization approach for stellarator design — •Issra Ali, Alan Goodman, and Ryan Wu — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Stellarators are a class of fusion reactor candidates which confine a hot plasma in a toroidal shape using powerful magnetic fields. One of stellarators' great strengths is their vast design space, which offers incredible flexibility in their physical properties. This flexibility is exploited via numerical optimization to carefully mold magnetic field geometries and corresponding coil designs to maximize confinement quality.

Gradient-based optimization methods are the industry standard for stellarator and coil optimization problems, and have recently proven effective in finding reactor-relevant stellarator designs. However, these problems are often multimodal and highly sensitive to initial conditions, meaning that gradient-based methods are at best unlikely to find global minima, and at worst unable to converge altogether without careful selection of initial conditions and optimizer hyperparameters. Global optimization methods, such as Bayesian Optimization, may offer a better way to explore the entire parameter space, but tend to scale poorly to high-dimensional problems such as stellarator optimization. Moreover, they do not exploit gradient information, which is a powerful tool in high-dimensional optimization spaces. In this work, we present a novel global optimization method that seeks global optima while still being guided by gradients.

P 17.6 Wed 16:15 ZHG Foyer 1. OG

Plasma termination studies in LHD and W7-X — •Hjördis Bouvain[1], Andreas Dinklage[1], Naoki Tamura[1], Hiroe Igami[2], Hiroshi Kasahara[2], Kieran McCarthy[3], Daniel Medina-Roque[3], Wendelstein 7-X Team[1], and LHD Experiment Team[2] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]National Institute for Fusion Science, Toki, Japan — [3]Laboratorio Nacional de Fusion, CIEMAT, Madrid, Spain

Control of potentially occurring plasma terminating events is crucial for safe operation of large fusion devices. In tokamaks, disruptions, caused by current driven instabilities, lead to rapid loss of stored kinetic and magnetic energy. Stellarators, however, are more resilient since the poloidal field is generated from external coils, avoiding the loss of magnetic energy. Thermal quenches, due to large impurity influxes, are barely investigated in stellarators. These can cause significant damage to the wall material if the heat loads exceed a critical threshold, making the development of mitigation measures necessary. Intentional injection of large amounts of tungsten impurities via TESPEL in LHD and W7-X plasmas to study thermal quenches in more detail are investigated. Radiative losses along propagating cold fronts may induce termination, but below a critical threshold of impurity amounts the plasma may recover to stored energies prior perturbation. Application of additional electron heating extended the plasma cooling phase; thus, different heating strategies were explored. Results suggest that, in stellarators, less efforts for mitigating termination events are needed due to their higher operational resilience.

P 17.7 Wed 16:15 ZHG Foyer 1. OG

Effect of stray magnetic fields on particles in the Wendelstein 7-X neutral beam box — •Lucas van Ham[1], Samuel Lazerson[2], Björn Hamstra[3], Paul McNeely[1], Norbert Rust[1], Dirk Hartmann[1], Sergey Bozhenkov[1], and the W7-X Team[1] — [1]Max Planck Institute for Plasma Physics — [2]Gauss Fusion GmbH, Germany — [3]Eindhoven University of Technology

A new comprehensive model for calculating ion trajectories inside the neutral beam injection (NBI) system of Wendelstein 7-X (W7-X) is presented. The model consists of two parts: First, the magnetic materials code MUMAT calculates the magnetic response of ferritic materials (including NBI shielding) to the magnetic field produced by the main W7-X coil system. This code has been verified through application to a scenario with a known magnetic field. Second, the Monte Carlo particle following code BEAMS3D follows particles through the resulting magnetic field and estimates heat loads on NBI components.

MUMAT calculations of the magnetic field inside the NBI system predict significant fields (>10 Gauss) inside the NBI neutralizer, indicating that stray magnetic fields penetrate the NBI system. Subsequent BEAMS3D simulations predict that heat loads on NBI components shift vertically due to this neutralizer field. These shifts agree qualitatively with experimental observations, and a quantitative comparison with infrared imaging and calorimetry is planned.

The NBI system is essential for achieving high performance plasmas in W7-X, and this new model can help improve NBI reliability and develop paths towards longer NBI heat pulses.

P 17.8 Wed 16:15 ZHG Foyer 1. OG

Simulations of the X-point Radiator in ASDEX Upgrade with Kinetic Neutrals and Impurities in JOREK — •Yu-Chih Liang[1,2], Andres Cathey[1], Matthias Hoelzl[1], Ulrich Stroth[1,2], Sven Korving[3], Mate Szuecs[1,2], Felix Antlitz[1,2], Daniël Maris[3], JOREK Team[1], and ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — [3]Eindhoven University of Technology, 5612 AZ Eindhoven, The Netherlands

The problem of power exhaust in the future thermonuclear fusion reactors, such as ITER and DEMO, necessitates operation regimes that can avoid extreme heat fluxes onto plasma-facing components. One promising regime is the X-point radiator (XPR), a cold, dense, and highly radiative plasma region that forms above the X-point of the single-null magnetic configuration in a tokamak plasma. This poster presents axisymmetric (2D) simulations of the XPR regime using the nonlinear magnetohydrodynamic (MHD) code, JOREK, extended with a kinetic particle framework for neutral deuterium particles and impurities. Three simulations are presented: one with a quasi-stationary XPR, one with the XPR moving vertically upwards and turning into an unstable solution (MARFE), and one with the XPR moving vertically downwards and being lost. These three simulations show JOREK's capability of simulating time-varying XPR, and they provide a baseline for the transition to 3D simulations, so the MHD activities and their interaction with the XPR can be studied.

P 17.9 Wed 16:15 ZHG Foyer 1. OG

Assessment of Radiation Asymmetries employing the new Imaging Bolometer diagnostic at W7-X — •Kevin Andrea Siever[1], Gabriele Partesotti[1], Felix Reimold[1], Glen Wurden[2], Fabio Federici[3], Byron Jay Peterson[4], and Kiyofumi Mukai[4] — [1]Max-Planck Institute for Plasma Physics, Greifswald, Germany — [2]Los Alamos National Lab, New Mexico, United States — [3]Oak Ridge National Lab, Tennessee, United States — [4]National Institute for Fusion Science, Toki, Japan

Estimation of the plasma radiation distribution is a key aspect in the context of power exhaust optimization. This is particularly demanding in Stellarators due to the intrinsically 3D plasma geometry. The InfraRed Video Bolometer (IRVB) diagnostic provides wide spatial coverage both in the poloidal and toroidal directions, enabling direct observation of the emission gradients in the divertor region. Here we combine its data with that from the resistive bolometry systems to quantify the emissivity asymmetries at Wendelstein 7-X. First of all, the thermal properties of the bolometer foil need to be calibrated to allow correct inference of the impinging power. Using synthetic simulations of the calibration process allows to identify the optimal procedure and settings.

Given the IRVB measurements, we then employ the 2D radiation patterns obtained from the resistive bolometers to generate reference patterns with constant emissivity along the field lines. Comparing with the latter allowed us to isolate better the features of interest and to assess the toroidal gradients in the plasma emissivity

P 17.10 Wed 16:15 ZHG Foyer 1. OG

Gyrokinetic studies of dominant instabilities in different particle transport regimes in Wendelstein 7-X — •Nico J. Guth, Josefine H. E. Proll, Sebastian Bannmann, Oliver P. Ford, and Gabriel G. Plunk — Max Planck Institute for Plasma Physics, Greifswald, Germany

One of the key aspects for ensuring efficient and stable fusion energy production in a future stellarator is to accurately predict the plasma density profiles and their time evolution. In a stellarator, ions and electrons stream freely along magnetic field lines, leading to nested toroidal surfaces of nearly constant density (and temperature). Thus, the main interest of the study of particle transport lies in the perpendicular (radial) direction, with a goal of understanding which plasma conditions lead to favourable density peaking near the magnetic axis and which conditions degrade particle confinement. Optimized stellarators, like Wendelstein 7-X (W7-X), are specifically tailored to reduce the average outward drifts of trapped particle orbits, leading to reduced neoclassical transport. Experiments have however shown that transport is larger than predicted, which can be attributed to turbulent processes in the plasma on the gyroradius scale. Recent experimental work (Bannmann et al 2024) indicates a change in turbulent particle diffusivity (and convectivity) above a critical density gradient. Using gyrokinetic simulations, this qualitative change is investigated with a focus on changes in dominant instabilities as well as simple quasilinear estimates of the corresponding fluxes.

P 17.11 Wed 16:15 ZHG Foyer 1. OG

Fluid Turbulence Modelling of Magnetic Islands in Stellarators — •Miguel Madeira, Sophia A. Henneberg, and Brendan Shanahan — Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, 17489 Greifswald, Germany

Understanding scrape-off layer (SOL) turbulence is crucial for advancing nuclear fusion technology, particularly in improving plasma confinement and performance. While extensive efforts have been dedicated to developing plasma fluid turbulence codes, most applications have focused on tokamak configurations. With the recent success of Wendelstein 7-X (W7-X) and the rising interest in stellarators, multiple codes have now been adapted for three-dimensional simulations and are ready to be leveraged for future physics studies.

This research aims to enhance the understanding of SOL turbulence around magnetic islands in stellarators, specifically focusing on W7-X, by utilizing two fluid turbulence codes, BSTING and GRILLIX. The flexible coil system of W7-X enables control over its magnetic islands' locations and sizes. Notably, when the 5/5 island chain is inside the last closed flux surface, a transition to improved electron transport has been observed. This state is characterized by higher plasma energy and periodic sawtooth crashes within the island region, known as island localized modes (ILMs). The frequency and amplitude of these crashes correlate with the island size.

Given the critical role of magnetic islands in improved confinement scenarios and the island divertor design for future stellarator reactors, this work explores how they influence turbulence behavior.

P 17.12 Wed 16:15 ZHG Foyer 1. OG

Improvement of impurity transport studies at Wendelstein 7-X by integration of 2D X-ray emission data — •Alice Bonciarelli[1,2], Birger Buttenschön[1], Felix Reimold[1], Christian Brandt[1], and The W7-X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald — [2]Politecnico di Milano, Italy

Impurities play an important role in fusion plasmas, since their presence and distribution have a strong influence on the plasma performance: the actual amount must be kept under control, within a suitable range defined by the need to avoid plasma dilution and radiation cooling (upper limit), and by their protective function with respect to the plasma facing materials from high power fluxes (lower limit). The impurity transport determines their distribution and it can be described by convection and diffusion coefficients. These coefficients can be determined from experiments and we use the transport code pySTRAHL to forward model the impurity density evolution for given coefficients. These can, in turn, can be used to predict synthetic line-integrated signals of various diagnostics using the atomic data available in the ADAS database. It is then possible to compare the measured and simulated data using Bayesian inference analysis to obtain more realistic transport coefficients. To increase the accuracy of transport coefficients as determined by spectroscopy alone, a fast 2D x-ray tomography system is introduced into this framework. The necessary methods of data reduction and first results of the extended set of diagnostics are shown in this contribution.

P 17.13 Wed 16:15 ZHG Foyer 1. OG

Landau Damping for Non-Maxwellian Distribution Functions — •Riccardo Stucchi[1,2] and Philipp Lauber[1] — [1]Max Planck Institute for Plasma Physics — [2]Technical University of Munich

Landau damping is one of the cornerstones of plasma physics. In the context of the mathematical framework developed by Landau in his original derivation of Landau damping, we examine the solutions of the linear Vlasov-Poisson system for different equilibrium velocity distribution functions, such as the Maxwellian distribution, kappa distributions, and cut-off distributions without and with energy diffusion. Specifically, we focus on the full set of roots that the dispersion relation of the linear Vlasov-Poisson system generally admits, and we wonder if the full structure of solutions might hint at a deeper understanding of the Landau damping phenomenon.

P 17.14 Wed 16:15 ZHG Foyer 1. OG

Frequency-sweeping calibration source for the dual-frequency CTS radiometer at W7-X — •Daniel Straus, Dmitry Moseev, Sergiy Ponomarenko, Laurent Krier, Heinrich Laqua, Stefan Marsen, and Torsten Stange — Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, 17491 Greifswald, Germany

The Collective Thomson Scattering (CTS) diagnostic at the Wendelstein 7-X stellarator must be calibrated. The current calibration process involves using two thermal sources, one roughly at room temperature and the other at -196 C (boiling point of nitrogen), with the black body radiation emitted by each source being significantly different. The CTS receiver works at two frequency bands: 138.5-141.5 GHz and 171-177 GHz, and it is important that the receiver is absolutely calibrated in both bands. These black body sources produce weak signals which require hours long averaging times in order to achieve an acceptable signal-to-noise ratio. With such time scales, the receiver electronics experience systematic drifts which also need to be accounted for, making the overall calibration procedure long and cumbersome. In this contribution, we will discuss the design and first results of a new sweeping calibrator that replaces the black body sources. This calibrator consists of a tunable continuous wave THz source, followed by attenuators, waveguide switches and a directional coupler, which splits the incoming signal into two distinct power levels. The THz source and other components are carefully characterized to protect receiver electronics from high power. The calibration tool is integrated with the CTS receiver and allows quick semi-automatic calibration.

P 17.15 Wed 16:15 ZHG Foyer 1. OG

Towards efficient accelerated 3D nonlinear MHD simulations with the finite element code JOREK — •Patrik Rác, Matthias Hölzl, and Ihor Holod — Max Planck Institute for Plasma Physics, Garching, Germany

Enabling next-generation simulations of realistic magnetic confinement fusion devices is crucial for understanding and controlling large-scale plasma instabilities. Current simulation codes, such as JOREK, are designed to run on traditional supercomputers but have yet to be optimized for efficient execution on modern accelerated platforms. With the increasing prevalence of accelerator architectures, like GPUs, in high-performance clusters, JOREK requires adaptation to harness the performance of these new systems. We ported the matrix construction and the iterative solver of the time-stepping loop to GPUs. Our approach aims for portability and minimal code changes, allowing scientists to continue working on the code and easily integrate future changes. We achieve this by combining OpenMP and highly optimized GPU libraries. By optimizing the code structure for GPU offloading and eliminating synchronization overhead through coloring the finite element mesh, we obtain comparable performance to the original CPU implementation, paving the way for fully integrated JOREK simulations on GPU-accelerated clusters. Future work will explore novel preconditioning methods, designed to run efficiently on accelerated hardware, with the possibility of harnessing machine learning for further acceleration.

P 17.16 Wed 16:15 ZHG Foyer 1. OG

Characteristics of the SOL ion-to-electron temperature ratio on W7-X with an island divertor configuration — •Jiankun Hua[1,2], Yunfeng Liang[1,2,3], Alexander Knieps[2], Kaixuan Ye[2,3], Carsten Killer[4], Erhui Wang[2], and Pei Ren[2] — [1]International Joint Research Laboratory of Magnetic Confinement Fusion and Plasma Physics, Huazhong University of Science and Technology, Wuhan, China — [2]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung Plasmaphysik, Jülich, Germany — [3]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, China — [4]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

The ion temperature, Ti, in the scrape-off layer (SOL) plays a critical role in understanding diverter plasma transport in magnetic confined fusion research. Previous studies have shown SOL Ti is typically higher than the electron temperature, Te. Moreover, as the ion collisionality (υ) increases, the ion-to-electron temperature ratio (τ) decrease accordingly. Experiments in the W7-X device, which employs an island divertor configuration, are consistent with earlier observations made in tokamaks. However, the Ti profile is non-monotonic due to the influence of the open magnetic island structure in SOL. Ti inside the island is lower than at the island boundary. When SOL plasma transitions from an attached state to a detached state by ramping up upstream plasma density, the υ increases, and both Ti and Te decrease in the SOL. Meanwhile, the relation between τ and υ remains consistent with the attached plasma, so the τ further decrease under the detachment.

P 17.17 Wed 16:15 ZHG Foyer 1. OG

A functional perturbation theory for rapid analysis of orbits and tori in magnetic confinement fusion research — •Wenyin Wei[1,2,3], Alexander Knieps[1], Jiankun Hua[1,4], and Yunfeng Liang[1,2,4] — [1]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics, Jülich, Germany — [2]ASIPP, Hefei, China — [3]USTC, Hefei, China — [4]HUST, Wuhan, China

This work presents a functional perturbation theory (FPT) that efficiently computes how orbits shift and tori deform under perturbation by considering the magnetic field as a function argument for these geometric objects. This approach acknowledges topological significance, inspired by the discovery from mature 3D magnetohydrodynamic simulations (e.g., EMC3-EIRENE, JOREK), which have revealed the distinctive lobe structure intertwined with stable and unstable manifolds of the outermost X-cycle (the field trajectory consists of X-points at all cross-sections). In practice, without delicate hardware acceleration, FPT completes computations in seconds for three-dimensional configurations like Wendelstein 7-X and almost instantly for tokamaks, offering near-real-time insights for device optimization and control. Based on this swift speed, FPT can guide experimental decisions by quickly predicting how coil setups or plasma responses affect magnetic topology, indicating whether flux surfaces remain intact or break into island chains. The framework is expected to support more agile, precise operations in existing fusion devices and inform the design of advanced configurations.

P 17.18 Wed 16:15 ZHG Foyer 1. OG

Deuterium Uptake and Isotope Exchange in Tungsten Displacement Damaged at High Temperature — •Laurin Hess[1,2] and Thomas Schwarz-Selinger[2] — [1]Technische Universität München, Arcisstr. 21, 80333 München — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching b. München

Retention of hydrogen fuel in tungsten is an active area of research, as it is an integral part of modelling the tritium inventory and certification of future fusion reactors. It has been shown that hydrogen retention significantly increases due to displacement damage produced by 14 MeV fusion neutrons. Over the last years, basic understanding of the behaviour of hydrogen in point defects was acquired. However, damage at high temperatures can also produce nm-sized voids. Only little research has been done to examine the behaviour of hydrogen in these voids. To improve the understanding of hydrogen in nm-sized voids, tungsten single crystals were self-damaged by irradiation with 20 MeV tungsten ions at 1370 K and decorated with different fluences of 5 eV deuterium from a low-temperature plasma. The retention of deuterium was measured via ^{3}He Nuclear Reaction Analysis as a function of D fluence. In addition, the exchange of retained deuterium with protium has been studied by exposing deuterium-decorated samples to different fluences of 5 eV protium.

P 17.19 Wed 16:15 ZHG Foyer 1. OG

Thermal-Hydraulic Modelling of Plasma Facing Components using OpenFOAM — •Ahmet KILAVUZ[1,2], Rudolf Neu[1,2], Jeong-Ha You[1,3], and Boštjan Končar[4] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technical University of Munich, Garching, Germany — [3]University of Ulm, Ulm, Germany — [4]Jožef Stefan Institute, Ljubljana, Slovenia

Plasma-facing components, like divertor targets in fusion reactors, operate under extreme thermal and hydraulic conditions, including high heat and mass fluxes and elevated pressures. Under such conditions, boiling phenomena occur in cooling channels, and boiling models are highly sensitive to flow conditions, complicating the creation of accurate models. OpenFOAM, an open-source CFD software, provides a customizable platform for developing these models. This study develops and evaluates conjugated heat transfer models in OpenFOAM for divertor-relevant conditions. Material properties were included as a function of temperature. The solver results were compared to ANSYS Fluent predictions, experimental measurements, and empirical correlations. The agreement between the two solvers was observed for temperature and velocity predictions, including armor surface and inner pipe temperatures, velocity profiles, and volume fractions. Both solvers aligned well with experimental data. Differences between single-phase model predictions and experimental data highlight the need to incorporate boiling effects for accurate thermal predictions in plasma-facing components.

P 17.20 Wed 16:15 ZHG Foyer 1. OG

Temperature-dependent grain boundary permeation in tungsten investigated by hydrogenography — •Fahrudin Delic, Armin Manhard, and Udo von Toussaint — Max Planck Institute for Plasma Physics, 85748 Garching, Germany

The temperature-dependent permeation of deuterium through grain boundaries in tungsten has been studied using a newly developed hydrogenography technique, which employs patterned films to laterally resolve hydrogen fluence density on the back side of the permeation samples. Primarily, a tungsten oxide layer was developed as a hydrogen indicator that could withstand greater temperatures than previously used yttrium, and a method for reliably quantifying the results was established. Ion-driven permeation with constant deuterium fluence was conducted using 50 μm thick recrystallized tungsten samples at various exposure temperatures. The temperature-dependent permeation indicated that the permeation fluence density of hydrogen isotopes in grain boundaries is dominant up to 660 K, with an increasing number of grain boundaries favorable for hydrogen transport as the temperature rises. At 660 K, a halo of hydrogen fluence density forms around several permeating grain boundaries, suggesting a desorption of hydrogen isotopes from grain boundaries and the initial signs of the transition towards predominant bulk permeation

P 17.21 Wed 16:15 ZHG Foyer 1. OG

Influence of the presence of deuterium on damage evolution in tungsten — •Z Shen, T Schwarz-Selinger, M Zibrov, and A 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 20.3 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. Nuclear reaction analysis (NRA) was used to determine the D depth profile and thermal desorption spectroscopy (TDS) was used to measure the total retention and de-trapping energy of D. Decorating the samples after annealing again with the same D plasma at room temperature shows decreased D retention with increasing annealing temperature both for plasma annealing and vacuum annealing. The presence of D during annealing has only a small stabilization effect for the defects.

P 17.22 Wed 16:15 ZHG Foyer 1. OG

Expanding the physics modeling capabilities of ASTRA from core to SOL and from tokamak to stellarator towards application in a multi-device flight simulator — •Fabian Solfronk[1,2], Emiliano Fable[1], Hartmut Zohm[1,2], Roberto Bilato[1], and the ASDEX Upgrade Team[3] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität München, 80539 München, Germany — [3]see the author list of H. Zohm et al. 2024 NF 64 112001

This work aims at augmenting the ASTRA transport code capabilities of simulating magnetic confinement fusion devices. In parallel, two avenues are pursued:

First, a few options for a reduced, theory-based scrape-off-layer (SOL)/exhaust model will be explored and implemented to allow simulations of seeded discharges and discharges with both low and high-recycling regimes displaying either impurity flush-out or detachment. Application to ASDEX Upgrade and future devices like ITER and DEMO, where the FENIX flight simulator (to which ASTRA is coupled) is being deployed, is foreseen.

Second, the implementation of an equation for the current diffusion compatible with a vacuum helical field (as in a stellarator device) will be pursued. After which, the inclusion of reduced models for stellarator physics may be initiated. The goal is to develop a tool that can be used for both tokamak and stellarator-reduced modeling, paving the way for a flight simulator that can also simulate stellarators.

P 17.23 Wed 16:15 ZHG Foyer 1. OG

Gyrokinetic pedestal studies varying shaping in AUG — •Facundo Sheffield[1], Tobias Goerler[1], Lidija Radovanovic[2], Elisabeth Wolfrum[1], Frank Jenko[1], and the ASDEX Upgrade team[3] — [1]Max-Planck-Institut für Plasmaphysik — [2]Institute of Applied Physics, TU Wien — [3]See author list of H. Zohm et al, 2024 Nucl. Fusion https://doi.org/10.1088/1741-4326/ad249d

The pedestal region in tokamak plasmas plays a critical role in determining overall confinement and performance, yet the interplay between turbulence and plasma shaping within this region remains to be fully understood. In this work, we present a comprehensive characterization of pedestal instabilities and their sensitivity to plasma shaping effects using the gyrokinetic code GENE. Key turbulence modes, including kinetic ballooning modes and electron temperature gradient modes (ETG), are identified and compared in differently shaped ASDEX Upgrade equilibria to assess their impact on transport and stability. Further insights into the nature and characterization of ion-frequency ETG modes are discussed. The influence of shaping parameters, mainly triangularity and elongation, is systematically explored with linear and global nonlinear simulations. The findings presented reveal novel dependencies between pedestal turbulence properties and shaping.

P 17.24 Wed 16:15 ZHG Foyer 1. OG

Investigation of Wendelstein 7-X Scrape-Off Layer Characteristic by Helium Line Ratio Spectroscopy — •Foisal B.T. Siddiki[1,2], Oliver Schmitz[2], Maciej Krychowiak[1], Erik Flom[3], Frederik Henke[1], Dorothea Gradic[1], and W7-X team[1] — [1]Max Planck Institute for Plasma Physics, Germany — [2]University of Wisconsin-Madison, USA — [3]Thea Energy, USA

Heat and particle transport in the Wendelstein 7-X(W7-X) scrape-off layer (SOL) significantly influences the performance of its divertor, which serves as the heat and particle exhaust system. To optimize the divertor concept, it is essential to understand the transport phenomena within the SOL, which can be achieved by studying plasma parameters like electron temperature (T_e) and the density (n_e). As a way of measuring the basic plasma parameters in the W7-X SOL, the diagnostic systems used consist of a gas injection system and multiple spectrometers with different spectral resolutions. They observe one upper and one lower divertor unit (downstream position) and for the first time also in the midplane area (upstream position). Line ratio spectroscopy based on a collisional radiative model of atomic helium is used to infer n_e and T_e. The helium beam diagnostic at W7-X has been thoroughly validated and widely utilized to map plasma parameters within the island divertor. The T_e , n_e profiles presented here in this work were measured using all three systems under various conditions, including detached and impurity-seeded plasmas. A comparison of the T_e , n_e profiles obtained at the downstream and upstream positions will be presented.

P 17.25 Wed 16:15 ZHG Foyer 1. OG

Modeling of the spatial and temporal dynamics of Cs in large negative hydrogen ion sources using the CsFlow3D code — •Daniele Mussini, Adrian Heiler, Christian Wimmer, Dirk Wünderlich, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik (IPP), Boltzmannstr. 2, 85748 Garching

Negative ion-based sources for ITER's neutral beam injectors (NBI) rely on the production of negative hydrogen ions on a low work function converter surface (plasma grid, PG). To reduce the work function of the PG (< 2eV), Cs is continuously evaporated into the source forming a layer on the PG. However, the plasma-surface interaction and the resulting redistribution of Cs inside the source lead to a temporally unstable and inhomogeneous layer. This is a key aspect to be investigated and understood in order to perform long pulses at ITER's requirements (several hundred s in H, 3600s in D). For this purpose, the Monte-Carlo Test-Particle code CsFlow3D is exploited. CsFlow3D models the Cs dynamics in the source, for which several input parameters (plasma parameters, electromagnetic fields, sticking coefficients, etc.) are required. The current target is to model the Cs dynamics during long pulses for the BATMAN Upgrade source in hydrogen. To validate the code, a synthetic laser absorption diagnostic (TDLAS) for the quantification of neutral Cs densities along different line-of-sights is implemented to compare to experimental results. This contribution presents the results of the code after the implementation of input parameters resulting from a fluid code and the benchmark of the code against experimental TDLAS results.

P 17.26 Wed 16:15 ZHG Foyer 1. OG

Impact of fishbone modes to core microturbulence with global gyrokinetic simulations — •davide brioschi[1], alessandro di siena[1], roberto bilato[1], alberto bottino[1], thomas hayward-schneider[1], alexey mishchenko[2], emanuele poli[1], alessandro zocco[2], and frank jenko[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]Max Planck Institute for Plasma Physics, Greifswald 17491, Germany

Fishbone instabilities (FBs) are a class of macroscopic plasma modes which develop inside tokamaks around rational surfaces. Theoretical and experimental results show a correlation between the development and/or sustainment of ITBs inside tokamak plasmas and the destabilization of FBs. These studies point out the need for a self-consistent description of the interaction of FBs with plasma microturbulence, i.e. the main driving mechanism of turbulent transport inside tokamaks detrimental for plasma confinement. Our work wants to study such an interaction through gyrokinetic simulations performed with the code GENE and ORB5, including both the n=m=1 FB (with n and m tororidal and poloidal mode number respectively) and the ion temperature gradient (ITG) mode branches inside the plasma. Multiscale interaction between turbulence, global FB structures and zonal flows is studied via dedicated nonlinear simulations, starting from results obtained through linear ones used to identify the ideal subset of the parameters space where all these modes are present at once.

P 17.27 Wed 16:15 ZHG Foyer 1. OG

First successful plasma start-up with X2 ECRH at a reduced field of 1.8T at W7-X — •Niklas Simon Polei, Torsten Stange, Heinrich Peter Laqua, Kai Jakob Brunner, Juan Fernando Guerrero Arnaiz, Georg Schlisio, and W7-X Team — Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

At Wendelstein 7-X (W7-X) the nominal magnetic field strength is 2.5T, but operation at a lower magnetic field strength is desired to achieve higher plasma beta (ratio of kinetic and magnetic pressure). The electron cyclotron resonance heating (ECRH) operates at 140GHz, corresponding to third harmonic (X3) heating at 1.8T. A plasma start-up is not possible with X3-heating, but one gyrotron was successfully tuned to 101GHz for an X2 start-up with 250kW. A multi-pass scenario was developed to ensure six passes close to the magnetic axis to increase the effective power in the first few milliseconds and allow a plasma breakdown even at low power. Neutral beam injection (NBI) with a power of 3MW was expected to be able to takeover the plasma from the X2 ECRH, increasing the electron temperature up to 1keV, so that X3 ECRH can take over.

The foreseen start-up scenario was successfully demonstrated in the last operational phase OP 2.2. The X2 ECRH alone can create a central plasma with a peak temperature of several keV and line integrated densities above $5 \cdot 10^{18} m^{-2}$. The plasma can be taken over by the NBI to increase temperature and density, for subsequent X3 ECRH takeover to maintain a steady plasma. This enables the low field operation of W7-X.

P 17.28 Wed 16:15 ZHG Foyer 1. OG

First measurements of divertor conditions in the new ASDEX Upgrade upper divertor — •Felix Albrecht[1,2], Dominik Brida[1], Tilmann Lunt[1], Bernhard Sieglin[1], Ou Pan[1], and the ASDEX Upgrade team[3] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technical University of Munich, Physics Department E28, Garching, Germany — [3]see author list of H. Zohm *et al.* 2024 *Nucl. Fusion* **64** 112001

The divertor is a crucial component for any magnetic confinement fusion machine, which enables efficient pumping of impurities and fusion-produced helium, as well as density and power exhaust control. In the divertor, the magnetic field lines of the outermost part of the plasma, the so-called Scrape-Off Layer (SOL), are intersected by a wall component, the divertor target, which experiences very high power loads. The target heat flux must be limited by the seeding of impurities, which radiate power away. However, a power plant divertor could require seeding rates which would be unacceptably high for the plasma core. A possible solution are Alternative Divertor Configurations (ADCs), which can help to induce detachment at lower impurity concentrations by enhanced control of the field configuration in the divertor region.

At the tokamak ASDEX Upgrade (AUG), the upper divertor has recently been equipped with additional coils to study a variety of ADCs, for the first time in a machine with high heating power and a tungsten wall. This contribution presents the first Langmuir probe measurements in the new upper divertor of AUG, and compares the divertor conditions between different field configurations.

P 17.29 Wed 16:15 ZHG Foyer 1. OG

The avalanche source for a 3D particle in cell model of runaway electrons — •Fiona Wouters[1], Matthias Hoelzl[1], Hannes Bergstroem[1], Guido Huijsmans[2,3], and Jan van Dijk[2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]Eindhoven University of Technology, Groene Loper 3, 5612 AE Eindhoven, the Netherlands — [3]CEA, IRFM, 13115 Saint-Paul-lez-Durance, France

Disruptions, i.e. major instabilities in which plasma confinement is lost, are a significant threat to tokamak operation. During a disruption the resistivity of the plasma increases as the thermal energy is quickly lost, causing the current to decrease. Due to the self-inductance of the plasma this leads to the generation of a strong parallel electric field. As the friction force experienced by fast electrons in a plasma has the peculiarity that it decreases with increasing electron velocity, this electric field can accelerate some fast electrons to relativistic velocities. These so-called runaway electrons (REs) can then exponentially multiply due to large-angle collisions with thermal electrons in what is known as the runaway avalanche. Because the avalanche is exponentially sensitive to the pre-disruption plasma current, this can lead to multi-MA RE beams in large future devices such as ITER, which may cause severe localized wall damage. Simulations including the RE sources in realistic 3D fields are needed to further the understanding of RE generation and losses and develop viable mitigation scenarios. For this purpose the avalanche source was implemented in the 3D nonlinear extended MHD code JOREK.

P 17.30 Wed 16:15 ZHG Foyer 1. OG

Turbulence imaging in the scrape-off layer of Wendelstein 7-X — •Floris Scharmer[1], Adrian von Stechow[1], Sean Ballinger[2], Seung-Gyou Baek[2], James Terry[2], Carsten Killer[1], Olaf Grulke[1,3], and the W7-X Team[1,4] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]MIT Plasma Science and Fusion Center, Cambridge, USA — [3]Department of Physics, Technical University of Denmark, Lyngby, Denmark — [4]See O. Grulke et al 2024 Nucl. Fusion 64 112002

Understanding the dynamics of the edge plasma is crucial for magnetic confinement fusion experiments, as it significantly impacts both core performance and plasma exhaust. In the Wendelstein 7-X stellarator experiment, a 2D poloidal cross section of the island scrape-off layer plasma is imaged with a gas puff imaging diagnostic. This system measures the fluctuations in H_α line emission, a proxy for plasma fluctuations, at a high spatio-temporal resolution by increasing the local light emission with an external neutral gas puff. In the latest operation phase (2024), the diagnostic capabilities were upgraded with the ability to use a high-resolution camera, which can be swapped with the existing avalanche photodiode detector array as needed. This enhancement allows for the study of turbulence statistics with higher spatial resolution and over a larger field of view, including the last closed flux surface. The turbulence statistics (e.g. skewness) have distinct features corresponding to the magnetic geometry and also depend on the operational regime. In this contribution, the results of the first measurements of the diagnostic extension are presented.

P 17.31 Wed 16:15 ZHG Foyer 1. OG

Improving the signal to noise ratio of a TALIF diagnostic applied to a hydrogen plasma for enhanced hydrogen EDF determination — •Julian Hörsch, Christian Wimmer, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching bei München, Germany

Two photon Absorption Laser Induced Fluorescence (TALIF) is a plasma diagnostic technique that can be used to measure the density and energy distribution function (EDF) of atomic hydrogen. The simultaneous absorption of two photons leads to the excitation of ground state hydrogen atoms to the n=3 level and a subsequent fluorescence decay to the n=2 level. The fluorescence decay emits Balmer H-alpha radiation, which can be detected for density and EDF measurements. Since the plasma emits strong H-alpha radiation, weak fluorescence signals received from TALIF are difficult to measure. The determination of the EDF requires an accurate measurement of the line profile, particularly in the wings of the line profile. For that it is important to distinguish the signal from the background noise. To be able to measure these wings of the EDF and thus the predicted deviations from a Maxwellian EDF, optimizations of the detector and the optical setup such as laser focusing and beam compression are investigated.

P 17.32 Wed 16:15 ZHG Foyer 1. OG

Plasma dynamics analysis with the fast helium beam at W7-X — •Sebastian Hörmann[1,2], Michael Griener[1], Maciej Krychowiak[3], Dorothe Gradic[3], Erik Flom[3], Mohammad Foisal Siddiki[3], Adrian von Stechow[3], Carsten Killer[3], Felix Reimold[3], Stepan Sereda[3], Ulrich Stroth[1,2], the ASDEX Upgrade Team[1], and the W7-X Team[3] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Physik-Department E28, Technische Universität München, 85748 Garching, Germany — [3]Max-Planck-Institut für Plasmaphysik, Greifswald 17491, Germany

Understanding and quantifying particle and energy transport at the plasma edge region is crucial for magnetic confinement fusion devices, as it determines plasma performance and wall loads. For the thermal helium beam systems in the island divertor of the stellarator W7-X, a new polychromator system with 1 MHz time resolution was installed, which is 25000 times faster than the existing system. This allows to measure and characterise turbulent structures, such as plasma edge modes and filaments and correlate their properties with plasma parameters. The diagnostic system measures within two magnetically connected divertors, which, in combination with the multi-purpose manipulator, enables the study of long-range correlation of modes. Utilising a collisional-radiative model, the diagnostic can measure fast density and temperature variations associated with plasma modes and filaments. It also provides high temporal resolution measurements of the detachment process in the divertor. This poster presents the design and implementation of the diagnostic and discusses the first results.

P 17.33 Wed 16:15 ZHG Foyer 1. OG

Investigation of perpendicular transport effects in W7-X divertor islands using 2D plasma parameter measurements with MANTIS. — •Joey Louwe, Felix Reimold, Valeria Perseo, Victoria Winters, Henry Greve, Thomas Klinger, Michael Griener, and W7-X team — Max Planck Institute for Plasma Physics, 17491 Greifswald/85748 Garching, Germany

To enhance the performance of fusion experiments, such as Wendelstein 7-X (W7-X), the divertor concept is employed to efficiently exhaust plasma particles, impurities and heat from the plasma. Both stellarators and tokamaks employ divertors, though their designs differ. W7-X implements the Island Divertor, which utilizes magnetic islands to divert and guide particles and heat along magnetic field lines to target plates. Compared to typical tokamak divertors, the stellarator divertor field lines have a significantly lower pitch angle, making perpendicular transport effects more significant. This study aims to characterize these perpendicular transport effects utilizing the Multispectral Advanced Narrowband Tokamak Imaging System (MANTIS) being build for the W7-X reactor. By integrating MANTIS with active gas puff imaging and helium impurity injections, we can measure specific spectral lines to create 2D images of electron density and temperature of the divertor islands. Additionally, the EMC3-EIRENE simulation code is employed in the determination of optimal helium injection positions, identifying six strategic locations for effective coverage of the divertor island region.

P 17.34 Wed 16:15 ZHG Foyer 1. OG

Towards a deeper understanding of the pronounced increase in co-extracted current density in H-/D- negative ion sources for fusion — •Joey Rubin, Niek den Harder, and Ursel Fantz — Max Planck Institute for Plasma Physics

Negative ion sources for fusion face stringent operational demands. ITER's sources must achieve a current density of 329 A/m^2 for H^- ions over 1000 s and 286 A/m^2 for D^- ions over 3600 s. Negative ions are generated on caesiated surfaces through the conversion of precursors formed in RF-drivers. Electrons are inherently co-extracted with the negative ions and must be removed from the beam before full acceleration. Magnets embedded in the extraction grid deflect and collect these electrons. During long pulses, the co-extracted electron current density increases, particularly in deuterium operation, limiting the pulse duration. At the ELISE test facility, which hosts a half-ITER-size source, a comprehensive set of diagnostics has been used to investigate the physics behind this phenomenon, and strategies to counteract it have been developed. This contribution reviews the current understanding of the mechanism driving the growth of co-extracted electron current density, highlighting the varying growth rates seen during beam extraction. Correlations with caesium dynamics and potential variations are discussed, along with open questions.

P 17.35 Wed 16:15 ZHG Foyer 1. OG

Calibration and Operation of the Imaging Motional Stark Effect Diagnostic at ASDEX Upgrade — •Lea Hollendonner[1], Alexander Bock[1], Andreas Burckhart[1], Thomas Pütterich[1], Rainer Fischer[1], and the ASDEX Upgrade Team[2] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]See author list of H. Zohm et al, 2024 Nucl. Fusion

Detailed knowledge on the current density distribution in the core of the plasma is essential in many research topics in the field of magnetic confinement nuclear fusion, examples comprising the investigation of sawtooth instabilities, flux pumping, or advanced scenario development. Experimentally, the current density distribution can be reconstructed from measurements of the magnetic field pitch angle. Of all diagnostics capable of measuring the field pitch angle in the plasma core, the Imaging Motional Stark Effect (IMSE) diagnostic offers the highest resolution. Moreover, it provides a two-dimensional image instead of data from a limited amount of channels. In order to routinely operate the IMSE with high resolution, the calibration must be equally accurate. Fine-tuning of the IMSE calibration is challenging and open to optimization. This work presents the state of the IMSE diagnostic at ASDEX Upgrade and investigates possibilities to improve the calibration of the diagnostic.

P 17.36 Wed 16:15 ZHG Foyer 1. OG

The role of turbulence and radial electric field in the achievement of high-performance regimes in W7-X — •Bojana Stefanoska[1], Daniel Carralero[2], Teresa Estrada[2], Thomas Windisch[3], Emmanouil Marakoudakis[2], José Luis Velasco[2], and the W7-X team[3] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Laboratorio Nacional de Fusion. CIEMAT, 28040 Madrid, Spain — [3]Max Planck Inst. for Plasma Physics, 17491 Greifswald, Germany

Prolonged operation of the NBI system during the 2023 W7-X campaign refined a high-performance scenario combining NBI and ECRH heating. The NBI+ECRH high-performance (HP) phase exhibits a substantial increase in ion temperature and plasma energy. To study this scenario, the Doppler reflectometry (DR) system was upgraded with an E-band reflectometer, enabling core measurements of density fluctuations and the radial electric field E_r in high-density discharges.

DR measurements show that density fluctuation amplitude decreases as a strong density gradient builds during the pure NBI phase. The strong dependence of turbulence amplitude on the gradient ratio η_i indicates ITG-like turbulence in the core. E_r profiles remain flat before the HP phase and form a strong negative E_r well during it, accurately predicted by neoclassical simulations. Further turbulence reduction is observed in the HP phase, correlating with regions of strong radial electric field. These findings highlight the role of high density gradients in suppressing ITG-like turbulence, enabling improved performance with additional heating.

P 17.37 Wed 16:15 ZHG Foyer 1. OG

Quantification and analysis on the formation of a secondary strike line in the Wendelstein 7-X stellarator — •Sebastian Dräger[1], Thierry Kremeyer[1], Yu Gao[1], Robert Wolf[1,2], and Felix Reimold[1] — [1]Max Planck Inst. for Plasma Physics, 17491 Greifswald, Germany — [2]Technical University of Berlin, Strasse des 17. Juni 135, 10623 Berlin, Germany

In future magnetic confinement fusion reactors, efficient particle exhaust is essential for sustained operation. Helium ash, generated during fusion reactions, and other impurities must be removed to enable steady-state fusion and maintain plasma stability. Since ionized particles are confined by magnetic fields, their removal requires neutralization. For this purpose, Wendelstein 7-X (W7-X) employs an island divertor system. Magnetic islands intersect with target plates, where particles neutralize upon contact, allowing their exhaust. These interactions form high-intensity regions known as strike lines. The divertor plates are meticulously engineered to endure the plasma's heat flux. However, unexpected shifts in heat flux topology pose a significant risk to their integrity.

Recent observations at W7-X have revealed under certain operational conditions the formation of a secondary strike line [1]. This phenomenon, identified through infrared imaging and H_α photon emission, represents a notable change in the heat flux pattern. A precise quantification of the secondary strike line and an analysis of its dependence on plasma parameters is presented.

[1] Yu Gao et al 2024 Nucl. Fusion **64** 076060

P 17.38 Wed 16:15 ZHG Foyer 1. OG

Hybrid kinetic-MHD simulations of interactions between tearing modes and runaway electrons in JOREK — •Shijie Liu[1], Hannes Bergstroem[1], Tong Liu[2], Haowei Zhang[1], and Matthias Hoelzl[1] — [1]Max Planck Institute for Plasma Physics, Garching b. M., Germany — [2]Dalian University of Technology, Dalian, China

Runaway electrons (REs) are of particularly importance to the safe operation of tokamaks. Electrons may be accelerated by the large toroidal electric field arising during a major disruption. Without adequate mitigation measures, these energetic electrons may eventually hit the first wall of the device focusing on an extremely localized area, which poses a serious threat to the safe operation of the device. To predict the runaway dynamics during a disruption and develop mitigation strategies, the mutual interaction between REs and the bulk plasma should be carefully considered.

In this work, we focus on developing a self-consistent coupling of the full-f relativistic PIC model for REs to the background plasmas with a guiding center treatment, using the nonlinear extended MHD code JOREK. The accurate representation of the radial force balance of a circular axisymmetric RE beam is verified by comparing to analytical results. Moreover, a comparison to the 3D tearing modes linear theory is done for the MHD simulation with REs. Finally, non-linear results are presented for tearing modes in the presence of runaway electrons with different Δ'.

P 17.39 Wed 16:15 ZHG Foyer 1. OG

In-situ Uptake Measurement and Modelling of Deuterium Atoms in Self Damaged Tungsten at Different Temperatures — •Abdulrahman Albarodi, Thomas Schwarz-Selinger, and Mikhail Zibrov — Max-Planck-Institute for Plasma Physics, Garching bei München

Self-damaged tungsten samples (damage dose 0.23 dpa) were exposed to low energy deuterium (D) atoms (< 5 eV) 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 at different uptake times. Thermal desorption spectroscopy was performed ex-situ to determine the bulk and surface model parameters. A modified surface coverage-dependent model was used to describe the results and extended to lower temperatures in the tungsten samples. The extended model was implemented in TESSIM hydrogen transport simulations. Effects of grain boundary diffusion on D depth profile evolution were also investigated by comparison with results from a D atom exposure experiment on a tungsten single crystal at 500 K.

P 17.40 Wed 16:15 ZHG Foyer 1. OG

Validation of a Comprehensive First-Principles-Based Framework for Predicting the Performance of Future Stellarators — •Don Lawrence Carl Agapito Fernando[1], Alejandro Bañón Navarro[1], Daniel Carralero[2], Jose Luis Velasco[2], Arturo Alonso[2], Alessando 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, Madrid, Spain — [3]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Validation studies are necessary to ensure the accuracy of simulation predictions relative to experimental results. In this poster, we showcase the results of the successful comprehensive validation of the GENE-KNOSOS-Tango simulation framework for predicting the steady-state plasma profiles in a stellarator. This framework couples the gyrokinetic turbulence code GENE, the neoclassical transport code KNOSOS, and the transport code Tango in a multiple-timescale simulation loop.

We perform ion-scale kinetic-electron and electron-scale adiabatic-ion flux-tube simulations to evolve the density and temperature profiles for four OP1.2b W7-X scenarios. The simulated profiles show excellent quantitative agreement with experimental data, while turbulence properties, such as density fluctuations and heat diffusivities, match the trends extracted from diagnostic measurements. The validation of the GENE-KNOSOS-Tango framework enables us to make credible predictions of physical phenomena in stellarators and reactor performance.

P 17.41 Wed 16:15 ZHG Foyer 1. OG

ECRH Power deposition and Te perturbation investigations using dynamic ECE analysis — •Vaishnavi Murugesan, Matthias Hirsch, Gavin Weir, Juan Fernando Guerrero Arnaiz, Neha Chaudhary, and Robert Wolf — Max Planck Institute for Plasma Physics

At Wendelstein 7-X, the plasma electron temperature profile is derived by assuming that the Electron Cyclotron Emission (ECE) behaves like a blackbody radiation from a certain layer in the plasma. When the plasma is heated using Electron Cyclotron Resonance Heating (ECRH), the microwave beams are absorbed in a thin layer where they are in resonance with the gyration frequency of the electrons. When the ECRH beam power is modulated, perturbations in plasma temperature are initiated, that propagate away from the deposition zone. This modulation is observed as an immediate response in the ECE signals. The goal of this work is to study this zone of power deposition.

A first approach is to do a conditional averaging over the modulation periods and deriving a slope of the local dT/dt that allows the calculation of the power deposition profile. To study the temperature profile during these modulation events, the radiometers should sample at a rate that is at least twice the collision rate of the electrons during these events. For this, a high frequency-resolution radiometer backend called the ZOOM system, has been upgraded to help monitor the power deposition zones at high sampling rates.

P 17.42 Wed 16:15 ZHG Foyer 1. OG

Divertor island studies with GRILLIX — •Barnabas Csillag, Andreas Stegmeir, Christoph Pitzal, Marion Finkbeiner, and Frank Jenko — Max Planck Institute for Plasma Physics, Garching, Germany

The global, electromagnetic, drift-reduced, trans-collisional Braginskii fluid turbulence code GRILLIX has been recently adapted to stellarator geometry. However, in order to perform comprehensive simulations of the Wendelstein 7-X Scrape-Off Layer (SOL) plasma, it is necessary to reconsider the treatment of boundary conditions in the model. So far the Immersed Boundary Approach (IBA) has been applied in GRILLIX, and using that the code was able to produce high fidelity tokamak edge-SOL simulations in diverted geometry. Nevertheless, the 3D geometry of the W7-X island divertors could present an insurmountable obstacle with such approach.

To examine the effects of boundary condition treatments in GRILLIX, a simplified divertor island geometry is investigated. In this test environment a circular toroidal magnetic field is applied with helical perturbations superimposed on it, creating the magnetic islands at a rational surface. In this model the magnetic islands can be intersected with poloidal target plates that are following the helical shape of the islands, similarly to the divertor plates of Wendelstein 7-X. Such setup is suitable to test the boundary condition treating methods, like the already implemented IBA, or if it is not found sufficient, for instance the Leg Value Fill scheme.

P 17.43 Wed 16:15 ZHG Foyer 1. OG

Simulation of fully global electromagnetic turbulence in the stellarator W7-X — •Yann Narbutt[1], Ksenia Aleynikova[1], Matthias Borchardt[1], Ralf Kleiber[1], Alexey Mishchenko[1], Edilberto Sánchez[2], and Alessandro Zocco[1] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstraße 1, 17489 Greifswald — [2]Laboratorio Nacional de Fusión, CIEMAT, Avda. Complutense 40, Madrid 28040

Magnetic confinement fusion needs high values of $\beta = \langle p \rangle/(B^2/2\mu_0)$, the ratio of plasma pressure to magnetic pressure, to achieve high performance. Moderate β can be beneficial for ion-temperature-gradient suppression. However, when β exceeds a certain threshold, the so-called kinetic ballooning mode (KBM) and other electromagnetic instabilities may be destabilized. These instabilities, driven by plasma pressure gradients and inherently electromagnetic, can result in strong outward-directed heat fluxes, thereby degrading plasma confinement, as has been shown by global nonlinear simulations. While KBMs have been successfully studied linearly and nonlinearly in the Wendelstein 7-X stellarator using flux-tube simulations, it has also been demonstrated that the instability tends to become most unstable as it develops a global structure on the magnetic surface. Utilizing the global gyrokinetic code EUTERPE electromagnetic instabilities and turbulence are investigated in the stellarator Wendelstein 7-X at β-values of 1%, 2.5% and 4%.

P 17.44 Wed 16:15 ZHG Foyer 1. OG

Tightest possible energetic bounds on local gyrokinetic instabilities — •Paul Costello and Gabriel Plunk — Max Planck Institute for Plasma Physics, Greifswald, Germany

The turbulence in fusion plasmas, which hampers their performance in many respects, is best understood with gyrokinetic theory. Recent work has shown that energetic upper bounds on the growth of turbulence causing gyrokinetic instabilities can be derived by seeking optimal modes, states of the gyrokinetic equation which maximise the growth of an energy norm [2]. Typically, an energy norm is chosen which is a nonlinear invariant of the gyrokinetic equation, such that the bounds are valid linearly and nonlinearly.

The growth of unstable linear eigenmodes, which are the focus of much theoretical and numerical work, is also bounded by the optimal mode growth rate. A natural question, which we seek to answer in this work, is, “How tightly can the linear eigenmode growth be bounded?” We find that using a special energy norm which is not a nonlinear invariant in most systems gives an upper bound equal to the growth of the most unstable linear eigenmode. This energy norm is a sum of projection coefficients in the linear eigenmode basis and is positive definite by the completeness of these modes [2]. Systems for which this energy norm is a nonlinear invariant are free from subcritical turbulence and may form a simple paradigm for turbulence saturation [3].

[1] G. G. Plunk & P. Helander. JPP 2022.
[2] K. M. Case. Annals of Physics 1959.
[3] G. G. Plunk. Phys. Plasmas 2015.

P 17.45 Wed 16:15 ZHG Foyer 1. OG

Feedback Controlled Phase Contrast Imaging at Wendelstein 7-X — •Max Zimmermann[1], Adrian von Stechow[1], Jan-Peter Bähner[2], Søren Kjer Hansen[2], Sean Ballinger[2], Olaf Grulke[1,3], Eric Edlund[4], Miklos Porkolab[2], and The W7-X Team[1] — [1]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [2]MIT Plasma Science and Fusion Center, Cambridge, MA 02139, USA — [3]Technical University of Denmark, 2800 Kongens Lyngby, Denmark — [4]SUNY Cortland, Cortland, NY 13045, USA

The phase contrast imaging (PCI) diagnostic at Wendelstein 7-X (W7-X) is used for detection of core turbulence density fluctuations [E.M. Edlund et al. 2018 Rev. Sci. Instrum. 89 10E105]. This is done by imaging electron density fluctuations using a CO_2 laser. The laser is aligned using several mirrors, some of which are attached to the outer vessel of W7-X and are therefore subject to vibrations from auxiliary systems (e.g. vacuum pumps). These vibrations lead to movements of the image plane and are visible in the PCI signal as low frequency components up to 250 Hz. A reduction of these vibrations leads to increased beam position stability and a higher signal saturation limit for PCI signals. A digital RST feedback controller is designed and implemented, which together with a piezo-based fast steering mirror and a four quadrant detector forms an active vibration compensation system. The controller design is validated by frequency response measurements and its impact on plasma fluctuation signals is evaluated.

P 17.46 Wed 16:15 ZHG Foyer 1. OG

Comparision of absolute calibration techniques for the Thomson scattering diagnostic at W7-X — •Jannik Wagner, Golo Fuchert, Ekkehard Pasch, K. Jakob Brunner, Jens Knauer, Sergey A. Bozhenkov, Matthias Hirsch, Robert C. Wolf, and W7-X Team — Max Planck Insitute for Plasma Physics, Germany

Thomson scattering is a cornerstone diagnostic for determining plasma electron density and temperature in many nuclear fusion experiments, such as Wendelstein 7-X (W7-X). To reconstruct these parameters, absolute spectral calibration factors of the diagnostics’ optical detection system are required. At W7-X, two calibrations are performed to determine these factors: A relative spectral calibration and an absolute calibration using Raman scattering of Nd:YAG laser pulses in Nitrogen. The relative calibration of the system is needed for electron temperature measurement, interpretation of the absolute calibration and extension of the latter into wavelength ranges inaccessible by Raman scattering. A recent study [1] proposes that Rayleigh scattering of laser pulses from a wavelength tunable optical parametric oscillator (OPO) in Argon could serve as a standalone-source for the absolute calibration. The calibration method has the potential to drastically reduce the systematic errors occurring from a strong dependence of the absolute calibration factors on the accuracy of the wavelength measurement in the spectral range of the Raman scattered signal. In this work, the conventional Raman calibration procedure is compared with the promising direct measurement using an OPO.

[1] E.R. Scott et al. JINST 14 C10033 (2019)

P 17.47 Wed 16:15 ZHG Foyer 1. OG

Towards a standard Diagnostic for not absorbed Electron Cyclotron Resonance Heating power at Wendelstein 7-X — •Jonas Zimmermann, Torsten Stange, Heinrich Laqua, Dmitry Moseev, and Johan Oosterbeek — IPP Greifswald

Electron cyclotron resonance heating (ECRH) at 140 GHz is the primary heating method of the Wendelstein 7-X device, a magnetically confined plasma experiment with the goal to demonstrate 30 minute plasma operation. Gaussian beams, with a power of about 1 MW each, are radially injected into the plasma, propagate as plasma waves, and are absorbed at the resonance where their frequency matches the 2nd harmonic of the electron cyclotron frequency. Non-absorbed radiation leaves the plasma and hits the wall opposite to the ECRH launchers. During long pulse operation, even a small percentage of non-absorbed power is sufficient to cause critical head loads on directly hit components. Therefore, a primary objective is to deposit the power only in the plasma and to guarantee the optimal parameters for polarization and direction of the beam. The wall opposite to the ECRH launchers is equipped with an antenna array called Electron Cyclotron Absorption (ECA) diagnostic, capable of detecting the power density and sensitive to the polarization of the transmitted beams. It is planned to use this diagnostic to routinely measure the fraction of non-absorbed power caused by various plasma effects or incorrect beam parameterization. This poster presents initial results of the ECA diagnostic on absorption, refraction, and beam parameter changes, and outlines steps toward a quantitative absorption diagnostic.

P 17.48 Wed 16:15 ZHG Foyer 1. OG

Characterisation of the assimilation of shattered pellets injected into a fusion plasma — •Ansh Patel[1], G Papp[1], A Matsuyama[2], S Jachmich[3], ASDEX Upgrade Team[4], and EUROfusion Tokamak Exploitation Team[5] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Kyoto University, Uji, Kyoto, Japan — [3]ITER Organization, St. Paul-lez-Durance, France — [4]See the author list of H. Zohm et al, Nucl. Fusion 2024 — [5]See the author list of E. Joffrin et al, Nucl. Fusion 2024

A disruption mitigation system (DMS) is necessary for reactor-relevant tokamaks like ITER to ensure the preservation of machine components throughout their designated operational lifespan. To address the intense heat and electromagnetic loads during a disruption, a shattered pellet injection (SPI) system will be employed. The SPI system involves injecting material into the plasma in the form of a cryogenic pellet that is shattered on a bent tube before entering the plasma. The penetration and assimilation of the injected material is influenced by various SPI parameters, including the fragment sizes, speeds, composition and the injection scheme. In this contribution, the material assimilation during SPI in the ASDEX Upgrade tokamak is characterized. The influence of different SPI parameters and different injection schemes on assimilation is carried out to determine optimal parameters for mitigation. The spatial distribution of material ablation and assimilation was carried out. Experimental analysis is also complemented with modelling with the 1.5D INDEX code to understand the plasma dynamics and its dependence on the aforementioned SPI parameters.

P 17.49 Wed 16:15 ZHG Foyer 1. OG

Fast Surrogate Modeling of Radio-Frequency Minority Heating at ASDEX Upgrade — •Michael Sieben, Markus Weiland, Roberto Bilato, and ASDEX - Team — Max-Planck-Institute for Plasma Physics

Auxiliary heating is essential to achieve the burning plasma conditions in fusion reactors. Radio-frequency waves in the Ion Cyclotron Range of Frequency (ICRF) are one of the possible auxiliary heating system in present devices and planned for ITER. The combined full-wave and Fokker-Planck code package TORIC-SSFPQL [1] provides accurate heating profiles for transport modeling in view of discharge analysis and design. However, long computation times pose challenges for fast transport simulations and real-time applications. We present a fast neural network (NN) surrogate model that reproduces minority heating profiles in deuterium-hydrogen plasmas at the ASDEX Upgrade (AUG) research reactor with real-time capability and high accuracy - comparable to an approach reported for NSTX and WEST [2]. We highlight possible directions for future work that could improve model accuracy - particularly by accounting for second harmonic heating and integrating equilibrium parameters into the model, which has been found to play a relevant role at AUG.

[1] M. Brambilla and R. Bilato. Nuclear Fusion, 49(8):085004, 2009.
[2] Á. Sánchez-Villar, Z. Bai, et al. Nuclear Fusion, 64(9):096039, 2024.

P 18: Codes and Modeling/HEPP

Time: Thursday 11:00–12:35 Location: ZHG102

Invited Talk P 18.1 Thu 11:00 ZHG102

Simulating W erosion, transport, and deposition in Ne-seeded discharges in ITER with full-W wall — •Christoph Baumann[1], Juri Romazanov[1], Sebastian Rode[1], Andreas Kirschner[1], Sebastijan Brezinsek[1,2], Tom Wauters[3], and Richard Pitts[3] — [1]FZ Jülich, Germany — [2]HHU Düsseldorf, Germany — [3]ITER Organization, France

Plasma-wall interaction processes like erosion are a challenge for efficient long-term operation of fusion devices. Numerical modelling of such processes is inevitable to get better understanding of experiments in present day machines like AUG, but also to make predictions for future machines like ITER. Especially the recent re-baselining to a full Tungsten (W) ITER requires dedicated studies on seeding impact on first wall erosion due to higher W sputter yields as compared to hydrogen isotopes in the plasma fuel. The present work therefore investigates W erosion and migration in Ne-seeded Q=10 H-mode ITER plasmas using the three-dimensional Monte-Carlo code ERO2.0. The code calculates both the erosion under ion or charge-exchange neutral impact and the migration of eroded impurities through the plasma, including atomic processes like ionization/recombination, as well as impurity re-deposition/re-erosion. The simulations reveal highly-charged Ne and W self-sputtering to be the main source of erosion, which is related to high far-SOL temperature conditions for electrons, 20 eV, and ions, 40 eV. The contribution of D on W erosion in contrast is smaller by two orders of magnitudes. In addition, strong W net deposition is observed in the inner divertor, indicating strong W transport into the divertor.

P 18.2 Thu 11:30 ZHG102

Structure-preserving Hybrid Code, STRUPHY: Energy-conserving Hybrid MHD-driftkinetic Model — •byung kyu na[1,2], stefan possanner[1], xin wang[1], and yingzhe li[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]Technical University of Munich, Boltzmannstraße 3, 85748 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 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 restored by adding additional terms derived from variational principles. The capabilities and properties of the implemented scheme will be investigated with the preliminary results of the ITPA benchmark case.

P 18.3 Thu 11:55 ZHG102

A Stochastic Variational Principle for a Two-Fluid Model Arising in Fusion Plasma Physics — •Sayyed Amin Raiessi Toussi[1], Omar Maj[1], and Tomasz Tyranowski[2] — [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

This work proposes a stochastic variational principle for a quasi-neutral, two fluid model of a plasma in a fixed magnetic field, including dissipative effects such as particle diffusion, viscosity and heat fluxes. The variational formulation is motivated by the development of a variational smooth particle method for transport simulation in complex stellerator geometries. In the absence of dissipative effects the model admits both a Lagrangian and a corresponding Euler-Poincaré reduced variational principle. The main variables in the Lagranigan picture are the fluid flows, which describe the displacement of the ion and the electron fluid, respectively. Dissipative effects are incorporated by stochastic perturbation of the underlying flows, closely following the work of Chen et al [X. Chen, A. B. Cruzeiro and T. Ratiu, J. Nonlinear Sci. 33, 5 (2023)]. In this formulation elements of the theory of compressible, viscous flows are combined with Lagrangian constraints coming from quasi-neutrality. Finally, using particle methods, we will present a semi-discretized version of the proposed variational principle.

P 18.4 Thu 12:20 ZHG102

Energy- and angle-dependent boundary condition for the electron kinetics of a plasma — •Clemens Hoyer[1], Felix Willert[1], Gordon K. Grubert[2], Detlef Loffhagen[3], Markus M. Becker[3], and Franz X. Bronold[1] — [1]Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany — [2]Universitätsrechenzentrum, Universität Greifswald, 17489 Greifswald, Germany — [3]Leibniz-Institut für Plasmaforschung und Technologie, 17489 Greifswald, Germany

For an electron Boltzmann equation we derive a Marshak type energy- and angle-dependent boundary condition, containing the electron microphysics inside the wall. It uses the electron surface scattering kernel [1], describing electron reflection as well as secondary emission from a microscopic solid-state physics point of view. We incorporate the kernel within an Legendre polynomial expansion approach for solving the electron Boltzmann equation [2], but the kernel can be also used for PIC-MCC simulations of the plasma's electron kinetics. Numerical results for an argon plasma in contact with a silicon surface are presented, showing the significance of the microphysics-based boundary condition compared to an energy- and angle-independent phenomenological one.

[1] F.X. Bronold and F. Willert, Phys. Rev. E **110**, 035207 (2024).
[2] M. M. Becker, G. K. Grubert, and D. Loffhagen, Eur. Phys. J. Appl. Phys. **51**, 11001 (2010). F.X.B. and F.W. acknowledge support by Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)–495729137.

P 19: Low Pressure Plasmas and their Applications II

Time: Thursday 11:00–12:30 Location: ZHG006

Invited Talk P 19.1 Thu 11:00 ZHG006

A plasma process model for high power impulse magnetron sputtering discharges — •Martin Rudolph[1], Daniel Lundin[2], and Jon Tomas Gudmundsson[3,4] — [1]Leibniz Institute of Surface Engineering (IOM), Leipzig, Germany — [2]Plasma and Coatings Physics Divsion, Linköping University, Linköping, Sweden — [3]Science Institute, University of Iceland, Reykjavik, Iceland — [4]Division of Space and Plasma Physics, KTH Royal Institute of Technology, Stockholm, Sweden

High-power impulse magnetron sputtering (HiPIMS) processes are widely used for thin-film deposition. They rely on pulsed high discharge currents to generate a dense plasma that promotes the ionization of sputtered atoms. The ionization region model (IRM) is a semi-empirical model of the HiPIMS process. Its advantage is its computational speed, a critical factor for a process model designed to explore the vast parameter space in HiPIMS. Using the IRM, the influence of external discharge parameters on relevant internal plasma parameters can be disentangled. In this contribution, we show how the electron density in the ionization region scales with the peak discharge current, while the electron temperature scales with the sputter yield of the target material. A fraction of the ionized sputtered atoms is drawn back to the target due to its negative voltage, resulting in their loss from the deposition process. Consequently, a higher ionization of sputtered species is inherently linked to a reduction in the deposition rate. We demonstrate how these two parameters can be optimized when developing a HiPIMS process.

P 19.2 Thu 11:30 ZHG006

Investigations of EUV-induced low density hydrogen plasma in a stand-alone high-intensity irradiation setup — •Adelind Elshani[1], Linus Nagel[1], Ismael Gisch[1], Sascha Brose[1,2], Hendrik Kersten[3], Annika Bonhoff[1], Thorsten Benter[3], and Carlo Holly[1,2] — [1]RWTH Aachen University TOS, Aachen — [2]Fraunhofer Institute for Laser Technology ILT, Aachen — [3]University of Wuppertal, Physical and Theoretical Chemistry, Wuppertal

The interaction of high-intensity EUV radiation with low-pressure hydrogen gas induces a low-density hydrogen plasma. Understanding the underlying chemical and dynamic processes is essential yet complicated due to plasma formation complexity. Influencing variables are often correlated, making it challenging to investigate relevant quantities independently in existing setups. Investigations that decouple these variables are crucial for a deeper understanding of EUV-induced plasmas. The developed stand-alone high-intensity irradiation setup (EUV-HIEX) reduces complexity and allows the investigation of fundamental dependencies with mostly unbiased parameters. High-intensity exposures are achieved with high spectral purity around 13.5 nm, high vacuum quality, and symmetrical vacuum chamber geometry. Coupling diagnostics enables detailed studies of plasma-induced chemistry and dynamics. Additionally, a modeling framework is developed to link experimental data with theoretical models. The presentation covers the key components of the EUV-HIEX setup, the modeling framework, and the first experimental results, along with an analysis of simulation results regarding electron dynamics.

P 19.3 Thu 11:45 ZHG006

Characterization of a combination sensor for the diagnostic of process plasmas — •Daniel Zuhayra[1], Caroline Adam[1], Michael Weise[2], Thomas Trottenberg[1], and Holger Kersten[1] — [1]Christian-Albrechts-Universität zu Kiel — [2]Optotransmitter-Umweltschutz-Technologie e.V.

Energy and particle fluxes significantly impact the surface properties of a substrate in contact with a plasma. Therefore, process control of these parameters by plasma diagnostic methods is of special interest for industrial applications. In this study, we characterized an in-house build, combination diagnostic comprised of a Retarding-Field-Analyzer (RFA) and a Passive-Thermal-Probe (PTP), called Retarding-Field-Thermal-Probe (RFTP), for the study of energy and particle fluxes. The PTP acts as the collector of the RFA and, thus, enables the nearly simultaneous measurement of ion energy distribution and energy influx. Thereby, it is possible to split the energy flux contributions of ions and neutrals. The functionality of the diagnostic was tested in a capacitively coupled plasma (CCP) at a frequency of 13.56 MHz, a conventional direct current magnetron (DC-magnetron), a radio frequency magnetron (RF-magnetron) and in HiPIMS at various discharge conditions. The results reveal an operational area for the RFTP at pressure < 10 Pa and moderately high discharge power, limited by the dimensions, heat capacity and grid transparency of the probe.

P 19.4 Thu 12:00 ZHG006

Characterization of a plasma source for atomic tritium — •David Frese for the KAMATE-Collaboration — Tritiumlabor Karlsruhe am Institut für Astroteilchenphysik, KIT

The Karlsruhe Tritium Neutrino (KATRIN) experiment will determine a neutrino mass with a sensitivity of <0.3 eV by electron spectroscopy of the tritium beta-decay spectrum. In order to improve the sensitivity on the neutrino mass down to inverted mass ordering range or below new technologies are necessary. One proposed improvement is to use atomic tritium instead of molecular tritium. In the beta-decay of the T-atom, the intrinsic molecular broadening of about 0.4 eV is absent in the beta-decay spectrum.

The first step in generating a source based on tritium atoms is the dissociation of T_2. Therefore, various atomic tritium dissociators need to be commissioned and characterized. To address this challenge, the joint Karlsruhe Mainz Atomic Tritium Experiment (KAMATE) group was established to investigate potential atomic tritium sources. The performance of commercial dissociators is studied initially by non-radioactive hydrogen and deuterium, before transitioning to experiments with substantial amounts of tritium.

This talk presents the dissociation concept of a plasma source and highlights its advantages and disadvantages. The plasma operation may sputter off boron nitride from the cavity walls which would be detrimental for the operation. This process will be investigated in a dedicated setup. After that, the atomic fraction of the plasma dissociator outlet is studied by mass spectrometry.

P 19.5 Thu 12:15 ZHG006

Plasma Sheath Tailoring for Advanced 3d Plasma Etching: Effects of Mask Geometry and Etching Materials — •Elia Jüngling, Gerardo Gutiérrez, Marc Böke, and Achim von Keudell — Ruhr University Bochum, Germany

Three-dimensional (3D) etching of materials by plasmas represents a significant challenge for microstructuring applications to produce advanced sensors, optics and microfluidics. Previously, we proposed the use of a local magnetic field in combination with a metallic mask to manipulate the plasma dynamics above the substrate and have achieved asymmetric etching profiles [1]. The experiments were explained regarding the $\vec{E} \times \vec{B}$ drifts during the local sheath expansion in the RF plasmas. This controls the plasma density distribution above and the transport to the surface.

This concept is further investigated for the application of glass and Si 3d etching in an Ar/CF4 plasma. In the case of glass, the effect of spatially different etching rates is significantly more pronounced than that of silicon. This is presumed to be due to the differences in the etching chemistry of silicon vs. glass. Furthermore, the effect of different mask geometries has been explored. It has been demonstrated that the mask shape influences both the redeposition of sputtered CF-containing polymers from the mask surface onto the substrate and the etching profiles.

References: [1] Jüngling et al. Plasma sheath tailoring by a magnetic field for three-dimensional plasma etching. Appl. Phys. Lett. 12 February 2024; 124 (7): 074101.

P 20: Magnetic Confinment Fusion/HEPP V

Time: Thursday 13:45–15:50 Location: ZHG102

Invited Talk P 20.1 Thu 13:45 ZHG102

First applications of the kinetic ion transport module in the EMC3-EIRENE code package — •Derek Harting[1], Dirk Reiser[1], Christoph Baumann[1], Sebastian Rode[1], Juri Romazanov[1], Sebastijan Brezinsek[1,2], Heinke Frerichs[3], Alexander Knieps[1], and Yuhe Feng[4] — [1]FZ-Jülich, Institute of Fusion Energy & Nuclear Waste Management - Plasma Physics — [2]HHU Düsseldorf, Faculty of Mathematics and Natural Sciences — [3]UW - Madison, Department of Engineering Physics — [4]MPG Institute for Plasma Physics

Impurity seeding in the scrape off layer plasma as well as controlling the contamination of the core plasma by high Z impurities are essential for ITER baseline scenarios. While fluid models are often used to describe impurity transport, short-lived lower ionization stages of high-Z impurities (e.g., W, Ar) may require a kinetic treatment due to their non-Maxwellian velocity distributions. To address these kinetic effects, the EMC3-EIRENE code package has been extended with a trace kinetic ion transport module in guiding center approximation. This module includes grad-B drifts, mirror-force effects and anomalous cross-field diffusion. Benchmarks with the kinetic ion transport code ERO2.0 showed fair agreement, validating the implementation. First simulations of a tungsten source in the ITER divertor region under an attached, medium-density L-mode plasma scenario demonstrate the module's capabilities. These advancements enhance predictions of impurity transport and plasma contamination control, crucial for ITER and future fusion devices.

P 20.2 Thu 14:15 ZHG102

About recent progress in collisional-radiative modelling of molecular hydrogen plasmas — •Richard Christian Bergmayr, Dirk Wünderlich, and Ursel Fantz — Max Planck Institute for Plasma Physics, Garching, Germany

Collisional-radiative (CR) models for molecular hydrogen are crucial for the quantitative analysis of molecular emission from low temperature plasmas (e.g. fusion divertor plasmas) and are suited to predict effective rate coefficients for neutral kinetic codes (e.g. EIRENE) in order to understand the extent to which molecules contribute to the detachment process. The accuracy of CR model predictions is limited by the availability of accurate reaction probabilities as model input. The latest advances in molecular input data motivate the development of a fully ro-vibrationally resolved CR model for molecular hydrogen. A multi-stage approach is pursued, in which population models with different detail level of (ro-vibrational) resolution are composed based on the Yacora solver. These models utilize specifically for their purpose composited databases of recent reaction probabilities, are successfully benchmarked on various experiments (e.g. divertor plasmas, linear devices and small scale laboratory experiments) and are employed for different, dedicated fields of applications. This includes the first time quantification of the influence of spin-mixing processes, post-processing EDGE2D-EIRENE JET L-mode profiles in comparison to predictions by the AMJUEL database (which is used as a standard in EIRENE) and unprecedentedly accurate, ro-vibrationally resolved Fulcher-α band emission predictions.

Invited Talk P 20.3 Thu 14:40 ZHG102

Simulating boundary turbulence in fusion reactors in different confinement, ELM and detachment regimes — •Wladimir Zholobenko[1], Andreas Stegmeir[1], Kaiyu Zhang[1], Konrad Eder[1], Jan Pfennig[1], Christoph Pitzal[1], Philipp Ulbl[1], Matthias Bernert[1], Michael Griener[1], and the ASDEX Upgrade Team[2] — [1]MPI for Plasma Physics, Garching, Germany — [2]see author list of H. Zohm et al., 2024 Nucl. Fusion

Magnetic confinement fusion reactors must combine high plasma energy confinement with manageable heat exhaust. Both are determined to a large degree by turbulent transport across the very plasma edge. While present day experiments focus on finding optimal regimes of operation, only first-principles based computer simulations can make reliable extrapolations to future fusion reactors.

This contribution focuses on recent progress with the GRILLIX code in understanding high-confinement, detached and ELM-free regimes on the ASDEX Upgrade tokamak. Transitions between various micro-instabilities, their non-linear dynamics and interaction with large-scale flows are shown to be important for the understanding of the varying plasma edge conditions. For optimal operation, plasma shaping and the control of the scrape-off layer and divertor dynamics are critical.

Turbulence is a multi-scale, chaotic, dynamical phenomenon. Simulating it challenges todays top tier supercomputers, in particular for even larger future machines. Therefore, optimized model complexity and software design are key to facilitate fusion reactor predictions.

P 20.4 Thu 15:10 ZHG102

Plasma turbulence modeling in detached regimes — •Konrad Eder, Wladimir Zholobenko, Andreas Stegmeir, Matthias Bernert, David Coster, and Frank Jenko — MPG-IPP, Garching, Germany

Predictive studies of the plasma edge in fusion reactors – particularly towards detachment – require self-consistent modeling of turbulent transport involving an interplay of plasma, neutral gas, and impurities.

We present extensions to the edge turbulence code GRILLIX, which applies 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. Particle recycling is modeled by introducing novel boundary conditions compatible with the Flux-Coordinate-Independent (FCI) approach, on which GRILLIX is based and which enables it to handle complex diverted geometries.

In simulations of an attached ASDEX-Upgrade (AUG) L-mode discharge we first investigate how the model extensions affect neutrals and plasma near the divertor. Next, the updated model is validated against a fully detached AUG discharge featuring an L-mode X-point radiator (XPR) as part of an L-H transition. We are able to reproduce the XPR structure (radiating >80% of input power), a first-of-its-kind for turbulence simulations, and find the simulations to be in good agreement with experimental measurements at the Outboard-midplane and the divertor. Finally, we analyze distinct interchange-type turbulence found near the XPR structure, which helps elucidate our understanding of the XPR regime.

P 20.5 Thu 15:35 ZHG102

Helium exhaust studies in ASDEX Upgrade with a quadrupole mass spectrometer — •Simon Krumm[1,2], Athina Kappatou[1], Volker Rohde[1], Thomas Pütterich[1,2], Andreas Redl[1], and the ASDEX Upgrade Team[3] — [1]Max-Planck- Institut für Plasmaphysik, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität München, 80539 München, Germany — [3]see the author list of H. Zohm et al. 2024 NF 64 112001

Helium is the product of the fusion reaction used in future fusion power plants. Thermalised helium dilutes the fuel and has to be efficiently removed to sustain the fusion process. To understand and optimise helium exhaust processes, diagnostics are necessary to measure helium from the plasma core all the way to the pump ducts. To measure helium in the pump ducts and to determine pumping speeds, quadrupole mass spectrometers are used. However, the low mass difference between molecular deuterium and helium makes mass spectrometry challenging. We present the application of the Threshold Ionisation Mass Spectrometry (TIMS) method to accurately measure He and D partial pressures with high time resolution. Following its performance characterisation in a laboratory we then utilise the diagnostic in ASDEX Upgrade plasmas to study helium exhaust dynamics and to determine the helium pumping speed achieved with ASDEX Upgrades's new activated charcoal coated cryopump.

P 21: Atmospheric Plasmas and their Applications V

Time: Thursday 13:45–15:45 Location: ZHG006

Invited Talk P 21.1 Thu 13:45 ZHG006

Vacuum UV spectroscopy at atmospheric pressure plasmas utilizing silicon nitride membranes — •Luka Hansen[1,2], Görkem Bilgin[1], Hendrik Kersten[3], 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 — [3]Institute for pure and applied mass spectrometry, University of Wuppertal, Wuppertal, Germany

Vacuum ultraviolet (VUV) radiation is crucial for several applications including, e.g., the biomedical field or photocatalysis. A fundamental problem is the transfer from VUV radiation produced in an atmospheric pressure environment into the vacuum for further diagnostics, as typical window materials like LiF or MgF_2 are not suited for this transfer due to their cut off wavelength at 115 nm. Different approaches have been pursuit in the past to overcome this problem involving, e.g., differential pumping [1] or an aerodynamic window [2].
A new approach is utilizing a ultra-thin Si_3N_4 membrane with a thickness of 20 nm as entrance window. These membranes can withstand the pressure gradient of one atmosphere and showed resistance against plasma and plasma-generated species [3].
This approach allows to resolve spectra down to 58.4 nm (He resonance line) and reveal interesting self-absorption effects of noble gases influencing previously reported VUV spectroscopy measurements.

[1] F. Liu *et al.*, 2020 *Plasma Sources Sci. Technol.* **29** 065001
[2] J. Golda *et al.*, 2020 *Plasma Process. Polym.* **17** 201900216
[3] L. Hansen *et al.*, 2023 *Thin Solid Films* **765** 139633

P 21.2 Thu 14:15 ZHG006

controlled synthesis of NO and helium metastable measurement in atmospheric pressure RF plasma — •Siqi Yu, Steijn Vervloedt, Laura Chauvet, and Achim von Keudell — Ruhr-Universität Bochum, Bochum, Germany

Non-thermal plasma catalytic technology has promising potential to improve gas conversion efficiency. Our research focuses on nitrogen oxide synthesis, especially NO production, because of its broad range of applications in biological processes. NO_x species are generated in a parallel-plate atmospheric pressure RF plasma from N_2/O_2 admixed to helium. The concentrations are measured by FTIR spectroscopy using a multi-pass cell. The results show that NO's is further oxidized with increasing oxygen admixture and ozone generation. It can be controlled by increasing the surface temperature and by using a catalytic material that preferentially quenches O_3. Helium metastable species act as an energy pool and play a crucial role during the discharge. Broadband absorption spectroscopy is used as an in-situ method to measure absolute densities of atomic $He(2^3S_1)$ and molecular $He_2(a^3\Sigma_u^+)$ metastable species. A 1D global model is developed to fit the experimental data and analyze metastable generation and destruction mechanisms. The helium metastable induced desorption of adsorbed water causes a decay of the metastable density along the plasma channel. Surface materials with a lower work function exhibit stronger secondary electron emission, affecting the local heating at the plasma boundary sheath. This increases the rate for $He(2^3S_1)$ and $He_2(a^3\Sigma_u^+)$ conversion.

P 21.3 Thu 14:30 ZHG006

Impact of Long-Term Stability of Atmospheric Pressure Plasmas on Vacuum UV Spectroscopy — •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 diagnostic of vacuum ultraviolet (VUV) photons generated by atmospheric pressure plasmas is challenging due to strong absorption of VUV photons in air and common window materials like lithium fluoride (LiF) and magnesium fluoride (MgF_2) [1]. Ultra-thin silicon nitride (Si_3N_4) membranes (20 nm) can withstand the pressure gradient and are resistant to plasma exposure, enabling VUV spectroscopic measurements.
During the operation of a capillary jet plasma source [2], the electrodes and plasma heat up, altering matching and reducing power input to the plasma. Stable operating conditions are essential to investigate potential changes in the Si_3N_4 membranes (e.g., chemical composition, transmission). Therefore, the existing setup was upgraded with a liquid cooling system.
VUV spectra with and without cooling highlight the need for active cooling to ensure stable operation. A stable VUV photon source is essential for studying long-term effects on the membrane. Additionally, the plasma source's tunability is shown by measuring VUV spectra while varying the working gas mixture.

[1] J. Golda *et al.*, 2020 *Plasma Process. Polym.* **17** 201900216
[2] T. Winzer *et al.*, 2022 *J. Appl. Phys.* **132** 183301

Invited Talk P 21.4 Thu 14:45 ZHG006

Hybrid fluid/MC simulations of radio-frequency atmospheric pressure plasma jets — •Mate Vass[1,2], Peter Hartmann[2], Zoltan Donko[2], Ihor Korolov[1], Thomas Mussenbrock[1], and Julian Schulze[1] — [1]Chair of Applied Electrodynamics and Plasma Technology, Ruhr-University Bochum, 44780 Bochum, Germany — [2]Institute for Solid State Physics and Optics, HUN-REN Wigner Research Centre for Physics, 1121 Budapest, Hungary

Radio-frequency (RF) driven atmospheric pressure micro plasma jets have a wide range of industrially relevant applications. In order to optimize them, a quantitative understanding of how the neutral species densities build up along the jet channel is needed. This is a result of the complex interplay between multiple processes on different timescales. While fluid simulations are usually employed for the description of these jets, they are unable to account for kinetic effects in case of the electrons, which however directly influences the plasma chemistry. Fully kinetic simulation methods, such as PIC/MCC, are, on the other hand, too impractical at atmospheric pressure, particularly for the complex gas mixtures relevant to applications. In this talk, a hybrid simulation method is presented, leveraging the time scale separation of physical processes and the kinetic description of electrons. The method combines a fluid model for charged and neutral species and a Monte Carlo module for electrons only. This approach achieves significant speedup compared to fully kinetic simulations while maintaining accuracy. Simulations of a He/O_2 mixture are presented, showing excellent agreement with experimental results.

P 21.5 Thu 15:15 ZHG006

Tunable diode laser absorption spectroscopy of all four Ar*(3p⁵4s) states in a pulsed-operated single-filament dielectric barrier discharge at atmospheric pressure — •Levin Krös[1], Hans Höft[1], Jean-Pierre H. van Helden[1,2], and Ronny Brandenburg[1,3] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Faculty of Physics and Astronomy, Ruhr University Bochum, Bochum, Germany — [3]Institute of Physics, University of Rostock, Rostock, Germany

Dielectric barrier discharges (DBDs) are a common plasma source for plasma enhanced chemical vapour deposition (PECVD), i.e. of thin functional films. Excited argon species have sufficient energy to dissociate or ionise molecular species and thus influence the discharge dynamics. Tunable diode laser absorption spectroscopy is utilised to measure absolute number densities of the $Ar^*(3p^54s)$ states. Detailed knowledge of the population distribution of the four lowest energetically excited states of argon ($Ar^*(3p^54s)$ states, i.e. the resonance states ($1s_2$, $1s_4$) and the metastable states ($1s_3$, $1s_5$)), is of major interest for the benchmarking of numerical models to tailor the operating parameters for PECVD, e.g., the characteristics of the applied high-voltage pulse and the gas flow rate. We report the first results of density measurements of these states in a pulsed-operated DBD with a 3 mm gas gap flown through with argon at atmospheric pressure. This work is funded by the DFG (project number: 504701852).

P 21.6 Thu 15:30 ZHG006

N-butane conversion in an RF plasma combined with a catalyst — •Fatma-Nur Seferoglu[1], Steijn Vervloedt[2], and Achim von Keudell[2] — [1]Institute of Fusion Energy and Nuclear Waste Management, Forschungszentrum Jülich GmbH, Jülich, GERMANY — [2]Experimental Physics II, Ruhr-University, Bochum, GERMANY

Volatile organic compounds (VOCs) such as n-butane can negatively impact the environment, contribute to air pollution and can affect human health. Plasma catalytic systems are a promising technology for VOC removal. These systems, particularly in-plasma catalysis, can be very complex due to numerous chemical and physical processes that can take place simultaneously. Recently, different reaction kinetic models for the plasma-assisted conversion of n-butane have been proposed. However, the key reaction channels are still not fully known yet. In this work, a capacitively coupled plasma is generated at 13.56 MHz in atmospheric pressure between two plane-parallel electrodes spray-coated with MnO_2 as a catalyst. Fourier-Transform Infrared spectroscopy has been performed for a helium flow of 250 sccm and two different gas admixtures O_2: C_4H_{10}: He = 0.135%: 0.124%: 99.741%, and CO_2: He = 0.81%, to determine the species concentration inside the plasma-catalytic system. The comparison between the experiment and the proposed models reveals that O_2 adsorption is less dominant than CO_2 adsorption on the catalytic surface in the case of the oxygen-deficient n-butane conversion. In all cases, electron-impact CO_2 dissociation plays a mayor role in the plasma-catalytic system.

P 22: Plasma Wall Interaction/HEPP

Time: Thursday 16:15–17:35 Location: ZHG102

Invited Talk P 22.1 Thu 16:15 ZHG102

High-resolution optical emission spectroscopy of neutral W lines: comparing near-threshold sputtering of W with different crystal orientation in PSI-2 — •Marc Sackers[1], Oleksandr Marchuk[1], Stephan Ertmer[1], Sebastijan Brezinsek[1,2], Fredric Granberg[3], and Arkadi Kreter[1] — [1]Forschungszentrum Jülich GmbH, Institute of Fusion Energy & Nuclear Waste Management - Plasma Physics — [2]HHU Düsseldorf, Faculty of Mathematics and Natural Sciences — [3]University of Helsinki, Department of Physics

Seeding gas ions, like Ar, having a kinetic energy of ≈ 100 eV, dominate the erosion of the plasma-wetted areas during the quiet phases of the discharges in fusion reactors. These ions create near-threshold sputtering. Thus, the collisional cascade stays within the surface layers, and the distribution function of the sputtered atoms can depend strongly on the crystallographic structure. Molecular dynamics simulations suggest precisely such a behavior for the erosion of W by low-energy Ar ions.

However, experimental studies of the near-threshold erosion of tungsten by seeding gas impurities are severely lacking. This contribution presents near-threshold erosion experiments of tungsten samples by Ar ion bombardment at the linear plasma device PSI-2. The modeling of the line shape emitted by sputtered W provides, via Doppler broadening, insights into the angular and velocity distribution functions. This contribution presents how to account for all relevant line broadening and splitting mechanisms. Notably, the line shape measured depends strongly on the crystallographic plane exposed to the plasma.

P 22.2 Thu 16:45 ZHG102

Manufacturing and testing of optimized composite heat sinks for plasma-facing component applications — •Robert Lürbke[1,2], Alexander von Müller[2], Bernd Böswirth[2], Henri Greuner[2], Johann Riesch[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, Germany — [3]Fraunhofer Institute for Casting, Composite and Processing Technology IGCV, 86159 Augsburg, Germany

In future magnetic confinement fusion reactors, plasma-facing components (PFCs) of the divertor will be subjected to high heat loads and intense neutron irradiation. This requires the development of reliable materials and robust component designs. An established state-of-the-art divertor PFC design is the so-called tungsten monoblock concept, which exhibits good damage resilience but is restricted in its width requiring a large number of PFCs. The so-called flat-tile is another well-known design option, which exhibits good heat removal capabilities, but there are basic concerns about the structural integrity of the material joints. In this study, we demonstrate the manufacturing and testing of a design that combines the advantages of both abovementioned PFC design approaches with an optimized tailored composite. Such composite structures are manufactured by infiltrating additively manufactured tungsten preforms with a copper (alloy) matrix. The contribution summarizes the results of high heat flux tests on different PFC mock-up specimens that were tested under cyclic loading at heat loads up to 20 MW/m^2.

P 22.3 Thu 17:10 ZHG102

Engineering tool for the mitigation of target loads at leading edges in multi-configuration island divertors — •Antara Menzel-Barbara[1,2], Joris Fellinger[2], Rudolf Neu[1,3], Dirk Naujoks[2], and Michael Endler[2] — [1]TUM, Munich, Germany — [2]IPP, Greifswald, Germany — [3]IPP, Garching, Germany

The Wendelstein 7-X divertor is designed to intersect magnetic field lines at shallow angles. Because of inevitable steps between divertor components, small exposed areas called *leading edges* can be intersected almost perpendicularly by magnetic field lines and thus receive highly increased heat fluxes. Traditionally, mitigating leading edges involves 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, exposing new leading edges when mitigating one. The tool presented here allows to demonstrate that while such overlapping particle deposition patterns are manageable, achieving good separation is essential for relaxed tolerances and reduced manufacturing complexity. Furthermore, methods for achieving this separation are explored via field-line tracing creating divertor geometries from scratch for single configurations. By maintaining incidence angles below critical thresholds, overloads can be avoided. By identifying shadowed regions, divertor targets can be designed for compatibility with multiple configurations, while eliminating overlapping leading edges. It is envisioned to use this tool to explore divertor solutions optimized for particle exhaust, cost and ease of installation.

P 23: Atmospheric Plasmas and their Applications VI

Time: Thursday 16:15–18:00 Location: ZHG006

Invited Talk P 23.1 Thu 16:15 ZHG006

Electric Field Determination for Fundamental and Applied Discharge Physics — •Tomas Hoder — Masaryk University, Brno, Czech Republic

The electric field is one of the key parameters describing gas discharges and their dynamics. The spatiotemporal distribution of the electric field is crucial not only for calculating local electron-driven chemistry but also, more broadly, as a central parameter for validating computational models and developing or cross-checking new diagnostic methods. In this contribution, we will discuss the evaluation of the electric field using multiple methods, primarily optical emission and laser spectroscopy based. We will demonstrate the application of these methods for understanding barrier discharges, both within the discharge volume and on dielectric surfaces, and briefly assess the applicability of each method. Special attention will be given to the comparison of experimental results with computer simulations. Examples from both fundamental and applied industrial research will be presented and discussed.

P 23.2 Thu 16:45 ZHG006

Ion energy distributions of a DBD-plasma jet impinging on surfaces — •Daniel Henze, Laura Chauvet, and Achim von Keudell — Experimental Physics II Reactive Plasmas, Ruhr-Universität Bochum

Ion energy distribution functions (IEDFs) originating from a kHz-DBD plasma helium jet expanding into open air were measured using a molecular beam mass spectrometer (MBMS). The plasma jet produces quickly propagating ionization waves as guided streamers. The species' transition into the MBMS occurs either through a 40μm metallic or 50 μm ceramic orifice. The analysis of the time-resolved IEDFs using the metallic orifice revealed that ions initially impacting on the surface are predominantly sampled at a reference energy, which is determined by the seeding of ions into the supersonic expanding helium beam formed when transitioning into the MBMS. After the impact, ions are continuously sampled at an energy a few 0.1 eVs higher than the reference. This is resolved by postulating a positive space-charge region in front of a positively charged surface. However, using the ceramic orifice, much broader IEDFs are observed. These IEDFs are in agreement with simulations by Babaeva and Kushner [2013 J. Phys. D: Appl. Phys. 46 125201].

P 23.3 Thu 17:00 ZHG006

Spatio-temporal ignition pattern in sinusoidal-driven dielectric barrier discharges — •Hans Höft[1], Markus M. Becker[1], and Ronny Brandenburg[1,2] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Institute of Physics, University of Rostock, Rostock, Germany

Dielectric barrier discharges (DBDs) driven by sinusoidal high-voltage (HV) waveforms feature distinct spatio-temporal ignition pattern, which differs significantly from pulsed-operated DBDs, and are of importance for the performance of plasma-chemical reactors. This was investigated using a spatially 1D multi-filament DBD arrangement with a 1 mm gap (dielectric alumina, 1 mm around each rod electrode) and a lateral gap length of ≈ 10 mm in synthetic air at 1 bar. Electrical measurements were synchronised with iCCD and streak camera recordings to obtain information on the number of filaments and their spatio-temporal inception during the positive and negative half-cycle of the applied sinusoidal HV waveform with 11 and 14 $\mathrm{kV_{pp}}$ at 10 kHz. It was found that the filament positions are fixed in both HV half-cycles corresponding to current pulse series. There are alternating positions during one half-cycle, i.e. the deposited surface charges prohibit the ignition for the same polarity of the HV waveform. This pattern, however, is stable only for some subsequent periods. Furthermore, the spatial stability disappears for higher HV amplitudes, when more than two filament series occur during one half-cycle of the HV waveform.
This work was funded by the Deutsche Forschungsgemeinschaft (DFG), project number: 535827833.

P 23.4 Thu 17:15 ZHG006

Impact of ambient humidity on the OH distribution in the effluent of an atmospheric pressure plasma jet — •Robin Labenski[1], Sebastian Burhenn[1], Maike Kai[1], Pia Pottkämper[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

Atmospheric plasma jets are essential in fields like plasma medicine, as they can generate and deliver reactive oxygen and nitrogen species (RONS) to specific targets. A detailed understanding of their generation mechanisms and interactions with the ambient atmosphere is critical, particularly for hydroxyl (OH) radicals. This study examines OH dynamics in the COST microplasma jet (COST-Jet) using helium (He) as the feed gas. By employing laser-induced fluorescence (LIF) spectroscopy, absolute OH densities are mapped in three dimensions. Varying the humidity in both the feed gas and ambient air, the contributions of plasma and post-plasma processes to OH generation are analyzed. When water vapor is added to the feed gas, uniformly high OH densities ($1 * 10^{14}\,\mathrm{cm^{-3}}$) are observed near the nozzle, followed by rapid axial and radial decay. In contrast, ambient humidity alone produces one order lower OH densities, localized at the effluent-air boundary. Higher ambient humidity shifts the OH density peak closer to the nozzle as humidity infiltrates deeper into the effluent. This work is supported by project PlasNOW and in collaboration with projects B2 and B11 of SFB1316

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Surface processes during plasma-based nitrogen fixation — •Steijn Vervloedt and Achim von Keudell — Experimental Physics II, Ruhr University Bochum, Bochum, Germany

Nitrogen fixation is a vital part of artificial fertiliser production. Plasma-based gas conversion is an alternative to thermal catalytic processes currently used by the chemical industry, because it is better suited to work for a decentralised and varying energy supply of renewable energy. The efficiency of these plasma-based processes might even be improved by introducing a catalyst. In this contribution, we present our results on the surface composition of an iron foil in direct contact with a nitrogen containing plasma. A low-pressure RF plasma is ignited in N_2/O_2 and N_2/H_2 gas mixtures to study surface processes related to NH_3 and NO_x synthesis, respectively. Infrared reflection absorption spectroscopy probes the surface composition in-situ. This technique yields reflectance spectra that show a fingerprint of the surface groups on the foil. The results in a N_2/O_2 plasma show the formation of N_xO_y species on the surface and O_3 in the gas phase. The N_2/H_2 plasma results show the change in the oxidation state of the iron foil and the incorporation of nitrogen species. The interplay between these species can be used to devise a kinetic model of these surface mechanisms.

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Influence of Nanosecond Pulsed Plasmas in Liquids on Copper Surfaces — •Pia-Victoria Pottkämper, Sven Weller, Neil Unteregge, 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 at an electrode immersed in liquid using high voltages, nanosecond pulses and fast rise times. The plasma and plasma-activated liquid is then used to modify a coppper surface. The plasma causes a dissociation of 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. These species elicit different reactions that lead to the modification of the copper sample. 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 cyclic voltammetry. The creation of uniform copper oxide 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 could be used to re-oxidize or create such catalytic surfaces. It is postulated that by combining an in-situ in-liquid plasma treatment with such a catalysis setup the lifetime of the catalytic surfaces can be extended.