Plasma Physics Division
Fachverband Plasmaphysik (P)

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Overview of Invited Talks and Sessions

(Lecture halls KH 02.016, KH 01.020, KH 01.012, KH 01.013, and KS H C; Poster Redoutensaal)

Plenary Talk of the Plasma Physics Divison

PV IV	Tue	9:00– 9:45	AudiMax	**Basics of plasma technologies: examples for applications and diagnostics** — •Holger Kersten

Invited Talks

P 3.1	Mon	16:15–16:45	KH 02.016	**EMC3-Eirene simulation of neutral source effects on density build-up in the W7-X island divertor** — •Victoria Winters, Felix Reimold, Yuhe Feng, Victoria Haak, Valeria Perseo, Georg Schlisio, The W7-X Team
P 3.2	Mon	16:45–17:15	KH 02.016	**Optimizing divertor heat loads on Wendelstein 7-X us- ing multi-objective optimization** — •Alexander Knieps, Michael Endler, Joachim Geiger, Jiankun Hua, Yunfeng Liang, Dirk Naujoks, Matthias Otte, Vincenzo Sanfratello, Yutong Yang
P 4.1	Mon	16:15–16:45	KH 01.020	**Data-integrated simulations and machine learning analysis of plasma processing of SiO_x/Cu memristive devices** — Tobias Gergs, Rouven Lamprecht, Ole Gronenberg, Sahitya Yarragolla, Hermann Kohlstedt, •Jan Trieschmann
P 4.2	Mon	16:45–17:15	KH 01.020	**A multi-ratio method for determination of the electric field from 2p states in transient argon discharges at atmospheric pressure** — •Zdenek Bonaventura, Zdenek Navratil, Detlef Loffhagen, Markus Becker, Tomas Hoder
P 5.1	Tue	11:00–11:30	KH 02.016	**Nanoparticles prepared by sputter-driven gas aggregation** — •Andrey Shukurov
P 6.1	Tue	11:00–11:30	KH 01.020	**Controlled Exposure of High-Temperature Ceramics in the Scrape-Off Layer of WEST** — •B. De Martino, J. P. Gunn, B. Guillermin, D. Mazon, A. Casner, L. Ciupiński, G. Komorowska
P 7.1	Tue	16:15–16:45	KH 02.016	**Post-puff SOL broadening on MAST-U: evidence for cross-field transport changes** — •Yacopo Damizia, Saskia Mordjick, Nick Walkden, Jack Lovell, Steven Thomas, Ekin Ozturk
P 8.1	Tue	16:15–16:45	KH 01.020	**Near-plasma Chemical Surface Engineering** — •Paula Navascués, Dirk Hegemann
P 9.1	Wed	11:00–11:30	KH 01.020	**Controlling spokes in magnetron sputtering discharges** — •Martin Rudolph
P 10.1	Wed	11:00–11:30	KH 02.016	**Laser fusion activities in Germany - applications in planetary and stellar astrophysics and experiments at high-power laser facilities** — •Dominik Kraus
P 11.1	Wed	13:45–14:15	KH 02.016	**Proxima Fusion - Building stellarators to power the future** — •Jonathan Schilling

P 11.2	Wed	14:15–14:45	KH 02.016	**Equilibrium and stability in Wendelstein 7-X high beta plasmas** — •Henning Thomsen, Christian Brandt, Charlotte Büschel, Edith V. Hausten, Martin C. Kelly, Kian Rahbarnia, Pedro Pons Villalonga, Sara Vaz Mendes, Ksenia Aleynikova, Golo Fuchert, Niklas S. Polei
P 12.1	Wed	13:45–14:15	KH 01.020	**Modelling and analysis of DBDs for thin-film deposition at atmospheric pressure** — •Marjan Stankov, Lars Bröcker, Claus-Peter Klages, Markus M. Becker, Detlef Loffhagen
P 13.1	Wed	16:15–16:45	KH 01.020	**Thin film deposition with dielectric-barrier discharges at atmospheric pressure: open questions and some answers** — •Lars Broecker, Claus-Peter Klages
P 15.1	Thu	11:00–11:30	KH 01.020	**Demonstration of X-ray Diagnostics for Heavy-Ion-Heated Matter** — •Julian Lütgert
P 17.1	Thu	16:15–16:45	KH 02.016	**Energetic proton damage for simulating fusion relevant neutron damage on reactor materials** — •Rahul Rayaprolu
P 18.1	Thu	16:15–16:45	KH 01.020	**High-energy-density and high-pressure states investigated with x-ray imaging at HED-HiBEF** — •Alejandro Laso Garcia
P 21.1	Fri	9:00– 9:30	KH 01.013	**Performance Pitfalls and Design Principles of Retarding Potential Analyzers** — •Thomas Trottenberg
P 21.2	Fri	9:30–10:00	KH 01.013	**Microwave cavity resonance spectroscopy: a novel approach for spatially resolved electron density measurements** — •Jens Oberrath
P 22.1	Fri	9:00– 9:30	KH 01.012	**ERO/ERO2.0 modelling for tokamaks, stellarators and linear plasma devices** — •Juri Romazanov, Henri Kumpulainen, Christoph Baumann, Sebastian Rode, Andriy Tarasenko, Andreas Kirschner, Georgii Timkovskii, Dmitry Matveev, Sebastijan Brezinsek, JET team, W7-X team

Sessions

P 1.1–1.2	Mon	14:45–15:35	KH 02.016	**Magnetic Confinement I**
P 2.1–2.3	Mon	14:45–15:50	KH 01.020	**Astrophysical Plasmas**
P 3.1–3.5	Mon	16:15–18:20	KH 02.016	**Magnetic Confinement II**
P 4.1–4.5	Mon	16:15–18:00	KH 01.020	**Codes and Modeling I**
P 5.1–5.5	Tue	11:00–12:30	KH 02.016	**Low Pressure Plasmas I**
P 6.1–6.5	Tue	11:00–12:30	KH 01.020	**Plasma Wall Interaction I**
P 7.1–7.6	Tue	16:15–18:55	KH 02.016	**Magnetic Confinement III**
P 8.1–8.8	Tue	16:15–18:45	KH 01.020	**Low Pressure Plasmas II**
P 9.1–9.5	Wed	11:00–12:30	KH 01.020	**Low Pressure Plasmas III**
P 10.1–10.5	Wed	11:00–12:30	KH 02.016	**High Energy Density Physics I**
P 11.1–11.5	Wed	13:45–15:50	KH 02.016	**Magnetic Confinement IV**
P 12.1–12.7	Wed	13:45–15:45	KH 01.020	**Atmospheric Pressure Plasmas I**
P 13.1–13.7	Wed	16:15–18:15	KH 01.020	**Atmospheric Pressure Plasmas II**
P 14.1–14.4	Thu	11:00–12:30	KH 02.016	**Magnetic Confinement V**
P 15.1–15.5	Thu	11:00–12:30	KH 01.020	**High Energy Density Physics II**
P 16.1–16.117	Thu	13:45–15:45	Redoutensaal	**Poster Session Plasma Physics**
P 17.1–17.5	Thu	16:15–18:15	KH 02.016	**Plasma Wall Interaction II**
P 18.1–18.4	Thu	16:15–17:30	KH 01.020	**High Energy Density Physics III**
P 19.1–19.3	Thu	17:30–18:15	KH 01.020	**Atmospheric Pressure Plasmas III**
P 20	Thu	18:30–19:30	KS H C	**Members' Assembly**
P 21.1–21.4	Fri	9:00–10:30	KH 01.013	**Codes and Modeling II**
P 22.1–22.5	Fri	9:00–10:30	KH 01.012	**Plasma Wall Interaction III**
P 23.1–23.2	Fri	11:00–11:30	KH 01.012	**Low Pressure Plasmas IV**
P 24.1–24.4	Fri	11:00–12:00	KH 01.013	**Laser Plasmas**
P 25.1–25.2	Fri	11:30–12:00	KH 01.012	**Plasma Wall Interaction IV**

Members' Assembly of the Plasma Physics Division

Thursday 18:30–19:30 KS H C
snacks included

- Reports
- Elections
- Miscellaneous

P 1: Magnetic Confinement I

Time: Monday 14:45–15:35 Location: KH 02.016

P 1.1 Mon 14:45 KH 02.016

Application of TALIF for the characterization of negative hydrogen ion production in ion sources for NBI — •Julian Hörsch, Christian Wimmer, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik

The understanding of the surface conversion process of hydrogen/deuterium atoms or positive ions to negative H^-/D^- ions at a low work-function surface is of special interest for the physics understanding of negative ion sources. The negative ion yield from surface conversion is determined by the work function of the converter surface, the flux of the precursor particles (H/D or H_x^+/D_x^+) on the surface and their energy distribution function (EDF). To investigate the flux, respectively the density of neutral hydrogen atoms and their EDF, a two-photon absorption laser induced fluorescence (TALIF) diagnostic is implemented at the negative ion source BATMAN Upgrade (BUG). TALIF measurements at BUG were previously limited by the low signal-to-noise ratio, which made an accurate EDF resolution that is required to resolve potential two-temperature EDFs impossible. Recent improvements of the TALIF diagnostic allowed for the first time the resolution and confirmation of a two-temperature EDF at BUG. This contribution discusses the results of investigations with the improved setup that enables now more in-depth investigations together with additional diagnostics as for H- density or plasma potentials.

P 1.2 Mon 15:10 KH 02.016

Modeling of the BATMAN Upgrade ion-source using the CsFlow3D code — •Daniele Mussini, Christian Wimmer, Dirk Wünderlich, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik (IPP), Boltzmannstr. 2, 85748 Garching

The ion sources for the neutral beam injectors (NBI) of ITER rely on the production of negative hydrogen ions on a surface featuring a low work function (plasma grid, PG). Cs is continuously evaporated into the source forming a layer on the PG in order to reduce the work function to low values (<2eV). However, the redistribution of Cs inside the source and the interaction of the plasma with the source surfaces lead to a temporally unstable and inhomogeneous Cs layer. The knowledge of Cs fluxes onto and out of the PG becomes thus necessary in order to be able to carry out stable long pulses at ITER's requirements (several hundred s in H, 3600s in D). Yet, the neutral Cs density can be measured, Cs fluxes are experimentally not accessible. The Monte-Carlo Test-Particle code CsFlow3D is used to model the Cs dynamics inside the BATMAN Upgrade ion-source exploiting several inputs such as plasma parameters, electromagnetic field as well as sticking coefficients. For the first time, 3D plasma parameters from a fluid code are implemented in CsFlow3D. Three different synthetic lines of sight for the quantification of neutral Cs are implemented into the code to validate the code with the experiment. This contribution presents preliminary results after the implementation of the new plasma parameters.

P 2: Astrophysical Plasmas

Time: Monday 14:45–15:50 Location: KH 01.020

P 2.1 Mon 14:45 KH 01.020

Astrophysical perpendicular shocks for intermediate Mach numbers — •Valentine Devos, Artem Bohdan, and Frank Jenko — Max Planck Institute for Plasma Physics, Garching bei München

This project investigates the microphysics and structure of collisionless shocks from planetary to astrophysical scales, focusing on the intermediate Mach-number regime. Using fully kinetic Particle-In-Cell simulations, we study the transition from low-Mach instabilities (whistler precursors, modified two-stream modes) to high-Mach regimes dominated by Weibel and Buneman instabilities.

A key objective is to characterise electron kinetics and the conditions enabling efficient acceleration through Diffusive Shock Acceleration (DSA), Shock Surfing (SSA), and Shock Drifting (SDA).

To identify and track instabilities, we compute theoretical whistler anisotropy thresholds from particle distributions, evaluate linear growth rates for whistler and Weibel modes, and compare them with simulation results. We also derive dispersion relations to link the observed wave activity to the underlying kinetic processes.

Overall, this work clarifies how micro-instabilities regulate electron heating and acceleration across Mach numbers, connecting low- and high-Mach collisionless shocks in space and astrophysical plasmas.

P 2.2 Mon 15:10 KH 01.020

Turbulence in Molecular Clouds — •Christian Heppe[1], Alexei Ivlev[2], Frank Jenko[1], and Daniele Villa[1] — [1]Max-Planck-Institute for Plasmaphysics, Garching — [2]Max-Planck-Institute for Extraterrestrial Physics, Garching

The bulk mass of gas in the interstellar medium (ISM) is located in so called Molecular Clouds (MCs), which are dense and cold environments also known as nurseries of stars. Due to highly energetic Cosmic Rays (CRs) these dense gases are still weakly ionized even deep into their centers. We investigate the effect of this partial ionization by means of 3D two-fluid MHD turbulence simulations in which we model the neutral and ionized gas coupled by a collisional drag term explicitly. As the coupling is collisional 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 direct impacts on linear MHD waves and consequently on the turbulent cascade in these systems. We investigate the impact of the decoupling on the energy transfer over scales in the turbulent cascade, attempt to generalize the characteristics of turbulence in these weakly ionized environments and present the implications for star formation and CR transport.

P 2.3 Mon 15:35 KH 01.020

Particle acceleration at oblique high-Mach-Number shocks propagating in a turbulent medium — •Eloise Moore[1], Karol Fulat[2], Mahmoud Al-Awashra[3], 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]Deutsches Elektronen-Synchrotron DESY, Platanenallee 6, 15738 Zeuthen, Germany

Astrophysical collisionless shocks are efficient particle accelerators that require some pre-acceleration mechanism in order for electrons to participate in diffusive shock 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 perform novel simulations of oblique non-relativistic high-Mach-number shocks propagating into an upstream containing pre-existing decaying turbulence. Such turbulence consists of perturbations in the magnetic field varying in amplitude, and a self-consistent current driven by the ions to limit the phase speed to low levels. We investigate the role of turbulence in modifying the shock structure, plasma instabilities and ultimately particle acceleration, by comparing our results to simulations with a homogeneous upstream.

P 3: Magnetic Confinement II

Time: Monday 16:15–18:20 Location: KH 02.016

Invited Talk P 3.1 Mon 16:15 KH 02.016

EMC3-Eirene simulation of neutral source effects on density build-up in the W7-X island divertor — •Victoria Winters[1,2], Felix Reimold[2], Yuhe Feng[2], Victoria Haak[2], Valeria Perseo[2], Georg Schlisio[2], and The W7-X Team[2] — [1]Universität Greifswald, Institut für Physik, Greifswald D-17489 Germany — [2]Max-Planck-Institut für Plasmaphysik, Greifswald D-17491 Germany

Achieving high plasma density near the divertor target in magnetically confined fusion devices is crucial for efficient heat and particle exhaust. The W7-X stellarator is qualifying the island divertor as a potential exhaust solution for a future stellarator reactor. Simplified models of the island divertor predict that increasing the internal island field line pitch (Θ) should have a beneficial effect on density build-up at the divertor. This hypothesis was tested numerically using the EMC3-Eirene code for three different W7-X magnetic configurations with increasing Θ (low iota, standard, and high iota). While the low iota configuration showed the poorest density build-up, as expected, no improvement in density build-up was observed between standard and high iota, even with the factor of 2 increase in Θ. This deviation from predicted behavior was attributed to the proximity of the X-point to a vertical divertor plate, introducing a limiter-like component. Removing the vertical target from the simulation recovered the expected scaling from the simplified models. This work underscores the importance of the island's neutral screening efficiency on density build-up. Potential consequences, such as inducing X-point radiators, will be discussed.

Invited Talk P 3.2 Mon 16:45 KH 02.016

Optimizing divertor heat loads on Wendelstein 7-X us- ing multi-objective optimization — •Alexander Knieps[1], Michael Endler[2], Joachim Geiger[2], Jiankun Hua[3], Yunfeng Liang[1,3], Dirk Naujoks[2], Matthias Otte[2], Vincenzo Sanfratello[1], and Yutong Yang[1] — [1]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management 1 - Plasmaphysik, Jülich, 52425, Germany — [2]Max-Planck-Institut für Plasmaphysik, Greifswald, 17491, Germany — [3]Huazhong University of Science and Technology, Wuhan, 430074, People's Republic of China

Modular stellarators such as Wendelstein 7-X offer considerable flexibility in their magnetic configuration space. Due to the many possible choices in configuration, it becomes possible to not optimize just for one target metric, but to combine multiple metrics into one study. Specialized methods exists for such multi-objective studies which can autonomously explore the Pareto front of different possible tradeoffs between objectives. In this talk, we show how to leverage multi-objective methods to explore configurations with reduced heat loads on plasma-facing components. Particularly, we explore how much heat loads can overall be reduced through tuning of the main coil currents, and then explore how much further reduction is possible by tolerating increased heat loads in other areas.

P 3.3 Mon 17:15 KH 02.016

Fast divertor plasma dynamics at Wendelstein 7-X — •Sebastian Hörmann[1,2], M. Griener[1], G. Birkenmeier[1,2], F. Reimold[3], M. Krychowiak[3], D. Gradic[3], F.B.T. Siddiki[3], C. Killer[3], A. von Stechow[3], U. Stroth[1,2], the ASDEX Upgrade Team[1], and the W7-X Team[3] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — [3]Max-Planck-Institut für Plasmaphysik, Greifswald 17491, Germany

Understanding and quantifying particle and energy transport at the plasma boundary, as well as detachment and its stability in the divertor region, is crucial for magnetic confinement fusion, as this determines both plasma performance and target loads. For this reason, several thermal helium beam systems, have been installed in the divertors of Wendelstein 7-X. These diagnostics allow the investigation of edge transport processes, such as modes and filaments, with high spatiotemporal resolution of 10 kHz in both n_e and T_e and up to 1 MHz in line intensity. The contribution will present the diagnostic implementation, validation and its possibilities. Furthermore, the talk will focus on the influence of large plasma events on divertor plasma and detachment in the island divertor regions, causing density and temperature changes in the island of up to 50% in a time range in the order of 0.1 ms to 10 ms. In combination with other diagnostics, as well as for different magnetic configurations and machine parameters, the nature of these events will be discussed, and the influence on the wall will be determined.

P 3.4 Mon 17:40 KH 02.016

Resilience of stellarator plasmas against thermal quenches induced by tungsten TESPEL injection — •Hjördis Bouvain[1], Andreas Dinklage[1], Naoki Tamura[1], Isabel Garcia-Cortes[2], Tomas Gonda[3], Katsumi Ida[4], Hiroe Igami[4], Andreas Langenberg[1], Hiroshi Kasahara[4], Kieran McCarthy[3], Daniel Medina-Roque[3], Keisuke Mukai[4], Yoshiro Narushima[4], Kian Rahbarnia[1], Chihiro Suzuki[4], Yuki Takemura[4], Tokihiko Tokuzawa[4], Thomas Wegner[1], Mikiro Yoshinuma[4], The W7-X Team[1], and The LHD Experiment Team[4] — [1]Max-Planck-Institute for Plasma Physics, Greifswald, Germany — [2]Laboratorio Nacional de Fusión, CIEMAT, Madrid, Spain — [3]Auburn University, Auburn, USA — [4]National Institute for Fusion Science, Toki, Japan

Plasma-terminating events, e.g. induced by the sudden influx of high-Z impurities due to mechanical failures, threaten the safe operation of large-scale fusion devices. Unlike tokamaks, in stellarators such an event cannot lead to a current disruption, but thermal quenches can still occur. To quantify the potential damage to plasma-facing components caused by the sudden energy loss, large amounts of tungsten were injected via TESPEL in W7-X and LHD plasmas. It was found that beyond a threshold of tungsten atoms and plasma parameters, impurity induced radiative losses along propagating cold fronts may induce termination. Close to this threshold, an intrinsic resilience to the perturbations was observed: despite energy losses up to ~90%, the plasmas recovered without external intervention. This underscores the improved robustness of stellarator plasmas to strong perturbations.

P 3.5 Mon 18:05 KH 02.016

Demonstrating the capabilities of the Electron Cyclotron Absorption (ECA) Diagnostic at W7-X in a case study. — •Jonas Zimmermann, Torsten Stange, Sergiy Ponomarenko, Heinrich Laqua, and W7-X Team — Institut für Plasmaphysik, Greifswald, Deutschland

Electron cyclotron resonance heating (ECRH) is the primary heating system of the Wendelstein 7-X (W7-X) device and a major component of the heating mix of most next-generation magnetically confined plasma experiments. Ensuring high heating efficiency is important for machine safety, experimental success, and cost-effectiveness. The propagation and absorption of a heating beam depend on plasma parameters as well as the coupling of the beam to the X- or O-mode at the plasma edge. The electron cyclotron absorption (ECA) diagnostic at W7-X measures ECRH beam shine-through, providing a first-pass heating efficiency measure. During X-mode operation, where full absorption is expected, shine-through power of a few percent was detected. A detector channel was upgraded to include a motorized polarization rotator. With this, the unabsorbed power could be attributed to partial O-mode coupling. Full absorption was finally achieved using a systematic optimization procedure for the coupled polarization. It was possible to measure the magnetic shear induced polarization rotation of the ECRH beam. Comparison of this measurement with the expected change in rotational transform (iota) along the beam path suggests the effective ECRH coupling point lies radially outward of the previously assumed last closed flux surface.

P 4: Codes and Modeling I

Time: Monday 16:15–18:00 Location: KH 01.020

Invited Talk P 4.1 Mon 16:15 KH 01.020

Data-integrated simulations and machine learning analysis of plasma processing of SiO_x/Cu memristive devices — Tobias Gergs, Rouven Lamprecht, Ole Gronenberg, Sahitya Yarragolla, Hermann Kohlstedt, and •Jan Trieschmann — Kiel University, Kaiserstraße 2, 24143 Kiel, Germany

The characteristics of SiO_x/Cu memristive devices [1] deposited by reactive magnetron sputtering are highly sensitive to the obtained material properties, requiring fine control over local physical conditions during plasma deposition. The latter are investigated through machine learning (ML) surrogate modeling, data-integrated physical simulations, and a data-driven analysis of corresponding wafer-level measurements. An ML surrogate model of the reactive plasma-surface interaction during Ar and O_2 ion impingement on SiO_x is integrated in an axially symmetric 2D particle-in-cell/Monte Carlo collision simulation with dynamic surface conditions. It provides a comprehensive prediction of discharge and surface conditions, e.g., fluxes, energy. Insights from this simulation are correlated with a data-driven classification of measured device-level electrical characteristics. A statistical analysis over a wafer is applied to over 50,000 devices to identify how processing conditions influence device behavior. The analysis reveals distinct device types linked to the local physical conditions during processing, highlighting the importance of plasma process control in determining functional outcomes in nanoscale electronic devices.

[1] Lamprecht et al., Adv. Eng. Mater. 27, 2401824 (2025)

German Research Foundation – Project-ID 434434223 (SFB 1461)

Invited Talk P 4.2 Mon 16:45 KH 01.020

A multi-ratio method for determination of the electric field from 2p states in transient argon discharges at atmospheric pressure — •Zdenek Bonaventura[1], Zdenek Navratil[1], Detlef Loffhagen[2], Markus Becker[2], and Tomas Hoder[1,2] — [1]Department of Plasma Physics And Technology, Masaryk University, Brno, Czech Republic — [2]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany

We present a theoretical analysis demonstrating that a multi-ratio optical emission spectroscopy (OES) approach can, in principle, be applied to determine the instantaneous mean electron energy and reduced electric field (E/N) in transient low-temperature argon discharges at atmospheric pressure, while also allowing recovery of the relative densities of the $\mathtt{Ar}_{1s5..2}$ states. The method is derived from an advanced reaction kinetic model for argon accounting for 23 species and 409 processes by means of a dominant-balance analysis used to identify negligible terms and define explicit validity conditions in terms of reduced electric field, pressure, and relative excited-state densities for simplified formulation. By combining simplified balance equations for pairs of $\mathtt{Ar}_{2p10...2}$ states, the dependence on the unknown electron density is eliminated, and densities of the $\mathtt{Ar}_{2p10...2}$ states appear only in mutual ratios. The influence of metastable and resonant states is incorporated through specific terms, whose impact on the method sensitivity is quantified.

P 4.3 Mon 17:15 KH 01.020

Modeling the Influence of Dielectric Materials on Plasma Characteristics in Capacitively Coupled Plasma Systems — •Mine Fakili, Neslihan Sahin, and Murat Tanisli — Department of Physics, Division of High Energy and Plasma Physics, Eskisehir Technical University, Eskişehir, Türkiye

In this study, the spatial distributions of plasma parameters in a 13.56 MHz single-frequency capacitively coupled plasma system were investigated with a focus on the effects of a dielectric material. The Poisson equation, together with the electron and ion continuity equations and the electron energy equation, were solved simultaneously. The system of equations was discretized using the finite difference method and iteratively solved employing the Newton*Raphson technique. The model considers the effect of the dielectric material placed between the electrodes on the electric field, charge density, plasma potential and electron temperature. Numerical results demonstrate that the dielectric material causes to significant variations in plasma density, potential profiles, and electron energy distribution. The model provides highly accurate results in the design and optimization of industrial plasma processes, making a significant contribution to fields such as semiconductor manufacturing and thin film deposition.

P 4.4 Mon 17:30 KH 01.020

Comprehensive comparison of relativistic particle pushers for Particle-in-Cell codes — •Holger Schmitz — Central Laser Facility, STFC Rutherford-Appleton Laboratory, Didcot OX11 0QX, United Kingdom

Computational investigations of kinetic processes in plasma physics routinely make use of the Particle-in-Cell (PIC) simulation technique. One of the core components in PIC codes is the particle pusher, which integrates the trajectories of the simulation particles in the electromagnetic fields. Traditionally, the Boris scheme has been chosen as the default integration scheme due to its simplicity and long-term stability. Over the last couple of decades, a number of new integration schemes have been proposed that attempt to address some shortcomings of the Boris pusher in the relativistic regime. However, these schemes are typically evaluated only in the scenarios for which they were originally designed, and no comprehensive, systematic comparison exists to date. In this work we present a comparison between several relativistic particle-integration schemes across a wide variety of test cases that probe different physical regimes and numerical challenges. An important class of these pushers can be generalised to provide higher order schemes. Some tests for the fourth order generalisations are also presented. The goal is to provide guidance for developers and users of PIC codes for the choice of particle pusher in relativistic simulations.

P 4.5 Mon 17:45 KH 01.020

CFD Simulation of Porous Wick Two-Phase Flow in Liquid Metal Heat Pipe for a Divertor Plasma-Facing Component — •Menno Bakker[1], Max Voncken[2], Alexis Terra[1], Seyedmohammad Vafaei[1], Yiran Mao[1], Jan Willem Coenen[1], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasmaphysics (IFN-1), Jülich 52425, Germany — [2]Eindhoven University of Technology, Power&Flow group, Department of Mechanical Engineering, Groene Loper 3, 5612 AE Eindhoven, Netherlands

The divertor plasma-facing components (PFCs) in fusion applications must withstand high heat loads that can reach up to 20 MW/m2 in steady state loading conditions. These extreme heat loads must be efficiently exhausted by suitable heat sink systems. In this work, a PFC based on liquid metal heat pipes (LMHP) is proposed (PFC-LMHP). Analytical and numerical models are developed to provide an initial assessment of the heat transfer rate of such PFC-LMHPs. Furthermore, CFD simulations are used to study the two-phase flow within the porous wick. The impact of porosity and the volume fraction of fluid on the liquid mass flow from the condenser to the evaporator of the LMHP is investigated. Preliminary analysis is initiated on commercially available LMHP to validate the models.

P 5: Low Pressure Plasmas I

Time: Tuesday 11:00–12:30 Location: KH 02.016

Invited Talk P 5.1 Tue 11:00 KH 02.016

Nanoparticles prepared by sputter-driven gas aggregation —
•Andrey Shukurov — Charles University, Faculty of Mathematics and Physics, Department of Macromolecular Physics, Prague, Czech Republic

Sputter-driven gas aggregation, first pioneered by the Freiburg group in the 1990s, has become a well-established and versatile method for synthesizing metal nanoparticles (NPs) through the condensation of atomic metal vapors in a cold inert gas. While planar magnetrons have traditionally been used for this process, the gradual evolution of their erosion tracks imposes limitations on process stability and controllability. Cylindrical magnetrons offer an effective way to overcome these constraints and significantly extend target lifetime. However, despite their widespread use in thin-film deposition, cylindrical magnetrons have not yet been adapted for gas-phase nanoparticle synthesis. In this contribution, we demonstrate the use of dc planar and cylindrical magnetrons for the gas-phase production of metal NPs, including hybrid bimetal nanoparticles with complex morphologies such as core@shell and Janus structures. We further present reactive sputtering in Ar/N2 mixtures, which enables the synthesis of metal nitride (MeN) nanoparticles, where Me = Ti, Zr, Hf, Cu, or Fe. By systematically varying gas composition, pressure, and discharge current, we obtain nanoparticles with tunable size distributions and chemical compositions. The resulting materials show strong potential for applications in refractory plasmonics, solar-light harvesting, and electrochemical CO2 reduction. Representative results will be presented and discussed.

P 5.2 Tue 11:30 KH 02.016

Influence of discharge parameters on the synthesis and properties of nanoparticles in reactive plasmas —
•Alexander Schmitz, Andreas Petersen, and Franko Greiner — Institute of Experimental and Applied Physics, Kiel University, Germany

Reactive plasma can be an attractive source for sub-micron particles of several 100 nm size. Such particles are be a candidate for pharmaceutical carriers, catalytic or functional material. The influence of the discharge parameters on the accretion growth process and the nanoparticle properties especially still pose open questions. Their precise determination is not only of importance for fundamental research on particle dynamics and electron depletion processes, but also for potential technical applications.

Modern *in-situ* diagnostics based on light scattering like full-Stokes imaging polarimetry offer valuable insight into the particle characteristics. It is a door opener for accessible computer vision and precise scattering modeling to access particle properties. We present a first study on the tunability of nanoparticle properties with regard to the particle size distributions, complex refractive index and their spatial dynamics.

P 5.3 Tue 11:45 KH 02.016

Calorimetric and electrostatic probe diagnostics of a gas aggregation source plasma —
•Caroline Adam[1], Viktor Schneider[1], Jessica Niemann[1], Daniil Nikitin[2], Jan Hanuš[2], Ronaldo Katuta[2], Iqra Wahid[2], Veronika Červenková[2], Andrey Shukurov[2], Hynek Biederman[2], and Holger Kersten[1,3] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Faculty of Mathematics and Physics, Department of Macromolecular Physics, Charles University, Prague, Czech Republic — [3]Kiel Nano, Surface and Interface Science KiNSIS, Kiel University, Kiel, Germany

Gas aggregation cluster sources (GAS) have been emerging as a key technology for the production of clusters and nanoparticles (NPs) of precise size and composition. The resulting NP properties are significantly affected by the thermal balance during their growth in the aggregation zone. In this study, the characteristics of a novel controllable GAS setup are investigated, using a post (cylindrical) magnetron with a rotating magnetic circuit [1] equipped with a copper target in Ar and/or N2 atmosphere, respectively. Energy fluxes are quantified by calorimetric measurements using passive thermal probes (PTP), while the plasma parameters are assessed by Langmuir probes. These quantities are critical to develop a comprehensive understanding of the correlation between (external) process parameters (e.g., current, voltage, continuous or pulsing, gas pressure) and (internal) plasma parameters and their correlation with NP growth, transport and microstructure.
[1] D. Nikitin et al., Plasma Processes Polym. 18 (2021).

P 5.4 Tue 12:00 KH 02.016

Non-adiabatic electron energization mechanism in plasmas with a magnetron configuration —
•Lukas Vogelhuber[1], Kevin Köhn[1], Dennis Krüger[1], Jens Kallähn[1], Yulia Sharova[1], Liang Xu[2], Ralf Peter Brinkmann[1], and Denis Eremin[1] — [1]Institute of Theoretical Electrical Engineering, Ruhr University Bochum, Universitätsstrasse 150, D-44801 Bochum, Germany — [2]School of Physical Science and Technology, Soochow University, Suzhou 215006, China

Partially magnetized plasma discharges in $E \times B$ configurations are versatile tools, with applications ranging from Hall-effect thrusters for space propulsion to high-power impulse magnetron sputtering (HiPIMS) for thin-film deposition. In these configurations, structures known as spokes can form as potential humps moving in the $\pm E \times B$ direction, and influence electron dynamics. Electrons confined in the racetrack region are typically considered to be magnetized, with their magnetic moment serving as an indicator of the degree of confinement; if the magnetic moment is conserved along the trajectory, the energization is adiabatic. However, various processes can disrupt this conservation, including collisions, field interactions, and resonant particle motion, leading to non-adiabatic energy gain by electrons. In this work, this phenomenon is studied to gain a deeper understanding of the collisionless energization of electrons at potential humps in magnetized plasmas.

P 5.5 Tue 12:15 KH 02.016

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 or shocks). The investigation of this interaction has been a topic of research for long times.

Interactions of a dusty plasma under microgravity disturbed by fast particle agglomerates were observed in experiments 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 can lead to dust-free cavities in the region of the agglomerates with varying shape and size dependent on the velocity of the agglomerate and its moving direction in relation to the plane of the illuminating 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 motion during the interaction with the fast agglomerates in three dimensions.

In this contribution observations of such interactions will be shown focusing on the velocities and density of the surrounding dust particles as well as the spatiotemporal characteristics of the the dust-free cavity.

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

P 6: Plasma Wall Interaction I

Time: Tuesday 11:00–12:30 Location: KH 01.020

Invited Talk P 6.1 Tue 11:00 KH 01.020

Controlled Exposure of High-Temperature Ceramics in the Scrape-Off Layer of WEST — •B. De Martino[1], J. P. Gunn[1], B. Guillermin[1], D. Mazon[1], A. Casner[2], L. Ciupiński[3], and G. Komorowska[3] — [1]CEA, IRFM, F-13108 St-Paul-Lez-Durance, France — [2]Université de Bordeaux, CNRS, CEA, CELIA (Centre Lasers Intenses et Applications), UMR 5107, F-33405 Talence, France — [3]Warsaw University of Technology, Faculty of Materials Science and Engineering, Woloska 141, 02-507 Warsaw, POLAND

The WEST tokamak Scrape-Off Layer (SOL) is equipped with mobile Langmuir probes that can be fitted with sample holders, enabling controlled exposure of materials to extreme heat ($10^6 - 10^8$ W/m^2) and ion fluxes ($10^{22} - 10^{24}$ m^{-1}s^{-1}). Two dedicated experiments were carried out to investigate the thermal response and ablation dynamics of High-Temperature Ceramics, using hydraulically and magnetically driven devices that target respectively the lower and upper ends of the accessible flux range. With the magnetically driven device, installed in the lower divertor, ablation of a SiC sample was achieved under strike-point fluxes. Strong Si emission lines are detected in VUV and visible spectroscopy immediately after exposure, indicating high sublimation rates. Divertor upper-view IR imaging shows saturation of the sample temperature, consistent with a phase change. The average parallel heat flux is estimated at 45 MW/m^2, with plasma conditions fully characterised by in-situ diagnostics. Post-mortem analyses enable the characterisation of the damage undergone by the exposed samples.

The full authors list will be presented in the talk.

P 6.2 Tue 11:30 KH 01.020

Experimental Investigations Of Hydrogen Isotope Interaction In Laboratory Boron Coatings — •Eduard Warkentin[1,2], Anne Houben[1], Marcin Rasinski[1], Sören Möller[3], Hans Rudolf Koslowski[1], Timo Dittmar[1], Marc Sackers[1], Arkadi Kreter[1], Tom Wauters[4], 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 — [3]Forschungszentrum Jülich GmbH, Institute of Energy Materials and Devices, Materials Synthesis and Processing (IMD-2), 52425 Jülich, Germany — [4]ITER Organization, Route de Vinon-sur-Verdon, CS 90 046 13067, St. Paul Lez Durance Cedex, France

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 amorphous boron layer, which is applied via glow discharge boronization during the regular wall conditioning phase, can reintroduce impurity gettering and a more efficient plasma operation can be obtained. In order to investigate hydrogen retention and permeation of mixed boron coatings, B:D layers were fabricated by magnetron sputter deposition on W and steel substrates. After characterization, the gas driven deuterium permeation flux was measuered and the layer permeability was obtained. B:D coated samples were exposed to different deuterium plasma in order to investigate retention via nuclear reaction analysis and thermal desorption spectroscopy.

P 6.3 Tue 11:45 KH 01.020

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

Magnetic confinement fusion power plants need for sustaining operation an efficient plasma exhaust. After heating the plasma, removal of fusion products is necessary or a steady-state can't be maintained. Even for today's experiments, density control via particle removal is valuable. Inside a device like Wendelstein 7-X (W7-X), the ionized particles of the plasma are confined by the magnetic field. An exhaust can only be accomplished after their neutralization. Therefore, in a divertor system, diverted field lines carry plasma away from the confining toroid onto target plates. Such a diversion can be achieved through X-points, -lines, or -loops. At W7-X, X-loops are created through a resonance on rational rotational transform surfaces, resulting in magnetic islands. The field lines of these islands, especially their separatrix, are intersected by the divertor target plates. At the intersection the ionized particles neutralize. Strike lines, high-intensity regions, emerge on the target surface. Here the divertor needs to sustain the incoming plasma heat flux. Unexpected changes in the flux topology may lead to a reduction in the exhaust efficiency or a risk of the divertor's integrity. To better understand and predict the strike lines behavior a set of experiment programs were evaluated. A full characterization of the strike lines dimensions and magnitudes was accomplished.

P 6.4 Tue 12:00 KH 01.020

Vision transformer based model regression for plasma exposed surface structures — •Torben Schmitz[1,2], Dirk Reiser[1], Jose Ignacio Robledo[3], and Sebastijan Brezinsek[1,2] — [1]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management Plasma Physics, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]Faculty of Mathematics and Natural Sciences, Heinrich Heine University Düsseldorf, 40225 Düsseldorf, Germany — [3]Forschungszentrum Jülich GmbH, Jülich Supercomputing Centre, 52425 Jülich, Germany

Exposing a surface to an ion beam or plasma leads to erosion and the development of surface structures on the nanoscale. Such nanostructures have been observed on tungsten samples exposed to plasma in magnetic confinement devices. A convenient description of the evolution of these structures is possible using a Kuramoto-Sivashinsky (KS) type model whose parameters we aim to infer for given experimental data. There exist previous approaches to this problem, one training a regression model on the Fourier transform of the surfaces, another using pretrained convolutional neural networks, finetuned on the regression task. We propose a different approach using the vision-transformer architecture and including additional input features to the training process. We show that training the model on our KS dataset leads to good predictive performance. We present details of the method and results on our synthetic (simulated) dataset. The results show the capability of our architecture to understand and extract information from fusion relevant surface structures.

P 6.5 Tue 12:15 KH 01.020

Investigation on the Limitations of Liquid Metal Heat Pipes for Fusion Applications by Thermal Resistance Modeling — •Max Voncken[1,2], Menno Bakker[2], Seyedmohammad Vafaei[2], Yiran Mao[2], Alexis Terra[2], Jan Willem Coenen[2], and Christian Linsmeier[2] — [1]Eindhoven University of Technology, Power&Flow Group, Department of Mechanical Engineering, Groene Loper 3, 5612 AE Eindhoven, Netherlands. — [2]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics (IFN-1), Jülich 52425, Germany

Liquid metal heat pipes (LMHPs) can manage extreme heat fluxes with exceptionally high thermal conductivity. This capability makes them a promising alternative to conventional monoblocks for cooling plasma-facing components (PFCs) in the divertor region of magnetic confinement fusion devices. In this study, the thermal limitations of sodium and lithium as candidate working fluids and viable design parameter ranges for the envelope, such as diameter, length, and wall thickness, are identified. This has been achieved by a relatively simplified model of thermal resistance, employed as a fast pre-design tool prior to detailed CFD simulations. The developed model is also used to evaluate the thermal performance of a commercially available LMHP, and it is validated against the experiments.

P 7: Magnetic Confinement III

Time: Tuesday 16:15–18:55 Location: KH 02.016

Invited Talk P 7.1 Tue 16:15 KH 02.016

Post-puff SOL broadening on MAST-U: evidence for cross-field transport changes — •Yacopo Damizia[1], Saskia Mordjick[1], Nick Walkden[2], Jack Lovell[3], Steven Thomas[4], and Ekin Ozturk[1] — [1]William & Mary, Williamsburg, VA, USA — [2]UKAEA, Culham Campus, Abingdon, Oxfordshire, OX14 3DB, UK — [3]Oak Ridge National Laboratory, Oak Ridge, TN, USA — [4]MIT Plasma Science and Fusion Center, Cambridge, MA, USA

We test whether density shoulder formation and evolution in the MAST-U scrape-off layer are governed by parallel draining or cross-field transport. Two L-mode discharges with similar parameters each receive a 50 ms deuterium puff and are measured with Thomson scattering, Dα and Langmuir probes. In both cases the divertor stays attached/high reciclyng while an upstream shoulder forms, but its post-puff decay is much slower in the lower upstream collisionality shot, indicating that shoulder persistence is set by modified cross-field transport rather than parallel draining.

P 7.2 Tue 16:45 KH 02.016

Gyrokinetic studies in pedestal plasmas — •facundo sheffield[1], tobias goerler[1], gabriele merlo[1], lidija radovanovic[2], felix wilms[1], elisabeth wolfrum[1], clemente angioni[1], frank jenko[1], and the asdex upgrade team[3] — [1]Max Planck Institute for Plasma Physics, Bolzmannstraße 2, Garching, Germany — [2]Institute of Applied Physics, TU Wien, Fusion@ÖAW, Wiedner Hauptstr. 8-10, Vienna, Austria — [3]See author list of H. Zohm et al, https://doi.org/10.1088/1741-4326/ad249d

The pedestal region in tokamak plasmas plays a critical role in determining overall confinement and performance. However, given the steep pressure gradients, high shaping and the interplay between several transport channels, the rich physics of the pedestal remains to be fully understood.

We therefore aim to shed light into key aspects of pedestal physics with high fidelity gyrokinetic simulations using the GENE and GENE-X codes. First we showcase the implementation and importance of parallel magnetic fluctuations in global pedestal simulations. Then, we study electron-scale pedestal instabilities propagating in the ion diamagnetic direction and show how they are still electron temperature gradient modes despite their unusual drift direction. Finally, we focus on the effects of shaping on the pedestal via changes in turbulent transport at multiple scales. Overall, our work advances the understanding of pedestal microinstabilities, clarifies the role of pedestal shape in turbulent transport, and showcases the relevance of parallel magnetic fluctuations in these systems.

P 7.3 Tue 17:10 KH 02.016

Reduced Models for Turbulent Transport in W7-X — •Don Lawrence Carl Agapito Fernando[1], Ionut-Gabriel Farcaş[2], Gabriele Merlo[1], Alejandro Bañón Navarro[1], and Frank Jenko[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Virginia Tech, Blacksburg, Virginia, USA

High-fidelity, first-principles simulations have become indispensable for understanding the complex turbulence dynamics in fusion plasmas. However, their high computational cost limits their use for rapid profile prediction, parameter scans, and optimization studies. This motivates the development of reduced models with robust predictive accuracy.

Here, we present reduced models for turbulent heat and particle fluxes in W7-X. These models are constructed from a database of adiabatic-ion electron-scale and kinetic-electron ion-scale simulations generated with the GENE-KNOSOS-Tango framework, supplemented by a number of simulations driven by a structure-exploiting sparse grid approach. An active-learning algorithm was used to identify the most informative data points for model construction and regression.

The resulting models depend on key plasma parameters such as normalized temperature gradients, the ratio of temperature to density gradients, and the E × B shear. Model predictions show good agreement with reference gyrokinetic fluxes within the training domain and at additional test positions. We also investigate strategies to generalize the models across arbitrary radial positions. These turbulent transport models for W7-X paves the way for faster profile prediction and reduces the computational effort of simulation-heavy workflows.

5 min break

P 7.4 Tue 17:40 KH 02.016

GENE-X edge/SOL gyrokinetic turbulence simulations with fluid neutrals — •Sabine Ogier-Collin, Philipp Ulbl, Wladimir Zholobenko, and Frank Jenko — Max-Planck Institute for Plasma Physics, Garching bei München, Germany.

In magnetic confinement fusion devices, the plasma edge and scrape-off layer (SOL) is not fully ionised. Neutral particles, by interacting with the plasma, affect radial profiles, gradient-driven instabilities, particle transport across the separatrix, and blob dynamics in the SOL. Understanding these processes is critical for optimising reactor core performance while ensuring efficient heat and particle exhaust.

We present the neutrals extension of GENE-X, a first-principles gyrokinetic turbulence code for edge and SOL transport in realistic magnetic geometries. This extension couples GENE-X's continuum full-f electromagnetic, collisional plasma model to a neutrals density evolution equation, as a first step towards a comprehensive neutrals fluid description. Charge-exchange reactions are modelled using a diffusion equation, and specially tailored conservative Krook operators have been derived for ionisation, recombination, and associated radiation.

Relaxation studies of electrons, deuterium ions, and deuterium atoms enable isolation of the effect of each coupling term on equilibration dynamics and plasma velocity-space structure. We also present first turbulence simulations in diverted geometry, targeting validation against the TCV-X21 dataset. This development enables gyrokinetic-level studies of how neutrals influence plasma turbulence in reactor-relevant regimes.

P 7.5 Tue 18:05 KH 02.016

Microtearing mode turbulence and its role in high-density-gradient plasmas in Wendelstein 7-X — •Hugo Isaac Cu-Castillo[1], Alejandro Bañón Navarro[1], Gabriele Merlo[1], Felix Reimold[2], Thilo Romba[2], Oliver Ford[2], Sebastian Bannmann[2], Markus Wappl[2], Joachim Geiger[2], Lila Vanó[2], Alessandro Zocco[2], and Frank Jenko[1] for the w7-x team-Collaboration — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

Following the successful optimization of the stellarator Wendelstein 7-X (W7-X) to reduce neoclassical transport, microturbulence prevails as the primary transport mechanism limiting its plasma confinement.

Using the gyrokinetic code GENE, we demonstrate that Microtearing Modes (MTMs) dominate turbulent transport in a W7-X experimental scenario with high a/L_{n_e}, corresponding to a plasma heated purely by only Neutral Beam Injection. The appearance of MTMs is attributed to the absence of competing instabilities under these plasma conditions and the stabilizing influence of the nearly max-J configuration of W7-X. Additionally, moderate collisionality and low magnetic shear further enable the appearance of MTM. Our simulations show that, when MTM turbulence dominates, they reproduce additional experimental signatures observed in W7-X plasmas with $a/L_{n_e} > 1$: (i) the turbulent heat flux is unaffected by the density gradient, and (ii) the electron heat channel by far exceeds the ion channel.

P 7.6 Tue 18:30 KH 02.016

Geometry-dependent energetic bounds on gyrokinetic instabilities — •Paul Costello and Gabriel Plunk — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald, Germany

Outward turbulent transport of heat and particles largely dictates the necessary size of a viable tokamak or stellarator power plant. This turbulence is initiated by micro-scale plasma instabilities that are driven by the radial gradients of temperature and density in the plasma. Gyrokinetic theory forms the basis of our understanding of these instabilities, and gyrokinetic simulations are a relied-upon, albeit expensive, tool for computing their growth rates. Here, we present a complementary approach to understanding linear instabilities: constructing energetic upper bounds on instability growth. These upper bounds are computed via a variational principle by seeking perturbations that maximize the extraction of free energy from the plasma gradients. In many cases, these upper bounds are governed by a low-dimensional system of equations, while still capturing the dependence of the linear growth rate on key parameters. We demonstrate methods to include magnetic geometry into the upper bound analysis through two main pieces of work. Firstly, we consider the effect of including trapped electrons in the analysis, finding a new stabilising mechanism possessed by quasi-isodynamic stellarators. Secondly, we present a method by which the upper bound can systematically be made tighter to the linear growth rate. We highlight the potential applicability of this approach to the optimisation of stellarators to reduce turbulent transport.

P 8: Low Pressure Plasmas II

Time: Tuesday 16:15–18:45 Location: KH 01.020

Invited Talk P 8.1 Tue 16:15 KH 01.020

Near-plasma Chemical Surface Engineering — •Paula Navascués and Dirk Hegemann — Empa, St. Gallen, Switzerland

The possibility of avoiding ion bombardment during plasma surface engineering, while simultaneously benefiting from the contribution of reactive plasma species, is a targeted objective for materials processing. In this context, we have recently developed a new experimental strategy called near-plasma chemical (NPC) surface engineering. By introducing a polymeric mesh between the substrate and the plasma, close to the plasma-sheath boundary, charged particles are attracted to the mesh. As a result, unlike direct plasma exposure, high-energy deposition at the sample surface can be mitigated without modifying the plasma properties. The beneficial impacts of NPC have been demonstrated for plasma activation of polymers to enhance wettability and durability, as well as for the deposition of thin films via plasma polymerization. Furthermore, NPC can prevent dust deposition onto the samples, even in highly dusty plasmas, resulting in smooth surfaces at the nanoscale. In this talk, the main aspects explored by our group and our collaborators for Near-plasma Chemical Surface Engineering will be presented, as well as different applications of surface modification and thin film deposition using this approach.

P 8.2 Tue 16:45 KH 01.020

Systematic investigations of static and dynamic effects determining the performance of the ELISE negative ion source in H and D — •Joey Rubin, Dirk Wünderlich, and Ursel Fantz — Max Planck Institute for Plasma Physics - Boltzmannstrasse 2, 85748 Garching-bei-Munchen

The ELISE negative ion source is designed to meet the requirements of ITER's NBI system: deliver high negative ion currents I_{ext} in hydrogen (H)/deuterium (D) for up to 1h, keeping an acceptable co-extracted electron current I_e, high beam uniformity and low divergence.

A major challenge is the rapid rise of I_e during pulses, more pronounced in D (isotope effect). Previous campaigns showed that static (set directly by source parameters) and dynamic (time- and location-dependent plasma and surface processes, arising from the presence of Cs and its own behavior) effects contribute to the evolution of I_e. A mechanism explaining the observed increase of I_e was proposed, based on datasets collected over multiple campaigns with varying source configurations. A dedicated campaign was carried out in which ELISE was operated with full diagnostic coverage, stable caesium conditioning and closely matched driver plasma densities in H and D. Systematic scans of the operational parameters were performed for short (10 s) and long (300 s) pulses, enabling to separate static and dynamic contributions. The results show that: the isotope effect is prominent in caesium density, extracted currents and beam divergence; the proposed mechanism for the dynamic rise of I_e is overall valid; beam divergence and uniformity do not simply correlate with plasma parameters.

P 8.3 Tue 17:10 KH 01.020

Plasma Sheath Tailoring for Advanced 3d Plasma Etching: Emission, Excitation and Etching Properties of a CCP Discharge — •Niklas Eichstaedt, Elia Jüngling, Meret Nürnberg, Marc Böke, and Achim von Keudell — Ruhr University Bochum, Germany

Three-dimensional plasma etching plays a crucial role in the fabrication of microstructures for advanced technological applications. The control and targeted manipulation of the ion density and flux are necessities to create three-dimensional structures. Previously, it has been demonstrated for an Ar/CF_4 plasma that the inclusion of a localized magnetic field leads to asymmetric etching profiles with dependencies on various factors, including the applied bias voltage. This has been attributed to ExB-drift.

However, the exact mechanisms, especially regarding the plasma dynamics, are still unclear. To address this issue, the temporal development and the steady-state shape of an asymmetrical plasma sheath of a capacitively coupled plasma were examined using time-resolved as well as time-integrated optical emission spectroscopy. These sheath geometries, as well as the resulting etching rates and profiles, are compared between different experimental parameters such as the bias voltage, the mask geometries and the material of the surface (Si or SiO_2). Based on those observations, we proposed a model explaining the influence of the observed plasma dynamics on the etching profiles.

P 8.4 Tue 17:25 KH 01.020

Holographic optical tweezers for dusty plasmas — Pascal König, Natascha Blosczyk, and •Dietmar Block — IEAP der CAU, 24098 Kiel, Germany

Dusty plasmas are well suited to study strongly coupled systems, because they allow to study their structure and dynamics at an individual particle level. To manipulate their dynamics, lasers are a very versatile tool. Laser heating as well optical tweezers have been realized in the past. This contribution will show first results of a new approach, which promisses a new level of particle manipulation. We replaced the conventional optics of our tweezers with Fourier optics. A spatial light modulator allows to map arbitrary holograms to a dust cloud. We present such a holographic setup and show that it allows to tweeze particles. Based on examples, the potential of this new manipulation tool is shown and compared to conventional laser tweezers.

5 min break

P 8.5 Tue 17:45 KH 01.020

Nanosecond discharges at high reduced electric fields as a tool for measuring energy efficiency (G-values) — •Inna Orel[1,2], Youssef Haouchat[1,3], Tat Loon Chng[1,4], and Svetlana Starikovskaia[1] — [1]Laboratory of Plasma Physics (CNRS, Ecole Polytechnique, University Paris-Sud, Observatoire de Paris, Sorbonne Universite, Universite Paris-Saclay, IPP), Palaiseau, France — [2]Ruhr University Bochum, Institute for Plasma and Atomic Physics, Bochum, Germany — [3]Biomedical Imaging Group, Ecole polytechnique federale de Lausanne, Lausanne, Switzerland — [4]Department of Mechanical Engineering, College of Design and Engineering, National University of Singapore, Singapore

We examine N-atom production in a pure N_2 cylindrically symmetric, nanosecond, repetitively pulsed discharge at moderate pressure and high reduced electric field (E/N). Two specific energy deposition (SED) cases - 1 eV/molecule and 10^{-2} eV/molecule - are investigated. On-axis N-atom densities are obtained using two-photon absorption laser-induced fluorescence (TALIF), and SED values are derived from voltage waveforms measured with back-current shunts. Radial species distributions are included in the analysis. The experimental G-values are compared with kinetic modelling. The results highlight the suitability of nanosecond discharges for studying dissociation efficiency at high reduced E/N.

P 8.6 Tue 18:00 KH 01.020

The influence of the electrode material on rf plasma sheaths observed by force measurements on optically trapped microparticles — •Philipp Naudiet, Jessica Niemann, Viktor Schneider, and Holger Kersten — Institute of Experimental and Applied Physics (IEAP), Kiel University

Using optically trapped microparticles, the sheath of a plasma can be probed in a non-invasive way. To investigate the effects of secondary electron emission from the surface of the electrode on the sheath of a capacitively coupled radio frequency plasma, the force upon single optically trapped microparticles was tracked along a path from the bulk of the plasma through the sheath towards the electrode. These measurements were carried out for electrodes made of stainless steel, aluminium, titanium and glass-ceramic, under a range of different argon gas pressures and rf voltages.

We observe significant changes in the electric field force onto the microparticle depending on the electrode material. We attribute the changes in the location of the sheath edge and the forces onto the particle to the emission of secondary electrons from the surface of the electrode, and resulting changes of the particle's charge.

P 8.7 Tue 18:15 KH 01.020

Characterizing pure electron plasmas with an electron beam diagnostic in a levitating dipole trap — •Veronika Bayer[1], Adam Deller[1,2], Alex Card[1], Patrik Steinbrunner[1], Matthew Stoneking[3], and Eve Stenson[1] — [1]Max Planck Institut für Plasmaphysik, Garching b München — [2]University of California San Diego, San Diego, CA, USA — [3]Lawrence University, Appleton, WI, USA

Electric fields play a dominant role in the dynamics of pure electron non-neutral plasmas (NNPs), such as those studied in the APEX levitating dipole trap (APEX-LD). Multiple different, ideally non-invasive, diagnostics verify the presence of a plasma and determine the confinement time. Existing diagnostics are able to confirm the presence of plasma, as long as the plasma density changes. A new electron beam diagnostic, which can detect plasma regardless of density peturbation is implemented on a levitating dipole; and first results from this diagnostic are presented. Electrons are emitted by this diagnostic onto a field line passing through the center of the floating coil and are collected on the opposite side. As plasmas become trapped within the magnetic field lines of APEX-LD, the resulting space charge potential can reflect the electron beam; the collected current therefore provides a way to determine the potential of the trapped plasma.

P 8.8 Tue 18:30 KH 01.020

Characterization of three-dimensionally extended dust clouds containing active particles under microgravity — •Stefan Schütt, Christina Knapek, Daniel Maier, Daniel Mohr, and André Melzer — University of Greifswald, Greifswald, Germany

It was found that metal-coated melamine formaldehyde particles suspended in an rf plasma can exhibit active behavior when they are illuminated by lasers. Inhomogeneities and defects of the coating lead to the emergence of photophoretic forces, resulting in a behavior similar to Janus particles. In laboratory experiments, a fraction of 10 to 20 % of the particles showed such active behavior.

Here, silver and gold-coated particles were used in the Zyflex chamber on parabolic flights. The setup allowed to study void-free extended dust clouds with minimal external stress. A section of the dust cloud was observed with a stereoscopic four-camera setup, allowing to reconstruct particle trajectories in three dimensions. A characterization of the active dust clouds using the three-dimensional data will be presented in this contribution, including velocity distributions as well as other statistical measures.

This work was funded by DLR (German Aerospace Center) grants 50WM2161 and 50WM2561.

P 9: Low Pressure Plasmas III

Time: Wednesday 11:00–12:30 Location: KH 01.020

Invited Talk P 9.1 Wed 11:00 KH 01.020

Controlling spokes in magnetron sputtering discharges — •Martin Rudolph — Leibniz Institute of Surface Engineering (IOM), Leipzig, Germany

Spokes in magnetron sputtering discharges are zones of enhanced excitation and ionization that rotate along the racetrack. Their visible properties like intensity and velocity are known to depend sensitively on discharge conditions. Very intense spokes appear under conditions of strong magnetic field and low working gas pressure. In this case, spokes stand out strongly with their high emission intensity against a relatively dim background along the racetrack. This suggests that the properties of film-forming species depositing onto a substrate is dominated by the presence of spokes. The control of spoke properties may thus be an additional means to tailor the particle flux and fine-tune thin film properties. In this contribution, we discuss how such a control can be achieved using typical process parameters. We show that spoke intensity can be tuned by adjusting the working gas pressure. Moreover, we demonstrate the deliberate excitation of spokes at a defined location by introducing a step in the magnetic field strength along the racetrack. Finally, we show that spoke velocities can be adjusted using the working gas pressure and discharge current with lower velocities observed at higher gas pressures and lower discharge currents. The controlled manipulation of spokes may in the future enable spokes engineering allowing thin film properties to be tailored through deliberate tuning of spoke characteristics.

P 9.2 Wed 11:30 KH 01.020

Metal-coated plastic spheres in dusty plasmas as active particles — •Andre Melzer, Tobias Marder, Stefan Schütt, Horst-Holger Boltz, Thomas Ihle, Christina Knapek, Daniel Maier, and Daniel Mohr — Institute of Physics, University of Greifswald, Greifswald, Germany

The dynamical properties of metal-coated dust microspheres confined in a gaseous plasma environment have been studied. It has been observed that such particles feature properties of active particles and that the particle activity changes over time and increases with the intensity of laser illumination. The dynamics of single particles as well as of small particle clusters have been analyzed quantitatively with various statistical methods to characterize their activity. Furthermore, clusters of metal-coated microspheres are observed to undergo a phase transition from an ordered to an unordered structure under increased laser illumination intensity due to the increased active motion of the particles.

P 9.3 Wed 11:45 KH 01.020

Global Clebsch coordinates for rectangular magnetron fields — •Ralf Peter Brinkmann, Dennis Krüger, Jens Kallähn, Kevin Köhn, Lukas Vogelhuber, Yulia Sharova, Liang Xu, and Denis Eremin — Ruhr-University Bochum

Large-scale rectangular magnetrons are the workhorses of modern high-throughput coating and other plasma-processing applications. This work introduces a tool to assist in the theoretical modeling and numerical simulation of such devices: global Clebsch coordinates [1]. Focusing on the region above the cathode, the magnetic field $\boldsymbol{B}(\boldsymbol{r})$ is shown to admit a divergence-free Clebsch formulation $\boldsymbol{B} = \nabla\Psi\times\nabla\Theta$, where $\Psi(\boldsymbol{r})$ is a magnetic flux function whose constant values define nested flux surfaces, and $\Theta(\boldsymbol{r})$ is a generalized azimuth labeling individual magnetic field lines. A third coordinate $S(\boldsymbol{r})$ measures the arc length along field lines and provides a natural parameterization. The triplet (Ψ, Θ, S) defines a system of field-aligned flux coordinates suited for describing plasma behavior in large rectangular magnetrons. The topological and geometrical principles of this construction are discussed and illustrated with a realistic rectangular magnetron field. The resulting mathematical framework provides a rigorous foundation for self-consistent modeling and simulation of plasma dynamics in field-aligned flux coordinates, with direct relevance to industrial-scale plasma processing.

P 9.4 Wed 12:00 KH 01.020

Characterization of millimeter-sized low-pressure argon plasmas in aeroglass — Karin Hansen[1], Jonas Lumma[2], Rainer Adelung[2], and •Franko Greiner[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Department of Materials Science, Kiel University, Kiel, Germany

Electrodes and other solid boundaries are invariably separated from the plasma by a layer known as the plasma sheath. Depending on the discharge pressure, this sheath has a minimum thickness on the order of the electron Debye length. The intrinsic properties of the material and its surface structure may affect the plasma. Macroscopic gaps in the surface are only filled with plasma if their size is comparable to the sheath thickness. To study how plasma-facing walls made from aeroglass[1] influence the characteristics of a low-pressure argon discharge, we generated a plasma inside a millimeter bore in an aeroglass cylinder with a height of 8 mm and a diameter of 8 mm. Since the ratio of interface area to plasma volume increases as the bore radius decreases, any influence of the aeroglass should become observable for these small systems. Plasma diagnostics were carried out using electrostatic dou-

ble probes. At discharge pressures of about 1000 Pa, we observed a high-density plasma mode that does not occur with conventional wall materials.

[1] Lena M. Saure et al., ACS Nano 2023, 17, 22, 22444*22455, DOI: 10.1021/acsnano.3c05329

P 9.5 Wed 12:15 KH 01.020

Ion energy dependence of plasma TMDC modifications — •Luka Hansen[1,2], Markus Borchardt[1], Ulrich Schürmann[2,3], Chithra H. Sharma[1], Kai Rossnagel[1,2], Lorenz Kienle[2,3], 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]Department of Materials Science, Kiel University, Kiel, Germany

Transition metal dichalcogenides (TMDCs) are two-dimensional quantum materials that could enable future technologies such as qubits or next-generation semiconductors [1]. While their intriguing electronic and structural properties have been studied extensively, questions remain about how to effectively tune these properties.

Plasma is a powerful TMDC tuning tool; e.g., it can etch multilayer systems to monolayer sheets [2]. However, the underlying plasma-TMDC interaction is not well understood. To gain more insight into these processes, we use a low-pressure reactor with inverted geometry [3], which enables us to control the ion fluxes and energies individually. Ion mass spectrometry allows us to characterize these fluxes and detect ions originating from the TMDC *in operando* as a signature of crystal decomposition. This approach will help identify plasma conditions under which TMDCs can be modified while preserving their structural integrity.

[1] K. S. Novoselov *et al.*, 2016 *Science* **353** aac9439
[2] A. Varghese *et al.*, 2017 *Nanoscale* **9** 3818
[3] C. Schulze *et al.*, 2022 *Plasma* **5** 295-305

P 10: High Energy Density Physics I

Time: Wednesday 11:00–12:30 Location: KH 02.016

Invited Talk P 10.1 Wed 11:00 KH 02.016

Laser fusion activities in Germany - applications in planetary and stellar astrophysics and experiments at high-power laser facilities — •Dominik Kraus — University of Rostock, Rostock, Germany — Helmholtz-Zentrum Dresden-Rossendorf

Research in the field of laser-driven inertial fusion ("laser fusion") has gained significant momentum following the achievement of the Lawson criterion for fusion ignition at the National Ignition Facility, triggering substantial public and private investment worldwide, including in Germany.

Despite this progress, a detailed understanding of the complex physical processes along the compression pathway toward inertial fusion plasmas remains essential for the realization of laser fusion as a practical energy source. The most widely pursued laser fusion schemes begin with the compression of the ablator and deuterium*tritium fuel to megabar pressures, corresponding to conditions similar to those found in planetary interiors. This stage is followed by a quasi-isentropic compression to gigabar pressures, reaching regimes comparable to stellar interiors. Both phases fall within the regime of so-called warm dense matter, which remains only partially understood.

This talk will review current developments and key challenges in laser fusion research and outline potential contributions from experimental facilities in Germany. In addition, selected examples will demonstrate how these facilities can be used to advance our understanding of dense astrophysical plasmas.

P 10.2 Wed 11:30 KH 02.016

Recent advances in the operation of nano-accelerators towards IFE applications — •Fabian Batsch[1], Daniel Rivas[1], Marius S. Schollmeier[1], Georg Korn[1], Hartmut Ruhl[1], and our collaborators[2] — [1]Marvel Fusion GmbH, Munich, Germany — [2]LMU Munich, Germany; ELI-NP, Romania; Thales LAS, France

We propose an alternative path towards inertial fusion energy (IFE) involving ultra-short pulse, petawatt-class lasers and nano-fabricated targets. These highly ordered nanowire arrays, or nano-accelerator (NA), can absorb laser pulses with intensities above 10^{20} W/cm^2, leading to a controlled and efficient energy transfer into radiation and kinetic particle energy. Optimal laser-solid interaction without preplasma formation is required for best performance of the NA, which requires ultra-high temporal laser contrast ($< 10^{-12}$ on ps timescales) that can be achieved through the strongly non-linear processes of either plasma mirrors or second-harmonic generation (SHG).

In this presentation we report on recent progress in the validation of the NA concept through experiments at two PW-class laser facilities: the influence of double plasma-mirrors and changes in nanowire parameters on the laser contrast, laser absorption and emitted particle spectra is studied at the Extreme Light Infrastructure for Nuclear Physics (ELI-NP, 800 nm, 10 PW). The scaling with laser wavelength will be evaluated through the second-harmonic of the ATLAS-3000 laser pulses at the Centre for Advanced Laser Applications (CALA, 400 nm, >25 J, 30 fs). First results on SHG conversion efficiency, focus quality and contrast improvements will be presented.

P 10.3 Wed 11:45 KH 02.016

Fusion energy research at the European XFEL: Current capabilities and future perspectives — •Ulf Zastrau — European XFEL, Holzkoppel 4, 22869 Schenefeld, Germany

The European XFEL in Schenefeld near Hamburg provides unprecedented opportunities to study matter under extreme conditions relevant to inertial fusion energy (IFE). Recent workshops and studies have outlined a coordinated strategy to exploit XFEL capabilities for diagnosing high-energy-density (HED) plasmas, characterizing fusion-relevant targets, and benchmarking hydrodynamic and radiation-transport models. In my talk, I will present the current capabilities of the HED-HIBEF instrument together with a roadmap for fusion-energy research at the facility. The program emphasizes precision X-ray probing of laser-driven plasmas, the development of dedicated diagnostics and target platforms, and the integration of a multi-kJ high-power laser at a new XFEL beamline for next-generation fusion experiments. These efforts aim to establish the European XFEL as a central hub for cross-disciplinary fusion-energy research, bridging basic plasma physics and applied energy science.

P 10.4 Wed 12:00 KH 02.016

Toward predictive modeling of Inertial Confinement Fusion plasmas — •Michael Bonitz, Daniels Krimans, Hanno Kählert, and Christopher Makait — Institute of Theoretical Physics and Astrophysics, Christian-Albrechts-Universität zu Kiel, 24098 Kiel, Germany

In Inertial confinement fusion (ICF) hydrogen rapidly undergoes compression, heating and ionization. Simulations have to take into account simultaneously laser-matter interaction, shock propagation, and nuclear reactions. Moreover, the initial phase of the compression is strongly influenced by nonequilibrium carriers, electronic quantum effects, and Coulomb correlations. Despite the rapid recent progress in theory and simulation of dense plasmas and warm dense matter [1], presently, no method exists that reliably captures all these processes, and commonly used radiation-hydrodynamics simulations do not have predictive capability. In Ref. 2 a solution of this dilemma has been proposed: a smart combination of a variety of different simulations, together with a first-principles based downfolding approach. The starting point are quantum Monte Carlo simulations, in equilibrium [3], and quantum kinetic theory [4], in nonequilibrium. This should allow for predictive ICF simulations in the near future.

[1] M. Bonitz et al., Phys. Plasmas **27**, 042710 (2020); [2] M. Bonitz et al., Phys. Plasmas **31**, 110501 (2024); [3] A. Filinov and M. Bonitz, Phys. Rev. E **108**, 055212 (2023); [4] M. Bonitz, "Quantum Kinetic Theory", 2nd ed. Springer 2016

P 10.5 Wed 12:15 KH 02.016

Equation of State and Electronic Transport Properties of Dense Liquid Hydrogen — Armin Bergermann[1], •Uwe Kleinschmidt[2], Siegfried H. Glenzer[1], and Ronald Redmer[2,3] — [1]SLAC National Accelerator Laboratory, Menlo Park CA 94309, USA — [2]Institute of Physics, University of Rostock, D-18051 Rostock, Germany — [3]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstr. 400, D-01328 Dresden, Germany

We present extensive first-principles calculations of the equation of state and electronic transport properties of hydrogen across a wide density ($0.2 < \rho < 70$ g/cm^3) and temperature ($10^3 < T < 10^6$ K) regime, encompassing conditions relevant to giant planet interiors, stellar envelopes, and inertial confinement fusion plasmas. The equation of state data recover the ideal-gas and fully ionized plasma limits. Electronic transport coefficients were obtained via the Kubo-Greenwood formalism. The electrical conductivity exhibits an inversion region near $\rho \sim$ 1-10 g/cm^3, where degeneracy and coupling parameters are of order unity, marking the transition from molecular to metallic hydrogen. The thermal conductivity rises monotonically with increasing density and temperature, bridging between the Wiedemann-Franz behavior in the degenerate regime and the Spitzer scaling in the classical limit. Comparisons with analytical models show good agreement within their respective validity regimes. Our data set provides a high-accuracy benchmark for warm dense hydrogen and a reliable reference for applications such as planetary modeling, stellar structure calculations, and ICF design.

P 11: Magnetic Confinement IV

Time: Wednesday 13:45–15:50 Location: KH 02.016

Invited Talk P 11.1 Wed 13:45 KH 02.016

Proxima Fusion - Building stellarators to power the future — •Jonathan Schilling — Proxima Fusion, Munich, Germany

Proxima Fusion is Europe's fastest-growing fusion company, building the first generation of fusion power plants using quasi-isodynamic (QI) stellarators - the clearest, most robust path to putting fusion on the grid. Proxima Fusion is the first spin-out from the Max-Planck-Institute for Plasma Physics and builds on the record-breaking successes of the Wendelstein 7-X stellarator. Its roadmap towards the peer-reviewed Stellaris commercial power plant concept progresses through demonstration milestones including the Stellarator Model Coil and the Alpha demonstration stellarator slated to achieve net energy gain in the early 2030s, culminating in a first-of-a-kind grid-connected fusion power plant within the 2030s. Assembling a world-class team from institutions such as Max Planck IPP, MIT, Google[X], SpaceX, and leading universities, and backed by significant public and private investment, Proxima Fusion accelerates fusion from scientific achievement to industrial-scale reality. Proxima Fusion collaborates across the European fusion ecosystem to solve physics, engineering, and systems-integration challenges, advancing stellarator design, high-performance magnets, and rapid prototyping toward fusion's transformative impact on global energy. This talk will give an overview of Proxima Fusion's roadmap and highlight recent achievements.

Invited Talk P 11.2 Wed 14:15 KH 02.016

Equilibrium and stability in Wendelstein 7-X high beta plasmas — •Henning Thomsen, Christian Brandt, Charlotte Büschel, Edith V. Hausten, Martin C. Kelly, Kian Rahbarnia, Pedro Pons Villalonga, Sara Vaz Mendes, Ksenia Aleynikova, Golo Fuchert, and Niklas S. Polei — MPI f. Plasmaphysik, Wendesteinstr 1, 17491 Greifswald

High plasma pressures, characterized by the plasma beta, are necessary for future stellarator fusion reactors. The Wendelstein 7-X stellarator (W7-X) has been optimized to achieve stable plasma conditions with a volume-averaged beta (the ratio of plasma pressure and external magnetic pressure) of up to $\langle\beta\rangle \approx 5\%$. In the recent campaigns, measurements of magnetic diagnostics and equilibrium reconstructions [1], as well as tomographic inversions of the plasma radiation in soft-X ray range in high beta plasmas ($\langle\beta\rangle \lessapprox 3\%$) have been used to experimentally validate this optimization goal. The measured outward shift of the flux surfaces (Shafranov-shift) is consistent with the predictions. Coherent mode activity has been observed [2] during high beta plasma phases. Pressure driven, non-ideal ballooning modes are possible candidates, since those instabilities were not included in the original optimization of the magnetic configuration of W7-X. A summary of the current status of high beta plasma investigations in the Wendelstein 7-X stellarator will be presented.

[1] E.V. Hausten et. al, this conference
[2] C. Büschel et. al, this conference

P 11.3 Wed 14:45 KH 02.016

Mode activity during high plasma beta at the Wendelstein 7-X stellarator — •Charlotte Büschel, Christian Brandt, Henning Thomsen, Ksenia Aleynikova, Kian Rahbarnia, Edith Victoria Hausten, Martin Clifton Kelly, Sara Vaz Mendes, Pedro Pons Villalonga, Kai-Jakob Brunner, Golo Fuchter, Jens Knauer, Ekkehardt Pasch, Andreas Langenberg, and W7-X Team — IPP Greifswald, Greifswald, Germany

During the last two campaigns of Wendelstein 7-X, starting in October 2024 and lasting until May 2025, high plasma β was achieved in three different plasma scenarios: injection of frozen hydrogen pellets, a combined heating scenario of NBI and ECRH, and operation at reduced magnetic field around 1.8 T. Averaged plasma β values up to $\langle\beta\rangle = 3\,\%$ and core beta values of $\beta_0 = 8.5\,\%$ were reached. This contribution categorizes the different types of mode activity observed at high plasma β and focuses on the characterization of quasi-coherent modes in a frequency range of $f = 20 - 60\,$kHz. The mode analysis is based on the line-integrated photodiode signals from the soft X-ray multi-camera system installed in Wendelstein 7-X utilizing the high spatial and temporal resolution of 360 photodiodes arranged in one poloidal plane of the plasma. The analysis includes the determination of the poloidal mode number, the ballooning character, the radial location and the propagation direction of the mode. The mode characteristics are analyzed with respect to their correlations to general plasma parameters such as temperature, density and confinement time.

P 11.4 Wed 15:10 KH 02.016

Fully global simulations of electromagnetic turbulence and pressure-driven instabilities in tokamaks and stellarators — •Yann Narbutt[1], M. Borchardt[1], T. Hayward-Schneider[1], R. Kleiber[1], A. Könies[1], A. Mishchenko[1], C. Nührenberg[1], J. Riemann[1], E. Sánchez[2], K. Aleynikova[1], and A. Zocco[1] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstraße 1, 17491 Greifswald, Germany — [2]Laboratorio Nacional de Fusión, CIEMAT, Avda. Complutense 40, Madrid 28040, Spain

Magnetic confinement fusion experiments require high $\beta = \langle p\rangle/(B^2/2\mu_0)$, the ratio of plasma pressure to magnetic pressure, to access high performance. Moderate β can be beneficial reducing for ion-temperature-gradient (ITG) driven turbulence. Typically, however, as β is increased above certain thresholds, pressure-driven instabilities appear which can potentially drive strong outward directed heat fluxes. To investigate these regimes we use the global gyrokinetic code EUTERPE to simulate plasmas in stellarators and tokamaks. Linear and nonlinear simulations, in the stellarator Wendelstein 7-X, show an unexpected absence of such instabilities as well as a reduction of heat fluxes as β rises. Given these results, additional simulations are performed in a tokamak for further understand pressure-driven instabilities from the perspective of global codes. Here, agreement between global gyrokinetics and ideal magnetohydrodynamics confirms that with large values of β pressure driven instabilities can indeed arise. However, in some parameter regimes these appear to be mitigated by kinetic and MHD effects.

P 11.5 Wed 15:35 KH 02.016

Transport investigations in pellet-fuelled plasmas of ASDEX Upgrade — •Florian Gschoesser, Clemente Angioni, Michael Bergmann, Emiliano Fable, Rainer Fischer, Peter Lang, Bernhard Ploeckl, Federico Stefanelli, Dirk Stieglitz, Giovanni Tardini, Hartmut Zohm, and ASDEX Upgrade Team — Max Planck Institute for Plasma Physics, Garching, Germany

Pellets are, for all practical purposes, the only way to fuel plasmas in a future fusion reactor. The injection of such a pellet, formed from cryogenic solid hydrogen, introduces large modifications to the plasma parameters, especially in density and temperature. The resulting momentary transition of the plasma into a non-stationary state leads to transport processes that will be investigated. This talk will focus mainly on two aspects: on one hand, it will address the experimental efforts to achieve reliable and robust profile measurements during a pellet injection; on the other hand, it will present an approach to derive information regarding the transport processes by comparing experimental observations (Thomson scattering, DCN interferometer, IDA) and simulation results (ASTRA). Progressing from lower to higher complexity, the following cases will be discussed: First, "single" repetitive pellet perturbations are analyzed. The second case deals with a high-density quasi-stationary phase, where strong fueling is applied. Finally, the transition from low to high density via a sudden injection of pellets at high frequency is discussed. Some first simulation results and conclusions will be presented.

P 12: Atmospheric Pressure Plasmas I

Time: Wednesday 13:45–15:45 Location: KH 01.020

Invited Talk P 12.1 Wed 13:45 KH 01.020

Modelling and analysis of DBDs for thin-film deposition at atmospheric pressure — •Marjan Stankov[1], Lars Bröcker[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

Dielectric barrier discharges (DBDs) at atmospheric pressure are widely used as plasma sources for thin film deposition. The quest for non-invasive diagnostic methods able to reveal the underlying physics in such applications of DBDs has led to modelling studies emerging as a powerful solution. This contribution provides an overview on how time-dependent, spatially one-dimensional (1D-t) and two-dimensional (2D-t) fluid-Poisson models enable the investigation of the influence of Si-containing precursors like HMDS, HMDSO and TMS on the behaviour of argon DBDs in different configurations. The presentation focuses on 1D-t modelling findings on the importance of Penning ionisation of precursor molecules by excited Ar states for electron production. It highlights the outcomes of the analysis of particle surface fluxes, identifying ions as the primary contributors to deposition in discharges with a short gas residence time. It also shows how the 2D-t modelling can explain a unique discharge mode experimentally observed in the presence of small amounts of precursors. The work is funded by the Deutsche Forschungsgemeinschaft – project no. 504701852.

P 12.2 Wed 14:15 KH 01.020

The Influence of Floating Materials on Streamer Propagation in sDBD Systems — •Dominik Filla, Nils Schoeneweihs, Gerrit Hübner, Ihor Korolov, Thomas Mussenbrock, and Mate Vass — Department of Electrical Engineering and Information Science, Ruhr University Bochum, D-44780, Bochum, Germany

The efficient conversion of greenhouse gases and volatile organic compounds (VOCs) remains a significant challenge for environmental sustainability and advanced chemical processes. Surface dielectric barrier discharges (sDBDs) driven by nanosecond pulses offer a promising approach to address these challenges by exploiting the complex interplay between streamer discharges and nearby floating metal materials. This study investigates how floating surfaces affect the behavior of positive and negative streamers in He/N_2 sDBD systems. Using 2D plasma-fluid simulations, we analyze the impact of floating metal surfaces on streamer propagation, velocity, and the resulting electric field configuration. Numerical results reveal that streamers deposit charge on the floating material, thereby modifying the local electric field and subsequently affecting the propagation behavior of both positive and negative streamers. The simulations show good agreement with experimental observations via phase resolved optical emission spectroscopy.
Supported by the DFG via SFB 1316.

P 12.3 Wed 14:30 KH 01.020

Spatio-temporal development of pulsed-driven dielectric barrier discharges in a single-filament arrangement in Ar — •Hans Höft[1], Alica Takáčová[2], Tomáš Hoder[1,2], and Markus M. Becker[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Department of Plasma Physics and Technology, Masaryk University, Brno, Czech Republic

Dielectric barrier discharges (DBDs) in argon were investigated using a double-sided, symmetric single-filament configuration with 0.5 mm alumina barriers and a 1 mm gas gap, which was housed in a Plexiglas cell and was flushed with a 100 sccm Ar flow at atmospheric pressure. The DBDs were driven by unipolar positive high-voltage pulses (50 ns rise/fall time, 10 kHz repetition frequency, 1 μs pulse width) with a varying amplitude (2.1–3.0 kV). Imaging by synchronised iCCD and streak camera measurements combined with fast electrical probes revealed a reproducible, thin constricted channel and surface discharges on both dielectrics. The discharge inception at the rising slope features as a cathode-directed streamer followed by a transient glow phase with complex characteristics; the streamer velocity was an order of magnitude lower than in air-like gas mixtures. Increasing the amplitude to 3.0 kV significantly altered the discharge inception and development compared to 2.1 kV, thus providing valuable data for modelling DBDs in Ar.
This work is funded by the Deutsche Forschungsgemeinschaft (DFG) – project number 504701852, and project LM2023039 funded by the Ministry of Education, Youth and Sports of the Czech Republic.

P 12.4 Wed 14:45 KH 01.020

Pressure-dependent streamer dynamics of a nanosecond-pulsed surface dielectric barrier discharge in He/N_2 — •Nils Schoeneweihs, Dominik Filla, Gerrit Hübner, Thomas Mussenbrock, Mate Vass, and Ihor Korolov — Ruhr University Bochum, Bochum, Germany

Surface dielectric barrier discharges (sDBDs) have been extensively studied for applications ranging from plasma-assisted gas conversion to surface treatment. In this work, sDBDs driven by nanosecond voltage pulses are investigated in He/N_2 gas mixtures and at various pressures. 2D plasma*fluid simulations (nonPDPSIM) and experiments are conducted to investigate streamer formation, propagation length and velocity and their implications for plasma-assisted conversion. Insights into the discharge dynamics are obtained by measuring emission from the He-I $(3s)^3S_1$ state (with an excitation energy of 22.7 eV) and by calculating the corresponding spatio-temporal excitation rate using phase-resolved optical emission spectroscopy (PROES). Good qualitative agreement is found between PROES measurements and simulations. The results suggest strong coupling between the positive streamer at the powered electrode and the negative streamer at the grounded electrode in a twin-sDBD configuration. Varying the pressure strongly influences the velocity and propagation length of the streamer. Supported by the DFG via SFB 1316 (Projects A5 and A7).

P 12.5 Wed 15:00 KH 01.020

Determination of the argon $3p^54s$ population distribution in a single-filament dielectric barrier discharge at atmospheric pressure — •Levin Krös[1,2], Hans Höft[1], Marjan Stankov[1], Detlef Loffhagen[1], Jean-Pierre H. van Helden[3], 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 — [3]Faculty of Physics and Astronomy, Ruhr University Bochum, Bochum, Germany

Atoms and molecules in excited states impact the discharge and chemical reaction kinetics by their contribution to the production of charge carriers, via, e.g., step-wise ionisation or chemi-ionisation processes. In argon discharges, these processes are mainly driven by the energetically lowest excited states in the $3p^54s$ group, namely in Paschen notation, the two resonance states $1s_2$ and $1s_4$ and the two metastable states $1s_3$ and $1s_5$. Measurements of number densities of all four $3p^54s$ states allow to determine the population distribution, which is valuable for benchmarking the kinetics of numerical models. We report spatio-temporally resolved number densities of those states measured in a single-filament dielectric barrier discharge operated with a sinusoidal high-voltage waveform at atmospheric pressure using tunable diode laser absorption spectroscopy. The population distribution will be compared with results of a time-dependent, spatially one-dimensional fluid model.
This work is funded by the DFG (project number: 504701852).

P 12.6 Wed 15:15 KH 01.020

Peculiarities of the current transfer on a copper cathode microarcs in air in presence of metal vapour — •Margarita Baeva[1], Jonas K. C. Ballentin[2], and Dirk Uhrlandt[1,2] —

[1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Institute of Electrical Power Engineering, University of Rostock, Rostock, Germany

Analysis of the current transfer on the copper cathode is performed for a switching arc arrangement operated at DC of 2 A at atmospheric pressure in a mixture air/Cu. The analysis is based on a unified non-equilibrium model that provides in a self-consistent manner the spatial distribution of the plasma properties needed for this analysis accounts for the increase of the gap length during the contact opening.

The presence of metal vapour in the plasma even in the considered mole fraction of 0.002 leads to the dominance of the singly charged copper ion. Ionization process occurs both in the space-charge region of the cathode and beyond the edge to the quasineutral plasma bulk. The computed spatial distribution of the electric potential indicates a maximum in the vicinity of the cathode, which causes an ion flux toward the plasma bulk. The predicted ratio of the ion to total current density amounts to 0.41-0.76 as a result of the interplay of increasing cathode voltage drop and in turn increasing ion mobility and drift velocity that overrules the decrease of the ion number density.

The work is funded by the German Research Foundation (DFG) Project number 524731006.

P 12.7 Wed 15:30 KH 01.020

Silicon Nitride Membrane for Vacuum Ultraviolet (VUV) Spectroscopy of Commonly Used Plasma Jets — •Görkem Bilgin[1], Jan Benedikt[1,2], and Luka Hansen[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 VUV photons generated by non-thermal atmospheric pressure plasmas is complicated by the strong absorption in air and common window materials (e.g., LiF, MgF_2) as these materials have cutoff wavelengths of around 110 nm [1, 2]. Various windowless techniques have been developed in the past to transfer the VUV photons into a vacuum, but each method has its drawbacks [2].

For this contribution, an evacuated monochromator, equipped with an ultra-thin (20 nm) silicon nitride (Si_3N_4) membrane as an entrance window for the VUV radiation, was upgraded compared to [2] using narrower entrance/exit slits and a new detector, in order to improve the spectral resolution and achieve higher intensities.

VUV spectra of the COST Jet [3], Capillary Jet [4], and kINPen [5] will be presented, and the VUV emission correlated with UV/VIS spectra and electrical measurements.

[1] J. Golda *et al.* 2020 *Plasma Process. Polym.* **17** 1900216
[2] L. Hansen *et al.* 2025 *Plasma Sources Sci. Technol.* **34** 12LT01
[3] J. Golda *et al.* 2016 *J. Phys. D: Appl. Phys.* **49** 084003
[4] T. Winzer *et al.* 2022 *J. Appl. Phys.* **18** 183301
[5] S. Reuter *et al.* 2018 *J. Phys. D: Appl. Phys.* **51** 233001

P 13: Atmospheric Pressure Plasmas II

Time: Wednesday 16:15–18:15 Location: KH 01.020

Invited Talk P 13.1 Wed 16:15 KH 01.020

Thin film deposition with dielectric-barrier discharges at atmospheric pressure: open questions and some answers — •Lars Broecker and Claus-Peter Klages — Institute for Surface Technology (IOT), Technische Universität Braunschweig, 38108 Braunschweig, Germany

Plasma-enhanced chemical vapour deposition (PECVD) with dielectric-barrier discharges (DBDs) at atmospheric pressure is still only partially understood, which makes choosing the most suitable discharge configuration and plasma parameters quite difficult. In particular, the relevance of possible film-forming species, e.g. radicals, charged particles or the monomer itself, and their influence on the mechanical properties and film chemistry is often speculated upon but not fully understood. The determination of characteristic times involved in the deposition process, namely the gas residence time, the times for the transport of neutral particles and ions to the surface by diffusion and drift, respectively, and the time scales of ionic or radical gas phase reactions, can provide important information about the significance of the species for the film deposition process. Interestingly, cations formed from neutral species by electron impact or chemo-ionization are often neglected, even though they drift to the substrate within a few mikroseconds. Recent experiments show that film deposition from ions dominates when the gas residence time is much shorter than the diffusion time of neutral particles. For certain monomers, cationic surface reactions appear to play a role, similar to initiated chemical vapour deposition (iCVD) processes.

P 13.2 Wed 16:45 KH 01.020

Impact of simultaneous laser irradiation and plasma treatment to a Cu catalyst for CO_2 reduction — •Alexander Schicke[1,2], Jannis Kaufmann[1], Sascha Chur[1], Marc Böke[2], and Judith Golda[1] — [1]Plasma Interface Physics, Ruhr University Bochum, Germany — [2]Experimental Physics II, Ruhr University Bochum, Germany

Catalysts are able to optimise selectivity, efficiency, and reaction rates in chemical reactions. Therefore, they are critical in industrial applications for enabling more environmentally friendly processes. The efficiency of a catalyst is influenced by surface characteristics such as surface morphology and chemical composition. The morphology can be changed by nanostructures produced by laser irradiation, and the chemical composition can be altered by reactive species produced by atmospheric pressure plasmas. The combined treatment increases the efficiency by oxidising the surface. However, this simultaneous interaction between laser, plasma, and surface is highly complex.
We investigated this complex interaction in regards to optimise the efficiency of a Cu catalyst for the CO_2-Reduction Reaction (CO_2-RR). The electric fields and energy of pulsed laser irradiation produce Laser Induced Periodic Surface Structures (LIPSS) and Pulsed Laser Induced Dewetting Structures (PLIDS) which increase the effective area of the catalyst. Different reactive oxygen species (ROS), such as O_2(a), O_2(b) and ozone, produced by a helium-oxygen plasma, are measured. Up to 30% Cu_2O and further up to 50 % CuO could be produced. The combined treatment increases the overall selectivity to C_{2+} products.

P 13.3 Wed 17:00 KH 01.020

characteristics of plasma catalytic conversion of n-Butane in micro cavity plasma array — •Yue Cheng[1], Henrik Van Impel[1], David Steuer[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

n-Butane is a common volatile organic compound in automotive exhaust and exhibits acute toxicity, so its efficient and harmless removal is important for environmental and public health. This study investigates DBD plasma conversion of n-Butane by FTIR in MCPA, focusing on the effects of gas composition, catalyst and temperature on conversion and product selectivity. Introducing MnO2, BiTiO3 or BiVO4 as catalyst substantially reduces the number of ignited cavities and lowers the maximum conversion to 20%, indicating an anti-synergistic interaction between these catalysts and the present discharge configuration. For BiVO3 and BiTiO4 raising the catalyst surface temperature accelerates carbon deposition on the dielectric, which further suppresses reaction efficiency. However, BiVO4 shows the lowest carbon loss and BiTiO3 gives the smallest unassigned fraction in the product selectivity, meanwhile MnO2 delivers the highest conversion at elevated temperatures up to 34%. Overall, developing plasma catalytic systems with enhanced anti-coking properties is key to improving conversion rates and steering selectivity toward target products. This work is supported by DFG within SFB1316 (A6).

P 13.4 Wed 17:15 KH 01.020

The Influence of Catalyst Structure on Plasma Properties in Plasma Catalysis — •Alexander Quack[1], Lennard Buck[1], Kerstin Sgonina[1], and Jan Benedikt[1,2] — [1]Institute of Experimental and Applied Physics, Kiel University — [2]Kiel Nano, Surface and Interface Science (KINSIS), Kiel University

In plasma catalysis, porous materials are often used to increase the catalyst surface area and number of active size. However, the plasma often can not reach these sites directly, limiting the transport of excited species from the plasma to the catalyst surface. Therefore, we investigate the influence of dielectric materials and porous structures of many sizes inside the plasma region and study the resulting modification on the formation, intensity and coverage of the plasma.

For the presented work, we use a custom-build reactor, which can be heated up to 600°C and has a transparent driven electrode for optical analysis with a camera. Additionally, the plasma gap can be modified from 0.5 to 8 mm changing the special dimension of the discharge and altering the plasma properties. The plasma is created at about 20 kHz and 8-20 kV_{PP} and analyzed with current-voltage measurements deriving the plasma power, capacitances and coverage. A gas mixture of H_2:CO_2 (3:1) is chosen to study the catalytic properties of the plasma with CH_4 and CO as chemical products that are detected by mass spectrometry as residual gas analysis. As dielectric materials, we use ceramic (ZrO_2) spheres of different sizes (0.7-2.5 mm) as model material and Co_3O_4 and CuZnO in forms of porous beads and powder as catalytic materials.

P 13.5 Wed 17:30 KH 01.020

Investigating the influence of pulsed plasmas in water on copper surface — •Pia-Victoria Pottkämper, Oliver Krettek, Nils Huber, Sven Weller, and Achim von Keudell — Ruhr University Bochum, Germany

In-liquid plasmas enable a variety of applications. For instance, they can be used to induce nanoparticle formation both in the treated liquid and on a surface in contact with the liquid. Plasmas in liquids, when ignited by voltage pulses with fast rise times and nanosecond pulse lengths applied to a small electrode wire, yield a high degree of dissociation of the molecules in the liquid, a high mass transport and efficient reaction rates. The in-liquid plasma causes the formation of reactive oxygen species from the water molecules. The reactive species can propagate through the liquid. When a surface is in direct contact with the liquid, the species can induce modifications of this surface.

In this project, the modification of copper surfaces by in-liquid plasma treatment is investigated. On copper surfaces, growth of CuxO nanocubes can be induced. One application of these nanocubes is the catalysis of the electrochemical reduction of CO2. The activity of these nanocube catalysts decreases with use over time. Therefore, the catalytically active surface needs to be replaced regularly. It is postulated that by an in-situ in-liquid plasma treatment a re-activation of the surface could be achieved, thereby extending the lifetime of the copper oxide catalysts.

P 13.6 Wed 17:45 KH 01.020

Enhancing plasma-surface interaction at atmospheric pressure by multiscale aeromaterials — •Kerstin Sgonina[1], Jannis Christiansen[1], Jonas Lumma[2], Rainer Adelung[2,3], Franko Greiner[1,3], and Jan Benedikt[1,3] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Department of Materials Science, Kiel University, Germany — [3]Kiel Nano, Surface and Interface Science (KiNSIS), Kiel University, Germany

The field of plasma-assisted catalysis is continuously growing in the last few years. However, a large breakthrough is still pending. One problem that has received more attention lately [1] is the huge distance between the plasma and the catalytic material that hiders the plasma activated species to interact with the materials surface. To overcome this challenge, multiscale aeromaterials could be the game changer, which have not been studied in this respect until now. With their high porosity, ultra low density and therefore extremely high surface area (several 100 m^2/g), they could enhance the plasma-surface interaction at atmospheric pressure.

Different reactor types has been used to, on the one hand, prove the feasibility of plasma ignition inside aeroglass at atmospheric pressure using high voltages at kHz, and on the other hand, prove the transparency of aeromaterials for ions. The ions transmitting through different thicknesses of aeromaterials of different plasmas at sub-atmospheric pressure (ranging from 20 to 80 mbar) has been detected using an ion mass spectrometer.

[1] Van Turnhout *et al.*, EES Catalysis **3**, 669-693, 2025.

P 13.7 Wed 18:00 KH 01.020

Post-Plasma Catalysis Schemes in Ammonia Synthesis — •Daniel Henze and Achim von Keudell — Ruhr Universität Bochum, 44801 Bochum, Germany

Current research in plasma catalysis focuses on in-plasma catalysis, where the plasma is operated directly in front of the catalyst surface. This approach poses significant scientific challenges, as the plasma-catalyst interaction may lead to synergisms or anti-synergisms when aiming at maximizing species conversion or species selectivity. This question is explored for plasma catalysis for ammonia production. We use a kHz DBD plasma jet array to study the role of plasma-generated species in ammonia synthesis. The discharge initiates guided streamers that impinge on the catalyst surface as shown in a previous experiment with a comparable plasma source [1]. Due to their short lifetime, the plasma-catalyst contact occurs only for about 2% of the pulse duration. This reduces the coupling of the plasma and the catalyst, to separate the plasma dynamics from the surface chemistry. The jet array consists of two sets of three individual jets. Each set of electrodes is powered independently and fed with different gases. They are operated sequentially to separate nitridation and hydrogenation steps in time similar to chemical looping for thermal catalysis. We characterize the discharge setup and investigate the impact of species injection and discharge timing on the ammonia yield by measuring the product density via a sampling orifice coupled to a molecular beam mass spectrometer.

[1] Daniel Henze et al 2025 Plasma Sources Sci. Technol. 34 095017

P 14: Magnetic Confinement V

Time: Thursday 11:00–12:30 Location: KH 02.016

P 14.1 Thu 11:00 KH 02.016

Understanding the impact of the divertor configuration on the L-H transition in the ASDEX Upgrade tokamak — •Roxána Takács[1], Michael Dunne[1], Gregor Birkenmeier[1], Matthias Willensdorfer[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 Nuclear Fusion

Future fusion devices, such as ITER, will operate in high-confinement mode (H-mode) to achieve the plasma confinement required for sustained energy production. H-mode is characterized by increased stored energy and the formation of a steep pressure gradient at the plasma edge. In the leading interpretation, the transition into H-mode occurs when the E×B shear becomes strong enough to suppress edge turbulence. Previous studies from many major tokamaks have shown that the power threshold for the L−H transition (P_{LH}) depends on various parameters, including the main isotope, plasma shape, and plasma density. This study investigates how the P_{LH} varies with different divertor configurations in the ASDEX Upgrade tokamak. The experimental dataset consists of lower- and upper single null plasma discharges, in low and high density regimes, with different divertor configurations. Significant variations in P_{LH} are observed across the different divertor configurations. This work presents an analysis of the divertor conditions as well as kinetic profiles at the midplane which aids in understanding the underlying physics of the L−H transition and improving our ability to optimize H-mode access in future fusion reactors.

P 14.2 Thu 11:25 KH 02.016

Multi-Color Gas Puff Imaging in the ASDEX Upgrade Divertor — •Manuel Herschel[1,2], Michael Griener[1], Felix Albrecht[1,2], Alessandro Mancini[1], Ou Pan[1], Christoph Pitzal[1], Tim Happel[1], Ulrich Stroth[1,2], 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, Garching, Germany — [3]H. Zohm et al. 2024 *Nucl. Fusion* **64** 112001

The divertor will play a critical role in a future magnetic confinement fusion power plant. It distributes heat and particle loads onto the plasma-facing materials and controls impurity influx into the main plasma volume.

To study the newly constructed upper divertor at the ASDEX Upgrade fusion experiment, it has been equipped with a variety of novel plasma diagnostics. One of these diagnostics is a Multi-Color Gas Puff Imaging (GPI) system to study fast (tens of μs) events in the divertor volume. The GPI system uses a small injection of helium gas to emit line radiation depending on local plasma parameters, which is detected by a fast camera.

The design of the diagnostic, operational challenges and results from the first experiments are presented. Various comparisons with other diagnostics and numerical turbulence simulations are shown.

P 14.3 Thu 11:50 KH 02.016

Characterization of Neutral Helium Beam Injection at ASDEX Upgrade — •Manuel Matsumoto[1,2], Athina Kappatou[2], Lucía Sanchis[3], Michael Dunne[2], Christian Hopf[2], Thomas Pütterich[2], Gregor Birkenmeier[1,2], Rachael M McDermott[2], and ASDEX Upgrade Team[2] — [1]Technical University of Munich, Germany — [2]Max Planck Institute for Plasma Physics, Garching, Germany — [3]University of Sevilla, Spain

The confinement and slowing-down behaviour of energetic alpha particles are critical for the performance of future reactors, as they are expected to heat the background plasma. Pulses with helium neutral beam injection (NBI) have been carried out at ASDEX Upgrade to produce an energetic helium population. Charge Exchange Recombination Spectroscopy (CXRS) measurements reveal a slowing down feature characteristic of the fast helium ion population.

To interpret the measurements, an ASCOT5 based particle tracking model is used to describe the helium beam ionization and slowing-down process in a fusion plasma. A forward model allows direct comparison between experimental CXRS spectra and synthetic spectra generated from ASCOT5 distribution functions. This approach allows the interpretation of the CXRS measurements, and the validation of the ASCOT5 model itself against the measurements.

Additionally, an analysis of the beam emission components of the measured spectra allows for a detailed characterisation of the helium neutral beam and its attenuation. The results quantify the impact of metastable populations in reproducing the CXRS spectra.

P 14.4 Thu 12:05 KH 02.016

Toward a nonlinear Schrödinger equation for the description of geodesic-acoustic-modes in tokamaks — •David Korger[1], Emanuele Poli[1], Fulvio Zonca[2], Matteo Valerio Falessi[2], Riccardo Stucchi[1], Alberto Bottino[1], and Thomas Hayward-Schneider[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, 85748, Germany — [2]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 nonstationary 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 Schrödinger 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. Analytic results are compared to gyrokinetic simulations.

P 15: High Energy Density Physics II

Time: Thursday 11:00–12:30 Location: KH 01.020

Invited Talk P 15.1 Thu 11:00 KH 01.020

Demonstration of X-ray Diagnostics for Heavy-Ion-Heated Matter — •Julian Lütgert — Universität Rostock, Germany.

In the transition between solid and plasma, a sample reaches the Warm Dense Matter regime, characterized by ambient densities and temperatures between 10,000 and 1,000,000 K. Typical schemes for the generation of such conditions use ultra-fast heating or shockwaves. However, these methods only create states with lifetimes up to tens of nanoseconds. Heavy ion beams can provide a different driving scheme enabling probing times on the order of microseconds, and thereby close the gap between experiments in the lab and real-world phenomena. Such experiments are now within reach, with the next generation of heavy ion synchrotrons, like FAIR at GSI (Germany), or HIAF (China), currently under construction.

As optical measurements typically fail for dense plasmas, X-ray based methods have been developed by the community. Here, we present first experiments combining heating by accelerated ions with laser-driven X-ray diagnostics, conducted at the currently available GSI infrastructure. We measure temperature and the graphitization threshold of a diamond target by comparison of spectrally resolved scattering signal to *ab-initio* simulations. Simultaneous X-ray diffraction and imaging measurements give insight into the integrity of the sample, indicating the onset of a temperature-driven phase transition around 2000 K. We identify unique challenges in integrating the established diagnostics with ion beams and propose initial mitigation strategies toward successful experiments at upgraded facilities.

P 15.2 Thu 11:30 KH 01.020

Model-free interpretation of X-ray Thomson scattering experiments with warm dense matter — •Tobias Dornheim — Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), D-01328 Dresden, Germany — Center for Advanced Systems Understanding (CASUS) at Helmholtz-Zentrum Dresden-Rossendorf (HZDR), D-02826 Görlitz, Germany

Warm dense matter is an extreme state that occurs in a variety of astrophysical objects (brown dwarfs, giant planet interiors, ...), and which is of key importance for technological applications such as inertial fusion energy. There are many ways to generate warm dense matter in the laboratory, but diagnostics even of basic parameters such as the temperature is difficult and often depends on models. Here, I summarize recent progress on the model-free diagnostics of warm dense matter from x-ray Thomson scattering measurements [1,2].

[1] T. Dornheim et al., Nature Commun. 13, 7911 (2022) [2] T. Dornheim et al., Nature Commun. 16, 5102 (2025)

P 15.3 Thu 11:45 KH 01.020

Electron dynamic and static structure factors in warm dense matter from density functional theory — •Zhandos Moldabekov[1] and Tobias Dornheim[1,2] — [1]Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), D-01328 Dresden, Germany — [2]Center for Advanced Systems Understanding (CASUS), D-02826 Görlitz, Germany

Understanding the behavior of warm dense matter is crucial for modeling compact astrophysical objects and advancing research in inertial confinement fusion. Density functional theory (DFT) is the standard theoretical tool used in this regime. We introduce a new approach that combines time-dependent DFT calculations of the dynamic structure factor with static DFT results for the density response [1], enabling accurate predictions of the electron-electron static structure factor in warm dense matter. We also present our recent methodological and computational advances in applying linear-response time-dependent DFT (LR-TDDFT) to calculate the electron dynamical structure factor [2-8].// [1] Z. Moldabekov et al., Matter Radiat. Extremes 11 (2), 025401 (2026).//[2] Z. Moldabekov et al., Matter Radiat. Extremes 10 (4), 047601 (2025).//[3] Z. Moldabekov et al.,J. Chem. Theor. Comput. 19, 1286*1299 (2023).//[4] Z. Moldabekov et al., Prog. Part. Nucl. Phys. 140, 104144 (2025).//[5] T. Gawne, Z. Moldabekov et al., Phys. Rev. B 109, L241112 (2024).//[6] T. Gawne, Z. Moldabekov et al., Electron. Struct. 7 025002 (2025).//[7] Z. Moldabekov et al., Phys. Rev. Research 6, 023219 (2024).//[8] D. Bespalov, U. Zastrau, Z. Moldabekov et. al., arXiv:2509.10107 (2025).

P 15.4 Thu 12:00 KH 01.020

Collective modes of dense hydrogen plasmas from semiclassical molecular dynamics simulations — •Hanno Kählert and Daniels Krimans — Christian-Albrechts-Universität zu Kiel, ITAP, Germany

Dense hydrogen occurs in the interior of giant planets and during laser-driven fusion. Its properties, such as the equation of state or transport coefficients, are of high interest for modeling applications. The dynamic structure factor (DSF) is related to many thermodynamic and transport coefficients. Here, the DSF is computed from semi-classical molecular dynamics (MD) simulations [1] using the improved Kelbg potential [2]. It is shown that the structural properties are in good agreement with first-principle quantum Monte Carlo simulations. The DSF is compared with wave-packet MD simulations [3]. While the electron-electron DSF from the two methods agrees qualitatively, excellent agreement is found for the ion sound speed extracted from the ion-ion DSF. The latter can be reproduced accurately with a Yukawa one-component plasma (YOCP) model. A method to determine the screening and coupling parameters of a YOCP solely from structural properties is discussed [4].

[1] H. Kählert, submitted (2025).
[2] A. V. Filinov, V. O. Golubnychiy, M. Bonitz, W. Ebeling, and J. W. Dufty, Phys. Rev. E **70**, 046411 (2004).
[3] P. Svensson, Y. Aziz, T. Dornheim, S. Azadi, P. Hollebon, A. Skelt, S. M. Vinko, and G. Gregori, Phys. Rev. E **110**, 055205 (2024).
[4] D. Krimans and H. Kählert, submitted (2025).

P 15.5 Thu 12:15 KH 01.020

Opacity of Jupiter's and Saturn's interior from ab initio simulations — •Martin Preising[1,2] and Ronald Redmer[1,2] — [1]Universität Rostock — [2]Helmholtz-Zentrum Dresden-Rossendorf

We calculate the Rosseland mean opacity along the pressure-temperature conditions of Jupiter's and Saturn's interior by using ab initio molecular dynamics simulations based on density functional theory. We evaluate the Kubo-Greenwood formula for the dynamic conductivity and derive the absorption coefficient and, thereby, the opacity via the dielectric function.

The opacity determines the effectiveness of radiation transport mechanisms from the hot center to the cool surface of a planet. Our results will inform interior and thermal evolution models for Jupiter and Saturn as prototypical gas giant planets, in particular for the region of warm dense matter in their deep interior where quantum and correlation effects are important.

P 16: Poster Session Plasma Physics

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

P 16.1 Thu 13:45 Redoutensaal

GPU Acceleration and Portability of the TRIMEG Code for Global Gyrokinetic Plasma Simulations using OpenMP — •Giorgio Daneri, Zhixin Lu, and Matthias Hoelzl — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching b. M., Germany

The TRIangular MEsh-based Gyrokinetic (TRIMEG) code solves the gyrokinetic equations using a particle-in-cell (PIC) scheme to simulate electromagnetic instabilities throughout the full tokamak volume.

In this work, we focus on the acceleration and portability of the TRIMEG code on multiple GPU architectures. The OpenMP framework is chosen as the methodological approach for GPU offloading in Fortran on NVIDIA and AMD platforms. The particle pushing procedure, as well as particle-to-grid operations have been adapted for GPU execution. The kernels were analyzed with the available profiling tools to gather metrics about resource occupancy, throughput, and memory usage. Their performance was evaluated by carrying out GPU grid size exploration, as well as multi-node scalability studies. In addition, the efficiency of hybrid MPI-OpenMP offloading parallelization was assessed.

The Ion Temperature Gradient (ITG) mode was simulated using the GPU-accelerated version for the economical Cyclone case and the TCV case, and its correctness was verified by comparing the physics results in terms of the energy growth rate and the two-dimensional mode structures.

P 16.2 Thu 13:45 Redoutensaal

Impact of RMPs on plasma rotation in ASDEX Upgrade — •Margherita Salerno[1], Matthias WIllensdorfer[1], Rachael McDermott[1], Tuomas Tala[2], Athina Kappatou[1], and Tabea Gleiter[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]VTT Technical Research Centre of Finland

Tokamaks, though designed for perfect axi-symmetry, experience unavoidable symmetry breaking from sources like toroidal field coil ripples, error fields, and resonant magnetic perturbation (RMP) coils used for ELM suppression. These non-axisymmetric perturbations are important as they drive non-ambipolar radial particle fluxes, resulting in the Neoclassical Toroidal Viscous (NTV) torque. This torque typically acts on the plasma by spinning-up or breaking the rotation, depending on the contributions from electrons and ions. For future devices like ITER, it is crucial to quantify the NTV torque as, in this device, it may be comparable to other applied and intrinsic torques and thus make a more important contribution to the momentum balance than typically observed in present-day beam-heated devices. This work will study the impact of RMPs on plasma rotation in ASDEX Upgrade. Our investigation will focus on i) radial distribution of the torque source via coil current modulations, ii) impact of the poloidal spectrum of the RMP coils on the torque and iii) impact of the ExB rotation frequency of the torque. The experimental results will be analyzed with GPEC, which is a linear code that works generalizing the perturbed equilibrium, and then benchmarked with other codes, like MARS-K and NEO-2.

P 16.3 Thu 13:45 Redoutensaal

Experimental Investigation into the Influence of Carbon on the Mechanical Properties of Tungsten — •Sebastian Estermann[1,2], Alexander Feichtmayer[1], Till Höschen[1], Johann Riesch[1], Thomas Schwarz-Selinger[1], and Rudolf Neu[1,2] — [1]Max Planck-Insitute for Plasma Physics, Boltzmannstr. 2, 85748 Garching — [2]Technical University Munich, Boltzmannstr. 15, 85748 Garching

Fusion power plants are a promising alternative for the electricity production with low CO_2 emission. In such power plants prevail extreme conditions, so likely used materials for plasma contact such as tungsten (W) must be well characterized for save operation. It is known, that even little amount of impurities, e.g. carbon (C) which can be present during manufacturing, can change the properties of W. Subject of this research is the change in mechanical properties of thin, ductile W wires under the influence of C. The embrittlement of W by C has so far only been investigated at temperatures well above 1100 °C. As materials behaviour also changes with temperature, there are two impacts combined. By irradiating the W wires with C ions, the implantation of C atoms into the W lattice is possible at temperatures below 1100 °C. This way the influence of the temperature from the influence of C itself can be seperated. A comparison to unirradiated samples that have been heat-treated for 8 h at 900 °C is done. For evaluation, the reduction in area at the fracture surface serves as a measure of ductility. In the range 0-2700 ppm C content, the wires retained their ductility and no systematic changes were observed.

P 16.4 Thu 13:45 Redoutensaal

Beat wave generation in the ion cyclotron frequency range by high power microwaves and how to measure them — •Niklas Simon Polei, Laurent Krier, Heinrich Peter Laqua, Dmitry Moseev, Sergiy Ponomarenko, Torsten Stange, and W7-X Team — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

The overlap of two waves will create a third wave beating with the frequency difference (Δf) of the two original waves. For the beat wave generation in the ion cyclotron frequency (ICF) range two gyrotrons of the electron cyclotron resonance heating system of Wendelstein 7-X (W7-X) are used. The gyrotrons are frequency stabilized by a phase locked loop, so that they are oscillating by 100kHz at most [1]. The Δf is set to the ICF in the overlap region, typically 35MHz to 37MHz.

The microwave beams can be either overlapped in the resonance region [2] or before the resonance region. Different processes are then transferring energy to the ions. In the latter case the overlap creates a strong electric field gradient, this results in an electron density wave created by the ponderomotive force. If the k-vector of the electron wave is chosen appropriately it can couple to the ion Bernstein waves.

So far only the ICRH antenna of W7-X was used in measurements.

However, no waves or ion heating could be observed. Therefore, it is planned to use the collective Thomson scattering (CTS) system and the fast ion loss detector (FILD) to detect ion heating or fast ions.

[1] L. Krier, et al. doi: 10.1109/IRMMW-THz50926.2021.9566847
[2] H.P. Laqua, et al. 2018 Nucl. Fusion 58 104003

P 16.5 Thu 13:45 Redoutensaal

Investigation of the Effects of Anomalous Heat Transport and Diffusion in the W7-X SOL — •Anja Hoffmeister[1], Nathan Barbe[2], Kelly Garcia[1], Nassim Maaziz[2], Felix Reimold[2], Victoria Winters[1], and W7-X Team[2] — [1]University of Greifswald, Institut for Physics, Felix-Hausdorff-Straße 6, 17489 Greifswald, Germany — [2]Max Planck Institute for Plasma Physics, Wendelsteinstraße 1, 17491 Greifswald, Germany

Anomalous heat and particle transport are expected to affect the performance of the Wendelstein 7-X (W7-X) island divertor scrape-off-layer (SOL). While the underlying physical principles are not yet well-understood, mean-field simulation codes like EMC3-Eirene require a suitable parameterization to mock-up their affects on the transport. Typically, this is done via specific input parameters to the simulation. However, previous simulation studies using EMC3-Eirene have indicated unexpected behavior of the plasma parameters with changes of the input anomalous heat and particle diffusion coefficients. The reason has thus far been poorly understood. This work presents a first systematic study of how the anomalous heat and particle diffusion input parameters independently affect the performance of the W7-X SOL in EMC3-Eirene simulations. The investigation focuses on heat-flux widths and density build up at the divertor target plate. First investigations have found that, at least in a convective regime, the anomalous heat diffusion coefficient influences divertor density build-up more strongly than the anomalous particle diffusion coefficient. Behavior at different plasma densities will be presented.

P 16.6 Thu 13:45 Redoutensaal

Gyrokinetic Turbulence in ECRH Reintroduction Scenarios in W7-X — •Emil Overduin, Josefine Henriette Elise Proll, Sebastian Bannmann, and Michael Jeffrey Gerard — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Recently, the neoclassically optimized stellarator Wendelstein 7-X (W7-X) has seen an increase in core ion temperature above the $\approx 2\,\mathrm{keV}$ clamping limit in the presence of peaked density profiles. Of special interest for this work are scenarios where the strong density gradient is created by Neutral Beam Injection (NBI), which is followed by an Electron Cyclotron Resonance Heating (ECRH) reintroduction.

The ECRH reintroduction leads to an increase of the ion temperature above the clamping limit in W7-X, while at the same time the core density peaking rate is reduced (ECRH pump-out). If the ECRH power is large enough a back-transition to a higher heat transport regime is observed. The ECRH power required for a back transition to occur is strongly dependent on the magnetic configuration of W7-X. This dependence is not well understood.

Using the local gyrokinetic code GENE the microinstabilities present in the plasma at parameters relevant for the pump-out and back-transition are investigated. The aim is to contribute to understanding the effect of turbulence on the density pump-out and back-transition. To this end, the simulations are performed at different radial locations in different configurations, and use experimentally consistent equilibria, corresponding to multiple time points during the discharges.

P 16.7 Thu 13:45 Redoutensaal

Integrated modelling of sawtooth cycles in tokamak plasmas — •Federico Stefanelli, Emiliano Fable, Clemente Angioni, Michael Bergmann, Davide Brioschi, Anja Gude, Philipp Lauber, Oleg Samoylov, Riccardo Stucchi, Markus Weiland, Haowei Zhang, and Hartmut Zohm — Max Planck Institute for Plasma Physics, Garching

Sawtooth cycles are periodic relaxations of the plasma core commonly observed in tokamak discharges. The cycle is characterized by a rapid MHD-driven collapse of the core temperature, density and current profiles, followed by a profile recovery driven by continued heating. Sawtooth cycles limit core pressure and thus lower the plasma performance. Even more critically, they can trigger secondary MHD instabilities, which in turn can lead to disruptions. On the other hand, the crash expels impurities from the core, aiding in the control of impurity and, in a reactor, helium ash accumulation. For these reasons, accurate modelling is essential for predictive transport simulations and reliable control of plasma behavior in future devices. An integrated model of these cycles is presented, which includes also the effects of additional MHD activity. The phases of a sawtooth cycle: (1) onset criterion, (2) collapse and (3) the recovery phase are modelled either via first-principles (1) and (3) or with an ad-hoc relaxation model (2). The collapse of the fast particle population and rotation profiles are also considered, as they actively and passively affect the sawtooth cycle and are in turn affected by it. The results are validated on ASDEX Upgrade discharges in presence of NBI and ECRH heating schemes.

P 16.8 Thu 13:45 Redoutensaal

Scaling observations of heat transport in the island divertor of W7-X — •Sebastian Thiede[1], Yu Gao[1], Marcin Jakubowski[1], Peter Manz[2], and the W7-X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald, Wendelsteinstraße 1, 17491 Greifswald, Germany — [2]Institut für Physik, Universität Greifswald, Felix-Hausdorff-Straße 6, 17489 Greifswald, Germany

Efficient power exhaust is one of the most important aspects of magnetic confinement devices due to the risk of overloading plasma-facing components (PFCs). Scaling laws of important heat transport parameters are readily available for tokamaks, allowing educated extrapolation to reactor relevant regimes. In the case of stellarators extrapolations are more difficult to justify due to significantly less data being available. Wendelstein 7-X (W7-X) is one of the most advanced stellarators to date. In its recent operational phases the scanned device parameter range was expanded greatly, facilitating the derivation of empirical heat transport scaling laws. A key diagnostic for this derivation is the thermography system that monitors all 10 divertor units of W7-X. Together with the finite-difference code DELVER it is used to get estimates of the impinging heat flux patterns on PFCs. These can be seen as "fingerprints" of different transport processes, and are the main interest of this work. From the variation of the magnetic configuration, the magnetic field strenght and direction, heating power and plasma density we hope to extract trends and possibly quantitative assesment of the relative importance that different transport channels in the scrape-off-layer (SOL) have.

P 16.9 Thu 13:45 Redoutensaal

Fluid Turbulence Simulations in Geometries with Internal Magnetic Islands — •Miguel Madeira[1], Andreas Stegmeir[2], Christoph Pitzal[2], Barnabas Csillag[2], Felix Reimold[1], and Peter Manz[3] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [2]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [3]University of Greifswald, Institute of Physics, Greifswald, Germany

Understanding edge turbulence is crucial for improving plasma confinement. Magnetic islands are especially relevant for the island divertor concept and their potential involvement in the formation of internal transport barriers. The plasma fluid turbulence code GrilliX now supports 3D geometries, including circular toroidal equilibria with magnetic islands and MGRID equilibria. The latter enables simulating the neoclassically optimized stellarator W7-X, with validation currently underway.

W7-X can operate in various magnetic configurations. In several limiter configurations, where the 5/5 islands lie inside the last closed flux surface, the plasma energy increases, peaking in the so-called FMM configuration. This study aims to validate Grillix's new capabilities and to investigate turbulence around W7-X's 5/5 magnetic island chain in limiter configurations. A critical island width for ExB flow around the islands is shown in a circular toroidal geometry consistent with previous studies. In the first W7-X simulations, the perpendicular plasma flow shape previously measured for the FMM configuration is reproduced, showing the characteristic "W" shape.

P 16.10 Thu 13:45 Redoutensaal

RF resolved measurements of the plasma and beam properties in ion sources for the ITER NBI — •Jasper Knaack, Christian Wimmer, Araceli Navarro, and Ursel Fantz — Max Planck Institute for Plasma Physics, Boltzmannstraße 2, Garching bei München, Germany

The neutral beam injectors (NBI) for ITER will require powerful negative ion sources. In such a device, a plasma is ignited in a set of cylindrical drivers. The negative ions are then generated by surface production. Part of the ITER NBI design is the use of RF plasma drivers. The frequency of the RF power that is injected into the driver is 1 MHz. The plasma parameters, such as the plasma potential, of an RF plasma can strongly vary during an RF cycle. Predictions drawn from numerical simulations have also shown large electron flux oscillations in the RF timescale. It is not known how these variations in the plasma parameters influence the extraction of negatively charged particles and thus the beam properties on the RF timescale. In order to study the oscillations in the plasma parameters, diagnostics will be implemented at the Batman UpGrade (BUG) testbed to measure the plasma parameters in an RF-resolved manner. First tests with an avalanche photo-diode have proved to be successful. Moreover, high-speed beam diagnostics will be implemented to study the effect of these plasma parameter variations on the resulting beam. This contribution discusses the planned diagnostics to be implemented in BUG.

P 16.11 Thu 13:45 Redoutensaal

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], Pierre David[1], Matthias Bernert[1], Elisa Buglione-Ceresa[1], Giovanni Tardini[1], Marco Zanini[3], Sehyun Kwak[3], Ulrich Stroth[1], Ou Pan[1], Hartmut Zohm[1,2], the ASDEX Upgrade Team[4], and the W7-X Team[5] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität München, 80539 München, Germany — [3]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany — [4]see the author list of H. Zohm et al. 2024 NF 64 112001 — [5]see the author list of O. Grulke et al 2024 NF 64 112002

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

First, a generic equation for the current diffusion compatible with stellarator geometry is implemented, and the code is coupled to the equilibrium solver VMEC. The equation is benchmarked against theoretical expectations and validated using experimental data from Wendelstein 7-X.

Second, a reduced XPR model, predicting XPR radiation, position, and stability, is developed and implemented in ASTRA. The model is validated against ASDEX Upgrade discharges in the Fenix flight simulator.

P 16.12 Thu 13:45 Redoutensaal

Characterization of plasma turbulence during ELM suppression with Resonant Magnetic Perturbations in ASDEX Upgrade — •Bojana Stefanoska[1], Wolfgang Suttrop[1], Matthias Willensdorfer[1], Rachael M. McDermott[1], Florian Rath[2], Arthur Peeters[2], and the ASDEX Upgrade Team[3] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]University of Bayreuth, 95447 Bayreuth, Germany — [3]see author list of H. Zohm et al. 2024 Nucl. Fusion 64 112001

ELMs pose a major challenge for future fusion reactors due to their potentially unsustainable heat loads on plasma-facing components. Resonant magnetic perturbations (RMPs) can mitigate or suppress ELMs, but the underlying physics of RMP-induced suppression remains unclear. Previous ASDEX Upgrade experiments have shown that the application of RMPs coincides with the onset of a characteristic turbulence regime at the plasma edge, leading to enhanced radial particle transport and a significant reduction of the pedestal density. However, the driving instability, the nonlinear saturation mechanism, and the structure of this turbulence remain open questions. The recently upgraded ECEI diagnostic at ASDEX Upgrade provides high-resolution, 2D measurements of electron temperature fluctuations and is expected to play a central role in the upcoming campaign. In preparation, we perform a systematic multi-diagnostic analysis of turbulence data in previous AUG RMP discharges to identify the dependencies of RMP-driven turbulence on plasma parameters and to guide future experimental strategies. The poster will present an overview of these findings.

P 16.13 Thu 13:45 Redoutensaal

Island divertor studies in 3D using GRILLIX — •Barnabas Csillag[1], Andreas Stegmeir[1], Christoph Pitzal[1], Konrad Eder[1], Miguel Madeira[2], Marion Finkbeiner[1], and Frank Jenko[1] — [1]MPI for Plasma Physics, Garching, Germany — [2]MPI for Plasma Physics, Greifswald, Germany

Understanding and predicting heat exhaust properties is one of the main challenges on the path towards a stellarator power plant. The island divertor is a key feature in the Scrape-Off Layer of most current stellarator reactor designs, and it is also experimentally investigated in the Wendelstein 7-X (W7-X) stellarator. Numerical modeling of island divertors usually relies on transport codes. However, discrepancies between these predictions and experimental data highlight the need for more sophisticated approaches.

In this work, we employ the transcollisional fluid turbulence code GRILLIX to simulate a simplified island divertor geometry. The configuration involves a helically perturbed circular toroidal magnetic field, generating a magnetic island chain at a rational surface. These islands are intersected by discrete target plates aligned with the island chain, mimicking the divertor topology of W7-X. Such model enables the investigation of general island divertor phenomena, including the structure of the electrostatic potential, and the influence of sheared poloidal flows. By analyzing these features, we advance our understanding of island divertor physics in tractable geometries - an essential step before tackling more complex geometries, like W7-X.

P 16.14 Thu 13:45 Redoutensaal

Predicting MANTIS performance in W7-X: Synthetic Modeling of the Expected Operational Regime Using EMC3-EIRENE — •Joey Louwe[1], Felix Reimold[1], Valeria Perseo[1], Victoria Winters[1], Nassim Maaziz[1], Alexander Knieps[2], Henry Greve[1], Mohammad Foisal Siddiki[1], and W7-X team[1] — [1]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [2]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management*Plasma Physics, 52425 Jülich, Germany

Modern large-scale magnetic confinement fusion devices use divertors to optimize particle and heat exhaust. At the Wendelstein 7-X stellarator (W7-X), this is achieved with an Island Divertor concept, where magnetic islands guide particles and heat along field lines to dedicated target plates. Due to its 3D geometry, diagnosing transport across the island is challenging with existing diagnostics. To address this, the new MANTIS imaging system will be combined with helium gas puffs in upcoming campaigns to provide localized measurements of island plasma parameters and infer transport dynamics. Simulation studies using the EMC3-EIRENE plasma fluid transport code were conducted and a new synthetic forward modeling tool to assess MANTIS performance and operational viability was developed. These predictions, informed by existing W7-X data (helium puff spread, electron temperature, and density profiles), enable optimized MANTIS system design and deployment. This contribution presents simulation results, MANTIS performance predictions, and its current integration status.

P 16.15 Thu 13:45 Redoutensaal

Simulations and experiments of early-heating reversed-shear discharges — •Lea Hollendonner[1], Alexander Bock[1], Thomas Pütterich[1], Jörg Stober[1], Jörg Hobirk[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 64 112001

Negative magnetic shear can lead to the suppression of microinstabilities and the formation of internal transport barriers (ITBs). These scenarios hold the potential of improved core confinement and high bootstrap-current fraction but may also lead to impurity accumulation in the core. In order to make predictions based on these scenarios, codes like TGLF must be able to capture the effects of negative shear on transport and quantitatively match experimental profiles in this regime. A prerequisite for these investigations is to achieve stable, distinct regions of negative shear in experiments, and to measure the q-profile with sufficient accuracy. The focus of this poster lies on the early-heating approach which slows down current diffusion of inductive current from the edge to the core region during the ramp-up phase of the discharge. Experiments of early-heating are presented that employ central counter-current ECCD during ramp-up. Based on these discharges, the timing and deposition of ECCD as well as the plasma current ramp is varied in simulations in order to investigate the effects of these actuators on the q-profile evolution.

P 16.16 Thu 13:45 Redoutensaal

Spontaneous density peaking in overdense W7-X plasmas — •Martina Licchelli, Josefine Proll, Golo Fuchert, Håkan Smith, Andreas Langenberg, and Torsten Stange — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Achieving reactor-relevant confinement in stellarators requires reducing both neoclassical and turbulent transport, which limit core temperature and density. In Wendelstein 7-X (W7-X), plasmas with peaked density profiles show reduced energy transport, likely linked to suppressed ion-temperature-gradient turbulence. Such profiles have mostly appeared in pellet- or NBI-fueled discharges, and how these scenarios scale to reactor conditions remains unclear.

A promising alternative is the spontaneous density peaking in overdense, O2-heated plasmas fueled solely by gas puffing. These plasmas exhibit a stable inward particle pinch under pure electron heating, attractive features for reactor operation. However, it is still uncertain whether the resulting density gradients are strong enough to suppress turbulence or whether the pinch mechanism itself changes, leaving important aspects of the scenario's physics unresolved.

This work presents experimental evidence of spontaneous density peaking in overdense W7-X plasmas, with measurements of density profiles, radial electric fields and transport coefficients showing changes in particle transport. Linear and nonlinear simulations identify microinstabilities in different regimes and preliminary analyses of the inward pinch are included. These results offer insight into density peaking and its potential relevance for future stellarator reactors.

P 16.17 Thu 13:45 Redoutensaal

Asymmetric scrape-off layer plasma parameter changes and their implications for diagnostic comparability in W7-X — •F Scharmer[1], A von Stechow[1], C Killer[1], SG Baek[2], S Ballinger[2], Y Gao[1], O Grulke[1,3], S Hörmann[1], M Jakubowski[1], E Maragkoudakis[1], S Thiede[1], A Tsikouras[1], M Vecsei[1], and the W7-X Team[1] — [1]MPI for Plasma Physics, Greifswald (Garching), Germany — [2]MIT PSFC, Cambridge, USA — [3]Department of Physics, TU Denmark, Lyngby, Denmark

The Wendelstein 7-X stellarator experiment uses the island divertor concept for power and particle exhaust. To characterize the scrape-off layer (SOL), different diagnostics view different magnetic islands. The five-fold toroidal symmetry is typically used to combine measurements of separate quantities from different islands. The gas puff imaging (GPI) diagnostic observes complex drift flow patterns in the islands. These flow patterns and SOL profiles are strongly dependent on the magnetic geometry of the island and discharge parameters, such as power and density. GPI measurements show sudden shifts in light emission and fluctuation parameters, indicating changes in plasma conditions. These transitions are not reflected in global core plasma parameters. In addition, divertor heat flux measurements and further SOL diagnostics viewing different islands show that these sudden transitions are often isolated to just one of the five islands. In this contribution, we investigate the prevalence and asymmetry of these SOL plasma parameter changes, as well as their implications for the comparability of physical quantities in different islands.

P 16.18 Thu 13:45 Redoutensaal

Profile Analysis of the Midplane Helium Beam for Scrape-off Layer Characterization at Wendelstein 7-X — •Foisal B.T. Siddiki[1,2], Oliver Schmitz[1], Maciej Krychowiak[2], Frederik Henke[2], Dorothea Gradic[2], and Miklos Vecsei[2] — [1]University of Wisconsin-Madison, Madison, USA — [2]Max Planck Institute for Plasma Physics, Greifswald, Germany

Optimizing the heat and particle exhaust system of Wendelstein 7-X (W7-X) requires a quantitative understanding of scrape-off layer (SOL) transport, informed by measurements of the electron temperature (Te) and density (ne). To investigate SOL transport, a new helium-beam system was installed at the midplane of W7-X and operated during the OP2.2 and OP2.3 experimental campaigns. The midplane helium-beam diagnostics consist of a controlled gas injection system and a high-resolution spectrometer, from which Te and ne are inferred using helium line ratios based on a collisional radiative model of atomic helium. In this work, we present the first results from the midplane helium beam and benchmark them against co-located alkali-beam measurements. Initial analysis of the midplane profiles reveals two distinct SOL transport regimes. SOL characteristic decay lengths and heat-flux width scaling derived from these profiles will also be presented.

P 16.19 Thu 13:45 Redoutensaal

Development of multi-diagnostic Bayesian analysis system for inference of plasma parameters in the W7-X edge — •Linnéa Björk[1], Felix Reimold[1], Chris Bowman[2], Takashi Nishizawa[3], and Gabriele Partesotti[1] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]Culham Centre for Fusion Energy, Culham Science Centre, United Kingdom — [3]Kyushu university, Kasuga, Japan

The W7-X machine is an experimental fusion device designed to study the reactor relevance of the stellarator concept. Its complex three-dimensional geometry makes it difficult to measure the full field of plasma parameters, particularly in the scrape-off layer (SOL), where plasma behaviour can be highly localized. For future reactor design it is important to understand the physics and transport mechanisms in this region. Consequently, a system for integrated Bayesian analysis is implemented for W7-X which will enable the reconstruction of key plasma parameters from a limited diagnostic coverage.

The first steps in the building of the analysis tool and its adaptation to W7-X geometry are here presented. For benchmarking of the system, inversions of bolometry data have been performed and compared to results from Gaussian Process tomography. The two methods agree well, with the full Bayesian inference scheme handling large errors better but being more computationally costly. Further results include introducing divertor spectroscopy both as constraints to the tomographic inversions and as part of the later effort to infer electron density and temperature.

P 16.20 Thu 13:45 Redoutensaal

Helium exhaust studies in ASDEX Upgrade — •Simon Krumm[1], Athina Kappatou[1], Antonello Zito[1], Volker Rohde[1], Gerd Schall[1], Marco Wischmeier[1], Rachael M. Mcdermott[1], and the ASDEX Upgrade Team[2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]see the author list of H. Zohm et al. 2024 NF 64 112001

Helium is one of 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. Recent work at ASDEX Upgrade (AUG) investigated the helium removal in Type-I ELMy H-modes both experimentally and numerically [A. Zito et al. 2023 Nucl.Fusion 63 096027 & 2025 Nucl.Fusion 65 046022]. Helium removal is hindered by its high wall retention in tungsten, as well as the inefficiency of active pumping in AUG. Most importantly, because of helium's high ionisation energy, its divertor retention is low compared to other impurities, leading to inefficient transport from the divertor to the pumping surfaces. The next step is to investigate reactor relevant scenarios - especially those compatible with power exhaust - to also assess their compatibility with helium exhaust. For this, neutral partial pressure measurements in the divertor are needed. We employ optical in-situ and ex-situ Penning gauges, as well as Threshold Ionization Mass Spectrometry in the pumping ducts. Additionally, utilising these diagnostics, the new activated charcoal cryopump [G. Schall et al. 2021 Fusion Eng. Des. 166 112316] recently installed on AUG can be characterised for its helium pumping capability.

P 16.21 Thu 13:45 Redoutensaal

Characterisation of phase velocities and dispersion relations in Wendelstein 7-X turbulence, assisted by sensitivity analysis of poloidal correlation reflectometry — Sander De Koker[1,2], Gavin Weir[2], Carsten Lechte[3], Andreas Krämer-Flecken[4], •Thomas Windisch[2], Olaf Grulke[2], and Peter Manz[1,2] — [1]University of Greifswald, Institute of Physics, Greifswald, Germany — [2]Max Planck Institute for Plasma Physics, Greifswald, Germany — [3]Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie, University of Stuttgart, Stuttgart, Germany — [4]Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics, Forschungszentrum Jülich GmbH, Jülich, Germany

Different instabilities in plasmas differ in terms of their phase velocity, which is therefore used to identify them. One diagnostic well suited for this is poloidal correlation reflectometry. The sensitivity of its measurement capabalities and its dependence on various parameters is however not fully understood. In order to improve the understanding of turbulence dispersion relations and phase velocities, an initial goal is to investigate and characterise this sensitivity. As a first step, full wave simulations have been performed, showing a dependence of the sensitivity on both turbulence poloidal wavenumber as well as antenna separation.

P 16.22 Thu 13:45 Redoutensaal

Towards photonic radiometry: Electron Temperature and Density profiles from broadband ECE spectra — •Taurino Reichert[1], Dmitry Moseev[1], Sergiy Ponomarenko[1], Vessen Vasilev[2], Ruwan Udayanga[2], Peter Andrekson[2], Annina Moser[3], and Benedikt Baeuerle[3] — [1]Max Planck Institut für Plasmaphysik, Greifswald, Germany — [2]Chalmers University of Technology, Göteborg, Sweden — [3]Polariton Technologies AG, Adliswil, Switzerland

The trend towards higher magnetic fields in future fusion experiments adds complexity to the design of heterodyne Electron Cyclotron Emission (ECE) radiometers used for measurement of electron temperature (T_e) profiles. The evaluation of a single ECE harmonic might require the acquisition of a broadband signal, effectively calling for multi stage systems or multiple separate radiometers. This work outlines the development of a proof-of-concept single stage broadband radiometer at W7-X. Here, ECE spectra between 140 GHz to 220 GHz will be acquired through up-conversion to the Short Wavelength Infrared (SWIR) range around 1550 nm using a plasmonic Mach-Zehnder-Modulator (MZM). The optical signals will be evaluated with a SWIR spectrometer. T_e profiles are directly obtained from the optically thick second harmonic X-mode (X2) while n_e profiles are reconstructed from the optically thin third harmonic X-mode (X3) using the ray-tracing code TRAVIS. The diagnostic is expected to yield ECE spectra with a frequency resolution of 1 GHz. The time resolution is yet to be found, aiming at a range between 1 ms to 10 ms.

P 16.23 Thu 13:45 Redoutensaal

Development of a surface retention model for plasma-wall interactions simulations in the SOLPS-ITER code package — •remo iannini[1,2], antonello zito[1], tim happel[1], david coster[1], klaus schmid[1], gregor birkenmeier[1,2], and the ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, Garching bei Munchen, Germany — [2]Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany

In a fusion reactor, particles escaping the last closed flux surface (LCFS) inevitably interact with the first-wall materials. These surfaces can behave as both sinks and sources for plasma particles, as these can be either absorbed or recycled. Accurately modelling these processes is therefore essential to predict the impact of plasma-wall interactions on plasma transport and exhaust. At present, the SOLPS-ITER code package represents the standard framework for plasma edge modelling. Processes contributing to a long-term retention of plasma particles within the wall surfaces are, however, not currently included within the code capabilities. This PhD project aims to develop a fully integrated, self-consistent wall retention module for the SOLPS-ITER framework, enabling more realistic simulations of plasma-wall interactions by allowing the presence of a temporary wall inventory of plasma particles. This would enable the assessment of impurity dynamics during plasma discharges, the long-term evolution of fuel retention in wall materials, and the prediction of the boronization layer lifetime for ITER.

P 16.24 Thu 13:45 Redoutensaal

GPU Acceleration of Hybrid Fluid-Kinetic Simulations of Runaway Electrons in JOREK — •edoardo carrà, patrik rác, hannes bergström, and matthias hölzl — Max Planck Institute for Plasma Physics

JOREK is a 3D nonlinear, extended magneto-hydrodynamic and hybrid fluid-kinetic code for investigating large scale transient plasma dynamics in realistic tokamak and stellarator fusion plasmas. In high-current tokamaks such as ITER, loss of plasma confinement in a disruption can generate highly energetic "runaway" electrons (REs), which can pose a serious threat to plasma-facing components. Understanding and predicting RE dynamics is therefore essential for safe operation of future fusion reactors. While JOREK supports MPI + OpenMP parallelization on CPUs, hybrid RE simulations span widely different timescales, making them computationally prohibitively expensive on conventional CPU architectures. This work addresses that challenge by porting the fluid and kinetic components of hybrid RE simulations to GPUs. Using OpenMP directives, we ensure portability and transparency across hardware platforms while achieving significant performance improvements. We detail the optimization strategies employed and present a comprehensive performance and verification study on NVIDIA and AMD accelerated architectures by benchmarking the linear growth rate of plasma instabilities in the presence of REs and performing a highly non-linear RE beam termination event as first large-scale physics application.

P 16.25 Thu 13:45 Redoutensaal

Characterising the Influence of E_r Magnitude and Shear on Turbulent Fluctuations in Wendelstein 7-X — •Jan Ricken, J. Proll, H. Smith, A. Langenberg, J. Bähner, G. Fuchert, E. Maragkoudakis, and G. Weir — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

In neoclassically optimised stellarators such as Wendelstein 7-X (W7-X), turbulence is the main driver of heat and particle losses, making its regulation crucial to understand. Although the radial electric field, E_r, and its shear are known to suppress turbulent transport in tokamaks, their quantitative impact in W7-X remains to be studied.

In this work, we present first results from a comprehensive database that link experimentally measured E_r profiles to (turbulent) fluctuations and transport indicators across a diverse set of W7-X programs. The database enables a systematic comparison of turbulence characteristics with both the magnitude and shear of E_r.

Experimentally observed trends are compared with neoclassical predictions from the code Neotransp to assess the consistency between measured and expected E_r profiles. In addition to providing neoclassical E_r estimates, Neotransp is also used to infer the level of turbulent transport required to satisfy power balance, thereby offering an estimate of turbulence-driven fluxes for a given E_r profile. Complementarily, GENE flux tube simulations are employed to isolate and quantify the sensitivity of turbulent fluctuations to experimentally relevant variations in the E_r shear.

P 16.26 Thu 13:45 Redoutensaal

Implementation of the non-linear Fokker-Planck collision operator for gyrokinetic codes using a moment approach — •Andrew Ivan Sulimro[1], Philipp Ulbl[1], Baptiste Frei[1], and Frank Jenko[1,2] — [1]Max-Planck Institute for Plasma Physics — [2]University of Texas at Austin

The performance of future magnetic confinement fusion power plants is primarily influenced by plasma confinement which is driven by turbulence. High-fidelity gyrokinetic simulations are key tools to investigate turbulence in fusion devices.

Accurate modeling of collisional physics is essential for these simulations. 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. On the other hand, the full Fokker-Planck collision operator is computationally expensive due to its integro-differential form.

In this work, the non-linear Fokker-Planck collision operator is solved using a moment approach. This approach provides a systematic manner to capture collisions up to a desirable accuracy while maintaining performance. The implementation is verified through relaxation and conservation studies. We will also demonstrate the physical impact of collisions in zonal flow damping.

P 16.27 Thu 13:45 Redoutensaal

Neural ODEs for Density and radiated Power Modeling — •Vadim Munteanu, Daniel Böckenhoff, and Maciej Krychowiak — Wendelsteinstraße 1, 17491 Greifswald, Germany

Real-time capable simulations of plasma in experimental fusion devices, known as flight simulators, are of interest for fusion research as they permit more informed session planning and the development and validation of control schemes before experimentation. Although for tokamaks mature simulators exist at relevenat fidelity, because of stellarator*s more complex geometry, similar models are much more costly, rendering them unfeasible for flight simulation. Recently, with the advent of computing power, data abundance and democratization of machine-learning tool-boxes, data-driven methods became feasible in solving the above mentioned shortcomings of traditional modelling techniques. We are investigating if neural controlled differential equations, a deep learning architecture designed for modelling of irregular time series, can efficiently represent plasma dynamics and serve as a potential simulator for control tasks. We train the model on a small dataset from the last experimental campaign of W7-X to model the evolution of several plasma diagnostics under control parameters such as gas fueling, imputiry seeding and electron cyclotron heating. We show that the model is able to capture correlations between actuators and plasma diagnostics. Next we plan to increase the dataset and to extend plasma state with additional diagnostics, and perform a hyperparameter search.

P 16.28 Thu 13:45 Redoutensaal

Equilibrium and stability of an electron plasma in a levitated dipole trap — •Patrick Steinbrunner[1], Adam Deller[1,2], Thomas O'Neil[2], Veronika Bayer[1,3], Matthew Stoneking[4], and Eve Stenson[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]University of California San Diego, La Jolla, California, 92093 USA — [3]Technical University of Munich, 80333 Munich, Germany — [4]Lawrence University, Appleton, Wisconsin, 54911 USA

As part of the APEX collaboration (An Electron Positron eXperiment) this work supports the experimental results obtained with pure electron plasmas in a levitated dipole trap using two distinct computational methods. The levitated dipole trap confines electrons on closed, purely poloidal magnetic field lines around a superconducting coil that is floating in a vacuum chamber due to external magnetic fields. In combination with positrons coming from NEPOMUC (NEutron induced POsitron source MUnich) this trap will ultimately confine a first of its kind, non-relativistic pair plasma. First measurements of the local space charge potentials are used to reconstruct the electron density distribution assuming a local thermal equilibrium along magnetic field lines and solving the Poisson-Boltzmann equation. In addition, results of a 2D drift kinetic model are presented that extend a linear stability analysis conducted previously. This model resembles the large-aspect-ratio limit of the levitated dipole trap, an infinite, current-carrying wire. The implementation of the actual magnetic dipole field is subject to a future study.

P 16.29 Thu 13:45 Redoutensaal

Applications of Plasma-KG, a knowledge graph for low-temperature plasma physics — •Markus M. Becker[1], Ihda Chaerony Siffa[1], Hidir Aras[2], Holger Israel[3], Thomas Koprucki[4], Burkhard Schmidt[4], and Markus Stocker[3] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]FIZ Karlsruhe – Leibniz Institute for Information Infrastructure, Eggenstein-Leopoldshafen, Germany — [3]TIB – Leibniz Information Centre for Science and Technology, Hanover, Germany — [4]Weierstrass Institute (WIAS), Berlin, Germany

Knowledge graphs (KGs) play an important role in the structured representation and linking of data, information, and knowledge. As a result, knowledge graphs are finding broad application in the field of research data management. Building on the established plasma metadata schema Plasma-MDS and the plasma ontology Plasma-O, the development of Plasma-KG (https://vivo.plasma-mds.org) was initiated to represent reusable entities with persistent identifiers in the field of low-temperature plasma physics. This contribution introduces the essential concepts of Plasma-KG and shows how various data sources can be connected via these formally described entities. The addressed fields of application include content enrichment from knowledge graphs for patents, scientific articles, and mathematical models. It is demonstrated how the future physics information service 'FID Physik' can benefit from Plasma-KG as a semantic data platform.

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P 16.30 Thu 13:45 Redoutensaal

ERO2.0 code validation using boron erosion experiments at PSI-2 — •Andriy Tarasenko[1,2], Christoph Baumann[1], Juri Romazanov[1], Sebastijan Brezinsek[1,2], Marc Sackers[1], and Arkadi Kreter[1] — [1]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics, 52425 Jülich, Germany — [2]Faculty of Mathematics and Natural Sciences, Heinrich Heine University Düsseldorf

Reliable predictions of plasma-wall interactions are essential for the design and operation of future fusion devices. In this work, the impurity transport code ERO2.0 is benchmarked against boron (B) erosion experiments performed at the linear plasma device PSI-2. Thin B layers on tungsten substrates were exposed to deuterium (D) plasmas with ion energies near the physical sputtering threshold, and erosion was quantified through post-mortem FIB-cuts analysis and optical emission spectroscopy. Experimentally inferred sputtering yields exceed classical BCA predictions, confirming earlier observations, such as those by Hechtl et al. of enhanced near-threshold B erosion. The exceeding yield can be caused by chemical erosion, which was investigated and compared with measured BD band emission. Using experimental plasma profiles, SDTrimSP sputter data, and synthetic emission line modelling, ERO2.0 reproduces key features of the measured impurity distribution and B emission profiles. The comparison highlights parameter sensitivities and demonstrates the capability of ERO2.0 to interpret PSI-2 measurements and support predictive modelling for ITER.

P 16.31 Thu 13:45 Redoutensaal

Secondary electron emission from coated plasma walls — •Franz Xaver Bronold and Felix Willert — Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany

Having in mind dielectrically coated metal electrodes, used in barrier discharges, we investigate–from a theoretical solid-state physics point of view–the emission of secondary electrons from solid structures consisting of a thin dielectric layer on top of a metallic or semiconducting halfspace. We thus extend the invariant embedding principle for the electron backscattering function, which we used so far for halfspaces [1], to a stack of two materials. In addition to two backscattering functions, one for the coating and one for the supporting material, the electron transmission function for the coating has to be computed now as well. Focusing on low energies, and describing the solid structure by a randium-jellium model, containing electron-phonon, electron-ion-core, and electron-electron scattering (leading to impact ionization inside the two materials), we obtain, as a function of layer thickness, the electron surface scattering kernel for the total structure as well as the energy- and angle-resolved secondary electron emission yield. Besides showing results for SiO_2/Si and SiO_2/Au, we also discuss the numerics used for integrating the set of matrix Riccati/Sylvester differential equations for the backscattering and transmission functions of the coatings, which now appear along with the algebraic equation for the support's backscattering function.[1] F. X. Bronold and F. Willert, Phys. Rev. E **110**, 035207 (2024). Supported by Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)–495729137.

P 16.32 Thu 13:45 Redoutensaal

Microphysical boundary condition for the electron Boltzmann equation of a plasma — Felix Willert[1], •Clemens Hoyer[1], Gordon K. Grubert[2], and Franz X. Bronold[1] — [1]Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany — [2]Universitätsrechenzentrum, Universität Greifswald, 17489 Greifswald, Germany

We set up an energy- and angle-dependent boundary condition for the electron Boltzmann equation containing the electron microphysics inside the wall [1]. At low energies the boundary condition is based entirely on a computed electron surface scattering kernel [2], while at higher energies measured emission yields are, in addition, fed into the microscopic model to obtain plausible data also in this energy range. We incorporate the kernel within the expansion approach of solving the electron Boltzmann equation, expanding the electron distribution function in Legendre polynomials and linking the expansion coefficients to the moments of the electron flux at the plasma-wall interface, but it can be also implemented in a PIC-MCC simulation of the plasma's electron kinetics. Numerical results for argon, helium, and oxygen plasmas in contact with Si and SiO_2 surfaces are presented, showing in particular the significance of the inelasticity of the microphysics-based boundary condition compared to an energy- and angle independent phenomenological one. [1] F. Willert et al., arXiv:2511.20346 (2025). [2] F.X. Bronold and F. Willert, Phys. Rev. E **110**, 035207 (2024). F.X.B. and F.W. acknowledge support by Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)–495729137.

P 16.33 Thu 13:45 Redoutensaal

Progress in modelling of shattered pellet injection experiments in fusion plasma — •Ansh Patel[1], Gergely Papp[1], Akinobu Matsuyama[2], Mengdi Kong[3], Stefan Jachmich[4], Umar Sheikh[3], Javier Artola[4], Paul Heinrich[1], and Eric Nardon[5] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Kyoto University, Uji, Kyoto, Japan — [3]EPFL, Swiss Plasma Center (SPC), Lausanne, Switzerland — [4]ITER Organization, France — [5]CEA, IRFM, France

Large tokamaks like ITER will require a disruption mitigation system (DMS) like the shattered pellet injection (SPI) to ensure machine protection during disruptions. The SPI system injects cryogenic pellets that are shattered before entering the plasma. For the DMS design validation, the effectiveness of SPI must be assessed by numerical simulations. For this purpose, reduced modelling is applied to scan the wide system parameter space available for optimisation and to understand experimental trends. In this poster, we present recent progress in the modelling of the SPI experiments at ASDEX Upgrade (AUG) and JET tokamaks using the INDEX code. We investigate the pre-thermal-quench (pre-TQ) duration trends for varying neon fraction injections in AUG, an important optimization parameter for multiple injections. We have also implemented a recently developed rocket-force model in INDEX and present some initial model estimates for AUG. Additionally, we also present simulation results of recent plasmoid-drift supression experiments at JET with neon doping.

P 16.34 Thu 13:45 Redoutensaal

EMC3-EIRENE predictions of radiative detachment scenarios in W7-X equipped with a tungsten based divertor — •Daniil Ryndyk[1], Derek Harting[1], Shuai Xu[1], Yuhe Feng[4], Florian Effenberg[3], Heinke Frerichs[2], Sebastijan Brezinsek[1], and W7-X team[4] — [1]FZJ GmbH, IFN-1, Jülich, Germany — [2]University of Wisconsin-Madison, Madison, WI, USA — [3]PPPL, Princeton, NJ, USA — [4]MPG IPP, Greifswald, Germany

The nuclear fusion experiment Wendelstein 7-X (W7-X) currently operates with carbon-fiber composite (CFC) plasma-facing components (PFC) forming the island divertor used for particle and power exhaust. In a future fusion reactor, carbon-based PFCs are not tolerable due to unacceptably high fuel retention. An alternative PFC material for a fusion reactor is tungsten (W), which shows in general low sputtering, low fuel retention, and good thermomechanical properties.

As a first systematic approach to study the impact of potential W PFCs in W7-X, we use EMC3-EIRENE as plasma boundary simulation code for 3D magnetic configurations. We investigate detachment scenarios with the standard magnetic configuration of W7-X equipped with a W divertor based on the current divertor geometry and analyze the dependence of detachment relevant parameters (e.g. target heat loads) on operation conditions (e.g. plasma density). In a comparison with the detachment behavior of the current C divertor, we discuss the accessibility of similar, impurity radiation determined detachment and the relevance of volume recombination processes.

P 16.35 Thu 13:45 Redoutensaal

Computational modeling of hot-cathode ionization gauges for fusion applications — •Alexander Glock[1,2], Michael Griener[1], Christian Drobny[1], Gregor Birkenmeier[1,2], Hans Meister[1], and Georg Schlisio[1] — [1]Max Planck Institute for plasma physics (IPP), Garching/Greifswald, Germany — [2]Technical University of Munich (TUM), Munich, Germany

In magnetic confinement fusion, the measurement of neutral gas densities is an essential metric for plasma control. Hot-cathode ionization gauges are commonly used for this purpose. The so-called ASDEX gauge is a diagnostic instrument designed to provide local and temporally resolved measurements of neutral gas pressure in the presence of strong magnetic fields. It is a hot-cathode ionization gauge with a linear geometry. Its operation relies on the measurement of an ion current produced when electrons emitted from the hot cathode collide with neutral gas particles. This gauge type has been successfully adapted for use in ASDEX Upgrade and Wendelstein 7-X, with further modifications developed for ITER. However, the linear geometry can also introduce signal instabilities due to complex particle interactions within the gauge head. The present project aims to deepen the understanding of the physical processes inside the gauge and to investigate these effects using a detailed computational model validated against experimental data. The gauge system is modeled with a kinetic Boltzmann approach solved through the particle-in-cell (PIC) method with Monte Carlo collisions (MCC), capable of performance prediction and design optimizations toward a robust and universal fusion diagnostic.

P 16.36 Thu 13:45 Redoutensaal

Towards neoclassical tungsten transport calculations in the edge and island divertor region of optimized stellarators — •Diogo Mendonça[1,2], Matthias Hoelzl[1], Orin Varley[1,2], Mate Szucs[1,2], and Luca Venerando Greco[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]TUM School of Natural Sciences, Boltzmannstraße 10, 85748 Garching, Germany

The successful operation of future nuclear fusion power plants requires strict control over tungsten (W) impurity transport during plasma discharges. If these high-Z impurities accumulate within the plasma, they may severely degrade fusion performance, or make it impossible altogether. This critical issue is not yet fully understood in tokamaks, and even less so in stellarators, which have recently seen renewed interest as promising magnetic confinement concepts. This contribution presents the first studies of collisional W transport using the kinetic model developed in the JOREK code, combined with its recently implemented reduced magnetohydrodynamics (MHD) stellarator model, focusing specifically in the trace impurity limit. By varying the initial positions of W particles within a fixed W7-AS stellarator equilibrium, we aim to quantify the influence of collisions, the electric field, and temperature around magnetic islands on the transport of W in the edge and island divertor region.

P 16.37 Thu 13:45 Redoutensaal

Reduced Modelling of MHD instabilities and Internal Transport Barriers — •Erik Eidsvig[1,2], Philipp Lauber[1,2], and the ASDEX Upgrade Team[2] — [1]Technical University of Munich — [2]Max Planck Institute for Plasma Physics

Experimentally, fishbones have been observed before the Internal Transport Barrier (ITB) formation in ASDEX Upgrade. In this work, the goal was to investigate the relationship between the fishbone instability and the internal transport barriers. As a first step, reduced models describing the fishbone dynamics and its relationship to turbulence were implemented numerically. The fishbone instability is connected to the turbulence through the current it generates, which drives a poloidal shear flow which can break up turbulent eddies. It was found that the deposition rate of trapped energetic particles, D was the most important factor for setting up the Internal Transport Barrier (ITB), agreeing with the findings from Liu and Fu (2023). The reduced models were tested on ASDEX Upgrade discharge #37114, and the simplified flow shear approximation alone is not sufficient to explain the temperature peaking in the shot. This may indicate that the magnetic shear plays a role in the ITB state observed in the shot.

P 16.38 Thu 13:45 Redoutensaal

A dual machine learning framework for electron density profile reconstruction — •Christos Vagkidis, Mirko Ramisch, Günter Tovar, and Alf Köhn-Seemann — IGVP, University of Stuttgart, Germany

Machine learning algorithms can be used either as surrogate models to replace high-fidelity codes or as tools to provide some physical information. In this work, a random decision forest is applied to replace a 3D full-wave model and a deep neural network (DNN) to reconstruct the electron plasma density profile.

The COMSOL Multiphysics software is used for the 3D modeling. A microwave is propagating through an axially symmetric plasma. The spatial power distribution of the wave is measured after the interaction with the plasma. The random forest is trained on these data and is able to predict the wave power for a given electron density profile.

A new dataset is created with the random forest and is used to train the DNN, which is used as an inverse model. By using the beam power as input, the DNN predicts the electron density. The final step is to test the DNN on actual experimental conditions. For this purpose, an atmospheric plasma torch will be used.

P 16.39 Thu 13:45 Redoutensaal

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 Tovar[1], and Alf Köhn-Seemann[1] — [1]IGVP, University of Stuttgart — [2]University of Greifswald

The plasma wakefield mechanism appears as a solution to produce particles with higher energies than circular accelerators. To achieve the necessary high electric fields, the plasma medium must have a large electron density to create strong gradients. Helicon plasma discharges allow to achieve the plasma densities necessary for effective plasma wakefield accelerators. This study aims to understand helicon wave propagation in linear devices for plasma wakefield optimization and the influence of different antenna geometries on the efficiency of helicon wave excitation. Furthermore, the evolution of the radial plasma density gradient on the coupling to the helicon wave is studied. Numerical modeling of helicon discharges is made using a finite element method (FEM) analysis through the COMSOL Multiphysics code package. Antennas are modeled using the AC/DC and RF modules, then the plasma column response is simulated using the Plasma module. In parallel, the 3D finite-difference time-domain (FDTD) code FHELI (FOCAL for HELIcon) is used for comparative analysis. The code solves the Maxwell equations in conjunction with the fluid motion equation for electrons in a cold magnetized plasma. The numerical scenarios are based on the VINETA.75 device parameters and geometry.

P 16.40 Thu 13:45 Redoutensaal

Influence of a spacially variable plasma on a cavity's resonance structure for use in a multimodal microwave cavity resonance spectroscopy approach using 3D EM-simulations — •Johanna Vogt[1], Michael Friedrichs[1], Andreas Petersen[2], Franko Greiner[2], and Jens Oberrath[1] — [1]Modelling and Simulation, South Westphalia University of Applied Sciences, 59494 Soest, Germany — [2]Institute of Experimental and Applied Physics, Kiel University, 24118 Kiel, Germany

Several techniques have been developed to bridge the gap between measurable inputs and important plasma parameters, one group of which is active plasma resonance spectroscopy (APRS). In it, a wide-band electromagnetic (EM) signal is coupled into the plasma, and the frequency response of the system is evaluated via a model to yield certain parameters, which can then be used to determine the electron density. One such method is the microwave cavity resonance spectroscopy (MCRS), which analyses the shift of resonance frequencies of a cavity inside a reactor. A promising application due to its non-invasive nature is the characterisation of nanodusty plasmas, and a multimodal approach may yield a spatially resolved electron density profile.

To achieve this, a 3D-EM simulator is used to compare the spectra of a cavity filled with a spatially variable plasma to a vacuum case, and the resulting frequency shifts are analysed to determine local profiles.

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P 16.41 Thu 13:45 Redoutensaal

Probing Ion Drag and Electric Field Forces in CCRF Plasmas with Optical Tweezers — •Jessica Niemann, Viktor Schneider, and Holger Kersten — Institute of Experimental and Applied Physics, Christian-Albrechts-University Kiel, Germany

Many different diagnostics can be used to measure the spatial distribution and temporal evolution of plasma parameters. Over the past decade, the concept of utilizing externally injected microparticles as non-invasive probes, influenced by various forces and energy fluxes in plasmas, has been implemented. Information about local electric fields, energy fluxes, and momentum transfer by ions to the particles can be obtained based on their behavior in the plasma. Especially, the manipulation of microparticles by an optical tweezer is of interest, as it enables the microprobe to be positioned in areas of the plasma typically inaccessible to conventional diagnostic methods, such as the plasma sheath. In this study, optically trapped microparticles in a highly focused laser beam are used to investigate both the electrostatic field force in the sheath and the ion drag force in the presheath of a capacitively coupled radio-frequency discharge. These forces differ by roughly one order of magnitude, requiring adjustments of the trapping laser power to control the sensitivity of the optical trap accordingly. By observing the displacement of the trapped particle under varying gas pressure and phase angle in dual-frequency discharges, the spatial structure and parameter dependence of both forces are resolved. These measurements allow the experimental reconstruction of the fundamental plasma structure comprising bulk, presheath, and sheath.

P 16.42 Thu 13:45 Redoutensaal

In-vacuo DBD-XPS surface study of Au and Ag electrodes exposed to N_2/H_2 plasmas — •A.A. Ben Yaala[1], R. Antunes[1], T. Höschen[1], A. Manhard[1], A. Hecimovic[1], and U. Fantz[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching, Germany — [2]University of Augsburg, 86149 Augsburg, Germany

Dielectric barrier discharge (DBD) reactors are one of the most commonly studied discharges for plasma-assisted ammonia (NH_3) synthesis due to their simplicity, low gas temperatures, and compatibility with catalytic materials. However, the limited access to the catalyst's surface in conventional DBD designs hinders a detailed fundamental understanding of the plasma-surface chemistry responsible for NH_3 formation.

In this work, an in-vacuo planar DBD-XPS (X-Ray Photoelectron Spectroscopy) setup developed to investigate the chemistry of electrode surfaces exposed to N_2/H_2 plasmas is introduced. The use of noble surfaces such as gold (Au) and silver (Ag) prevents formation of metallic nitrides and enables studying the effect of adsorbed NH_x species. This contribution compares the concentrations of the adsorbates resulting from various plasma conditions with the ammonia synthesis rates determined with mass spectrometry.

P 16.43 Thu 13:45 Redoutensaal

Investigation and characterization of a linearly extended microwave plasma source for a metal foil pump — •Tim Werz, Stefan Merli, Andreas Schulz, Matthias Walker, and Günter Tovar — University of Stuttgart, Germany

Future fusion power plants use only a fraction of the fuel materials. Being able to separate and recirculate tritium and deuterium from the exhaust gas is a critical step towards industrialization. A promising design to achieve isotope separation is a metal foil pump (MFP). The MFP utilizes superpermeation of atomic hydrogen isotopes to separate it from molecular hydrogen, helium and plasma enhancing gases. This separation technique can even be used against a pressure gradient.

In order to generate the atomic isotopes on the upstream side, the Duo-Plasmaline, a linearly extended and highly scalable microwave plasma source, is utilized. This plasma source is being investigated via a number of different analysis techniques, such as optical emission spectroscopy and Langmuir-Probes. A energy dispersive mass spectrometer is used to obtain information about the ion energy and types. The plasma density, temperature, distribution and type of ions, as well as impurities and non metalic layers on the metal foil play a critical role in its performance. Besides hydrogen species, heavier atoms and ions such as carbon, nitrogen and oxygen are being investigated.

P 16.44 Thu 13:45 Redoutensaal

Design and simulation of a Cylindrical Deflection Analyzer — •Leo Zeidler, Thomas Trottenberg, and Holger Kersten — Christian-Albrechts-Universität Kiel

Electric propulsion (EP) thrusters have become standard in satellite systems since the 1990s [1]. The growing demand for space missions has accelerated the development and refinement of new thruster concepts [2]. The Ref4EP project, a collaboration between Kiel University, Giessen University, and IOM Leipzig, aims to standardize pre-flight testing procedures for EP devices. This involves the development of a 127° Cylindrical Deflection Analyzer (CDA) which is an alternative to traditional Retarding Potential Analyzers (RPAs) for measuring ion energy distribution functions (IEDFs) in ion beams. While on-flight diagnostics typically rely on robust top-hat analyzers, the CDA offers advantages for laboratory environments due to simple electrode geometry and higher energy resolution.

The final CDA design along with numerical simulations are presented.

[1] K. Holste et al., Rev. Sci. Instrum. 91 (2020) 061101
[2] T. Trottenberg et al., EPJ Tech. Instrum. 8 (2021) 16

P 16.45 Thu 13:45 Redoutensaal

The ALBATOR project: A 3.5-year visionary project pioneering a contactless solution for space debris removal — •Viktor Schneider for the ALBATOR-Collaboration — Institute of Experimental and Applied Physics, Christian-Albrechts University Kiel

ALBATOR, proposes the use of the Ion Beam Shepherd method as a concept for contactless space debris removal, which relies on momentum transfer from a collimated, multiple charged plasma beam. The project focuses on designing and developing an Electron Cyclotron Resonance (ECR)-like ion beam system. To achieve that ambition, ALBATOR will optimize the ion beam system by gaining a deep understanding of plasma discharge and plume expansion physics. It will create advanced models to simulate plasma discharge and its interaction with debris, accounting for factors such as multiple charged ions, electromagnetic wave behavior, and materials interactions like sputtering, which influence momentum transfer. A series of vacuum chamber tests will be conducted to characterize the ion beam's properties, such as ion current, energy, and composition, under simulated space conditions. Additionally, the interaction of the ion beam with various satellite materials will be studied to assess its efficieny in momentum transfer. The systems versatility will also be tested using different propellants. The results from these tests will contribute to simulations of various mission scenarios, including debris deorbiting and detumbling.

P 16.46 Thu 13:45 Redoutensaal

Simulation of a Birdcage Antenna for Efficient Helicon-Mode Excitation — •Bennet Schahl, Luis Herrera Queseda, Alf Köhn-Seemann, and Günter Tovar — IGVP, University of Stuttgart, Germany

Helicon discharges can generate plasma densities significantly higher than those of conventional radio-frequency sources at comparable input power, making them attractive for applications ranging from plasma wakefield accelerators and plasma propulsion to fusion-relevant experiments and semiconductor manufacturing. Helicon waves are bounded whistler waves belonging to the family of right-hand polarized waves.

Birdcage antennas offer a promising geometry for coupling RF power into magnetized low-temperature plasmas. They form resonant network structures consisting of repeated parallel assemblies of inductive and capacitive elements that support distinct sets of resonant modes. This work focuses on optimizing a birdcage antenna for efficient excitation of electromagnetic waves in the so-called "helicon regime".

The study is conducted using COMSOL Multiphysics with the primary objective of optimizing the birdcage antenna design. The electromagnetic properties of the antenna are modeled to identify parameters that maximize field structures favorable for helicon-mode excitation. Based on these optimized configurations, the model may optionally be extended to include a plasma domain, enabling the evaluation of power deposition, mode formation, and the resulting plasma response.

The combined results aim to guide the design of future experimental setups.

P 16.47 Thu 13:45 Redoutensaal

Simulation of electron swarms in cylindrical magnetrons and their interaction with a boundary — •Gibran Brune[1], Lukas Vogelhuber[1], Kevin Köhn[1], Dennis Krüger[1], Jens Kallähn[1], Yulia Sharova[1], Liang Xu[2], Denis Eremin[1], and Ralf Peter Brinkmann[1] — [1]Institute of Theoretical Electrical Engineering, Ruhr University Bochum, Universitätsstrasse 150, D-44801 Bochum, Germany — [2]School of Physical Science and Technology, Soochow University, Suzhou 215006, China

In this work, the motion of electrons in a cylindrical magnetron is simulated using predefined analytical electric and magnetic fields. Electrons are modeled as particles with an initial Maxwell-Boltzmann velocity distribution and are uniformly initialized within the simulation domain. Particle trajectories are computed using the Boris algorithm formulated in cylindrical coordinates. Due to the underlying geometry, the magnetic field exhibits azimuthal symmetry typical of cylindrical planar magnetron configurations. A diagnostic routine is employed to evaluate electron impacts on the cathode. This simplified simulation yields characteristic impact profiles in a realistic geometry and provides insights into electron dynamics and their dependence on the magnetic field configuration. Furthermore, more complex boundary interactions are investigated under simplified conditions.

P 16.48 Thu 13:45 Redoutensaal

Electron dynamics in a linear magnetron magnetic field configuration — •Zahra Alinia[1], Lukas Vogelhuber[1], Kevin Köhn[1], Dennis Krüger[1], Jens Kallähn[1], Yulia Sharova[1], Liang Xu[2], Denis Eremin[1], and Ralf Peter Brinkmann[1] — [1]Institute of Theoretical Electrical Engineering, Ruhr University Bochum, Universitätsstrasse 150, D-44801 Bochum, Germany — [2]School of Physical Science and Technology, Soochow University, Suzhou 215006, China

Magnetrons are essential devices in both scientific research and industrial applications. They are highly versatile and are used in a wide range of geometrical configurations. Two prominent configurations are the cylindrical magnetron, characterized by its inherent azimuthal symmetry, and the linear magnetron, which is structurally more complex but of greater industrial relevance. In this work, we employ a particle-based simulation to study electron dynamics in a linear magnetron magnetic configuration. Electrons are traced using the Boris pusher in cartesian coordinates. The magnetic field is modeled analytically based on a spatial arrangement of magnetic dipoles. An optimal structuring of these dipoles produces a magnetic field geometry that closely resembles the field configuration of a linear industrial magnetron in a so-called "stadium geometry". Electrons moving in this magnetic field experience the Lorentz force and are therefore confined near the racetrack region. Electron dynamics in this stadium geometry are numerically investigated and analyzed.

P 16.49 Thu 13:45 Redoutensaal

Wave phenomena in plasmas - a students' experiment — •Alf Köhn-Seemann[1] and Bayane Michotte de Welle[2] — [1]IGVP, Uni Stuttgart, Germany — [2]NASA, Goddard Space Flight Center

This presentation describes a plasma physics experiment developed as part of a Master's level student lab course at the University of Stuttgart. The experiment is designed to convey fundamental plasma properties through the investigation of wave phenomena such as oscillations at the plasma frequency and ion acoustic waves. The plasma is generated by thermionic discharges in a double-plasma device. A multi-cusp magnetic field, produced by permanent magnets mounted on the vacuum vessel wall, leads to relatively high plasma densities while maintaining a magnetic field-free region in the plasma bulk. This enables clear observation of fundamental wave phenomena under well-controlled conditions. The experimental set-up allows great flexibility in the external control parameters, enabling students to gain hands-on experience with plasma diagnostics and wave excitation. The experiment has proven a versatile and robust platform for teaching key concepts in plasma physics.

P 16.50 Thu 13:45 Redoutensaal

System-theoretic view of the pMRP — •Paria Keramatbaksh[1], Dennis Krüger[1], Jens Oberrath[2], Crispin Ewuntomah[2], and Ralf Peter Brinkmann[1] — [1]Ruhr-University Bochum, Germany — [2]South Westphalia University of Applied Sciences, Germany

The term *Active plasma resonance spectroscopy (APRS)* denotes a family of diagnostic methods which exploit the ability of low-pressure plasmas to exhibit pronounced resonances when excited by a signal in the radio-frequency range. The *planar multipole resonance probe (pMRP)* implements this time-honored concept in a wall-embedded, non-intrusive geometry suited for industrial environments.

For modeling purposes, a system-theoretic point of view is adopted. The radio-frequency signal source is coupled via a $50\,\Omega$ coaxial transmission line to a spatially extended probe structure, which is interpreted as a four-port network. Through a planar interface, the probe is coupled to the plasma, represented as a two-port characterized by its spectral admittance $Y(k,\omega)$. Earlier studies have established a quantitatively accurate representation of $Y(k,\omega)$ based on kinetic theory [1]. In the present work, the focus is instead on the mathematical formulation of the coupling itself. As a deliberate simplification, the plasma response is described by the classical Drude model. This reduced description provides a transparent baseline for analyzing probe-plasma coupling and enables systematic comparison with commercial electromagnetic simulations.

[1] C. Wang et al. *Plasma Sources Sci. Technol.* **30**, 105011 (2021)

P 16.51 Thu 13:45 Redoutensaal

ICCD-Measurements of rf-discharges in the Zyflex chamber — •Baldo Bán Kabuss, Christina Knapek, and André Melzer — Institute of Physics, University of Greifswald, 17489 Greifswald, Germany

In dusty plasmas the properties of the discharge strongly affect how clouds of embedded microparticles behave. Usually forces created by the plasma induce a large void in the center of the dust cloud. The Zyflex chamber is a device with four independent rf electrodes which is capable of creating homogeneous dust clouds under microgravity conditions. In this contribution the shape and intensity of the plasma glow is observed on a nanosecond time scale using a very light-sensitive ICCD-camera. From this data the spatially and time resolved excitation is calculated. The investigation allows deeper understanding of how phase and/or amplitude differences between electrodes change the plasma and thus affect dust cloud shape and structure.

P 16.52 Thu 13:45 Redoutensaal

Dust particle dynamics in a pulsed discharge in microgravity — •Christina A. Knapek, Daniel P. Mohr, Stefan Schütt, Daniel Maier, and Andre Melzer — Institute of Physics, University of Greifswald, 17489 Greifswald, Germany

The charge of micrometer-sized particles immersed in a low-temperature plasma is determined mainly by the electron temperature. If the plasma is operated in a pulsed mode, it is partially in temporal afterglow, and the time-averaged electron temperature decreases. This is expected to impact the particle charge, as well as observable interactions and particle dynamics.

Experiments were performed as part of a parabolic flight campaign with the Zyflex chamber, a versatile plasma chamber designed for the future microgravity complex plasma facility COMPACT. Particles were injected into the plasma during the microgravity phase, while the plasma source, a four-channel radio-frequency generator connected to four separate electrodes, was operated in a pulsed mode. Different operation scenarios were applied (e.g. random successive pulsing of the four channels). One operation mode introduced "off"-times, during which the plasma was in the temporal afterglow for a short while. First experimental results of the impact of the pulsed mode on particle dynamics, and complementary plasma diagnostic measurements are presented.

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P 16.53 Thu 13:45 Redoutensaal

Optical system for COMPACT — •Daniel P. Mohr, Stefan Schütt, Christina A. Knapek, Daniel Maier, and Andre Melzer — Institute of Physics, University of Greifswald, 17489 Greifswald, Germany

The future complex plasma facility COMPACT [1] will allow the investigation of large three-dimensional complex plasmas under microgravity conditions aboard a space station. COMPACT is a project with international scientific contributions, supported by space agencies (DLR, NASA, ESA) and NSF.

Camera-based observation of dust particles is the most important diagnostic for complex plasma experiments. So far, however, measuring their three-dimensional positions has not been possible in low Earth orbit.

For COMPACT a sophisticated optical system is foreseen, including 2D and 3D diagnostics. This system consists of the camera setup, the recording hardware and software as well as the evaluation software (e. g. [2]). We will present concepts/design for the camera setup as well as concepts for the evaluation.

This work was and is funded by DLR/BMWi (FKZ 50WM2161, 50WM2561).

[1] C. A. Knapek et al., DOI: 10.1088/1361-6587/ac9ff0
[2] D. P. Mohr et. al., DOI: 10.3390/jimaging5020030

P 16.54 Thu 13:45 Redoutensaal

Effects of electrode geometry and circuit on electric breakdown in atmospheric-pressure argon — Aleksandar Jovanović, •Margarita Baeva, and Markus M. Becker — Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany

Electrical breakdown and subsequent re-breakdown are pivotal phenomena for the performance of switching and protective devices. This contribution presents a detailed modelling study of the electrical breakdown in argon at atmospheric pressure under direct current (DC) voltage in pin-plane geometry. A time-dependent and spatially two-dimensional fluid-Poisson model is employed to capture the spatio-temporal evolution of the discharge. An external electrical circuit involves the DC power supply, a series resistor, and an external capacitor. A parametric study of the influence of the resistance, capacitance and electrode shapes reveals distinct operation regimes, ranging from a low-current corona discharge to a high-current transient spark. The observed mode transitions are caused by the interplay of the circuit components and the discharge configuration. In all regimes, the gas and electrode temperatures differ considerably. Maximum temperature is localised in the cathode sheath, where the electric field is strongest and affects the cathode heating. The results reveal the coupling between geometry, electrical circuit and discharge, providing insights for optimisation of high-frequency switching and ignition devices.

The study was supported by the DAAD in the framework of Projekt-ID 57703239.

P 16.55 Thu 13:45 Redoutensaal

Analysis of spatio-temporal ignition patterns in dielectric barrier discharges — •Cristian Flores, Hans Höft, Klaus-Dieter Weltmann, and Markus M. Becker — Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany

The occurrence of a repetitive spatio-temporal filament pattern in a dielectric barrier discharge (DBD) is analysed with a combined experimental, modelling, and equivalent circuit approach. The symmetric multi-filament DBD arrangement consists of two parallel tube electrodes (alumina-covered metal rods) separated by a 1 mm gas gap in synthetic air at atmospheric pressure. The system is driven by a high-voltage sinusoidal waveform with 11 kV_{pp} at 10 kHz. Under these conditions, it is observed that the filaments ignite in two stages at alternating positions during each half-period. A fluid-Poisson model is used to study the dynamics of the DBD and to validate the estimations of the filament ignition times obtained from the equivalent electric circuit (EEC) in terms of the breakdown voltage, transferred charge, and an initial condition for the gap voltage. The validated expressions of the EEC model are then used to interpret the experimentally observed filament ignition patterns. The results suggest that a spatial variation in the gap voltage is responsible for the observed effects.

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P 16.56 Thu 13:45 Redoutensaal

CO_2 Conversion and Oxygen Removal in the Effluent of a Plasma — •Katharina Wiegers[1], Thomas Schiestel[2], Rodrigo Antunes[3], Andreas Schulz[1], Matthias Walker[1], and Günter Tovar[1] — [1]University of Stuttgart, Stuttgart, Germany — [2]Fraunhofer IGB, Stuttgart, Germany — [3]Max-Planck-Institute IPP, Garching b. München, Germany

Plasmas offer a promising pathway for energy-efficient CO_2 conversion into CO. However, their performance is strongly influenced by the chemistry in the plasma effluent. Consequently, the suppression of back-reactions is essential, which can be achieved by employing tailored gas nozzle designs. This study investigates how the nozzle geometry enhances CO_2 conversion by modifying the effluent flow. A major challenge in CO_2 plasma conversion is the formation of oxygen in the product gas, which reduces the efficiency of subsequent reactions. Oxygen-conducting hollow-fiber membranes are employed to selectively extract O_2 from the effluent of an atmospheric microwave plasma torch. The influence of microwave power on the temperature distribution in the plasma membrane reactor and the resulting oxygen permeation flux is analyzed. Furthermore, the effect of a nozzle positioned between the plasma and the membrane module is examined; it alters flow and species distribution in the effluent, significantly affecting O_2 permeation. Finally, integration of up to 21 hollow-fiber membranes into the effluent stream demonstrates efficient and scalable oxygen removal.

P 16.57 Thu 13:45 Redoutensaal

Electron densities and temperatures of a microsecond pulsed plasma in water — •Oliver Krettek, Pia-Victoria Pottkämper, Neil Unteregge, Sven Weller, Nils Huber, and Achim von Keudell — Experimental Physics II, Ruhr-Universität Bochum, 44801 Bochum, Germany

Plasma ignition in liquids enables a wide range of applications, including the production of hydrogen peroxide, nanoparticle formation in solution and on surfaces, and plasma-assisted electrolysis, for example in the reactivation of copper catalysts for electrochemical reduction of CO_2. While nanosecond pulsed plasmas typically generate higher yields of reactive species, microsecond pulsed plasmas offer the advantage of easier integration into electrolysis cells. To better understand the behavior of such plasmas prior to their use in an electrochemical system, key plasma characteristics must be determined. In this study, optical emission spectroscopy is applied to investigate the H-alpha and O 777 nm emission lines of a microsecond pulsed plasma in water. By fitting the measured line profiles with a model incorporating Stark, van der Waals, and Doppler broadening, electron densities of up to $10^{22}\,m^{-3}$ and electron temperatures around 2500 K are obtained for different ignition voltages and pulse frequencies. Additionally, the ignition behavior as a function of electrode distance is examined. Experimental ignition thresholds for varying electrode gaps and voltages are compared with a simulation, showing very good agreement. Remaining discrepancies in the observed slopes may be related to transient bubble formation caused by Joule heating during ignition.

P 16.58 Thu 13:45 Redoutensaal

CH_4 Conversion with a microwave plasma torch — •Clemens Kranig[1], Ante Hecimovic[1], and Ursel Fantz[1,2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2 — [2]University of Augsburg, Universitätsstr. 1, D-86159 Augsburg

The use of microwave plasmas for converting various gases into value added chemicals is a promising technology, as the process relies solely on electrical power input and offers short start-up times - both advantageous when integrating such a technology with renewable power in terms of energy storage. In that regard, methane is an attractive feedstock due to its high volumetric hydrogen content. In a plasma torch, a low-temperature plasma with gas temperatures of 4000 - 6000 K is generated, enabling endothermic reactions such as methane pyrolysis ($CH_4 \rightarrow 2H_2 + C_s$) and dry reforming of methane ($CH_4 + CO_2 \rightarrow 2H_2 + 2CO$). Deposition of solid carbon and post-plasma water condensation complicate atomic balances (H, C, O), posing key challenges for process analysis. This contribution investigates the conversion of CH_4 and CH_4/CO_2 mixtures for H_2 or syngas production. Plasma characterization is performed via optical emission spectroscopy, complemented by downstream gas analysis using gas chromatography and mass spectrometry.

P 16.59 Thu 13:45 Redoutensaal

Modelling and experimental study of decomposition dynamics of nitric oxide in a helium radio frequency atmospheric pressure discharge — •Marjan Stankov[1], Florian Sigeneger[1], Ronny Brandenburg[1,2], Eva Wolfe[3], Aditya Bhan[3], and Peter Bruggeman[4] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Institute of Physics, University of Rostock, Rostock, Germany — [3]Department of Chemical Engineering and Materials Science, University of Minnesota, Minneapolis, MN, USA — [4]Department of Mechanical Engineering, University of Minnesota, Minneapolis, MN, USA

The reduction of nitric oxide (NO) in a helium radio frequency (13.56 MHz) atmospheric pressure plasma jet has been investigated using combined modelling and experimental approaches. The plasma jet under investigation comprises a quartz tube, a tungsten needle as the inner electrode, and a copper ring as the outer electrode. Using a plug-flow model, the modelling study couples particle balance equations for the considered species, mean electron energy equation and a heat equation, taking into account He-NO chemistry involving approximately 300 volume and surface reactions. The modelling results are validated using molecular beam mass spectrometry measurements of NO, N_2, O_2, O and NO_2 over a range of input powers, gas flow rates and initial NO concentrations. The model reproduces the measured trends, identifies the production and loss channels for the species considered, and reveals how varied parameters influence NO decomposition. This work has been funded by the DFG-NSF project no. 509169873.

P 16.60 Thu 13:45 Redoutensaal

CO_2-to-CO conversion in a micro cavity dielectric barrier discharge and initial data-driven analysis — •Michael Roloff, Henrik van Impel, David Eiselt, Volker Schulz-von der Gathen, Marc Böke, and Judith Golda — PIP, Ruhr-University Bochum, D-44801 Bochum

The micro cavity plasma array (MCPA) is an atmospheric pressure dielectric barrier discharge [1]. It serves as a research reactor to investigate ways of improving conversion by adding a catalyst. Fourier-transform infrared spectroscopy quantifies CO_2-to-CO conversion under different conditions. We present experiments using 1 slm helium with 0.1 % CO_2 and up to 2 W power, yielding conversion rates of 15.5 % (no catalyst), 14.5 % ($SrTiO_3$), and 12 % ($BaTiO_3$). Additionally, the gas flow pattern were optimized in order to increase conversion efficiency.

A second separately aspect of the project covers data-driven methods to extract useful information from plasma diagnostics. In first tests, we applied neural networks and simple statistical tools to measured signals (e.g. current or spectra) to understand method behavior and interpret basic plasma characteristics.

The experiments and data-driven analysis are intended to be combined in the future to enable machine learning-based parameter estimation.

Supported by DFG within project A6 (SFB 1316)

[1] Dzikowski et al. 2020 Plasma Sources Sci. Technol. 29 035028

P 16.61 Thu 13:45 Redoutensaal

A novel reactor to observe changes in ion composition *in operando* by continuously changing the plasma facing material — •Maurice Artz[1], Jannis Christiansen[1], Kerstin Sgonina[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

In atmospheric pressure plasmas it is difficult to observe *in operando* the formation of ionic species. However, this observation is crucial e.g. for the understanding of the correlation of materials and plasma properties in the field of plasma-assisted catalysis. Therefore, a sub-atmospheric pressure radio frequency (RF) reactor was developed to bridge this research question. It allows for the *in operando* speciation analysis during the continuous change of the plasma facing material. The influence of the material facing the plasma region on the plasma composition can be observed in this reactor.

The sub-atmospheric RF reactor is operated in a pressure range from 20 to 80 mbar. The reactor is mounted atop the sampling orifice of an ion mass spectrometer, acting as a grounded electrode, so that the plasma is directly ignited above the orifice and created ions can be studied. Halfly coated walls can be moved along the plasma by continuously measuring the changes of ion fluxes. In first measurements the walls were coated with carbon for etching experiments or cobalt containing catalysts for conversion experiments.

P 16.62 Thu 13:45 Redoutensaal

Validation of nitrogen-seeded XPR simulations and comparison with other impurities on ASDEX Upgrade using JOREK — •Mate Szucs[1,2], Andres Cathey[1], Matthias Hölzl[1], Yu-Chih Liang[1], Matthias Bernert[1], Ou Pan[1], Daniel Maris[3], Sven Korving[2], Javier Artola[2], Richard Pitts[2], and The ASDEX Upgrade team[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]ITER Organization, St. Paul Lez Durance Cedex, France — [3]DIFFER, Eindhoven, Netherlands

The X-Point Radiator (XPR) regime is a promising exhaust solution for future large-size tokamaks, featuring a cold, dense, highly radiative region above the X-point, inside the confined region. Such regimes have been achieved experimentally on several tokamaks, with different seeded impurities, and ELM suppression is seen when the XPR reaches a threshold height. Modeling with several codes has successfully reproduced several features seen in experiments. However the the effects on the pedestal which results in ELM suppression has not been studied. In this contribution, we present the current status of modeling of the XPR regime on the ASDEX Upgrade (AUG) tokamak with the visco-resistive nonlinear MHD code JOREK. An extension treats neutrals and impurities kinetically, including their interactions with the background fluid plasma. This extension is under constant development, allowing for benchmarking with other codes and experimental validation. Nitrogen-seeded simulations are compared to SOLPS-ITER and AUG experiments, further modeling is presented using different impurity species such as argon and neon.

P 16.63 Thu 13:45 Redoutensaal

Algorithms and optimizations for global non-linear hybrid fluid-kinetic finite element stellarator simulations — •Luca Venerando Greco[1], Matthias Hoelzl[1], Guido Huijsmans[2], and Edoardo Carrà[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching b. M., Germany — [2]CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France

Predictive modeling of stellarator plasmas is crucial for advancing nuclear fusion energy, yet it faces unique computational difficulties. One of the main challenges is accurately simulating the dynamics of specific particle species that are not well captured by fluid models, which necessitates the use of hybrid fluid-kinetic models. The non-axisymmetric geometry of stellarators fundamentally couples the toroidal Fourier modes, in contrast to what happens in tokamaks, requiring different numerical and computational treatment.

This work presents a novel, globally coupled projection scheme inside the JOREK finite element framework. The approach ensures a self-consistent and physically accurate transfer of kinetic markers to the fluid grid, effectively handling the complex 3D mesh by constructing and solving a unified linear system that encompasses all toroidal harmonics simultaneously. To manage the computational complexity of this coupling, the construction of the system's matrix is significantly accelerated using the Fast Fourier Transform (FFT). The efficient localization of millions of particles is made possible by implementing a 3D R-Tree spatial index, which supports this projection and ensures computational tractability at scale.

P 16.64 Thu 13:45 Redoutensaal

High-strength material for fusion reactor magnet sections — •Fareeha Ashraf[1,2], Zahra Abbasi[2], and Klaus-Peter Weiss[2] — [1]IGVP, University of Stuttgart, Germany — [2]Karlsruhe Institute of Technology (KIT) , Institute for Technical Physics, Germany

The demand for high-strength materials for the mag- net sections of future fusion reactors requires a struc- tural material that can sustain exceptional mechani- cal performance at cryogenic temperatures. Conven- tionally used steels, such as 316LN, JK2LB, Incoloy 908, and JJ1, face limitations in achieving the tar- get properties of Yield Strength yield strength yield strength (YS) $>$ 1500 MPa and fracture toughness (KIC)$>$ 130 MPa m1/2. XM-19, a non-magnetic, Corrosion-resistant austenitic stainless steel offers high strength and toughness; however, its perfor- mance at cryogenic temperatures has not yet been finalized. This work focuses on XM-19 manufactured by controlled casting, forging, and heat-treatment routes. The mechanical testing, including tensile testing, fracture toughness evaluation, and fatigue assessment, combined with optical and electron mi- croscopy, will be used to correlate material response with deformation modes, grain characteristics, and precipitate stability. The results focus on the struc- tural evaluation of XM-19 under cryogenic opera- tions and its potential for large-scale fusion applica- tions.

P 16.65 Thu 13:45 Redoutensaal

Density dynamics of shattered pellet injection using a dispersion interferometer — •Andrew Moreau[1,2], Alexander Bock[1], Stefan Jachmich[3], Umar Sheikh[4], Gergely Papp[1], Anshkumar Patel[1], and Thomas Pütterich[1,2] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Ludwig Maximilian University, Munich, Germany — [3]ITER Organization, St Paul Lez Durance Cedex, France — [4]Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland

High-current tokamaks contain a severe risk from unmitigated disruptions. Loss of plasma confinement in these scenarios could lead to excessive heat and force loads on a reactor and create runaway electron beams capable of causing intense localized damage inside the device. Shattered pellet injection is a promising candidate for disruption mitigation, controlling the thermal and current quenches during an unavoidable disruption.

The core density evolution following injected hydrogenic and neon-doped hydrogenic fragments is a key indicator of the disruption mitigation effectiveness. At ASDEX Upgrade, the line-integrated electron density through the core is evaluated using a dispersion interferometer. Results from the 2025 campaign show how a small quantity of neon doping ($\sim 0.1\%$) in a deuterium shattered pellet injection can result in significantly higher density retention ($\sim 4 \cdot 10^{20}$ m^{-2}) at much later phases in the current quench. Furthermore, the multiple pellet injection schemes have been shown to achieve high densities while lengthening the duration of the pre-thermal quench.

P 16.66 Thu 13:45 Redoutensaal

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, Boltzmannstr. 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

Plasma **disruptions** in tokamak machines determine the interruption of confinement and the development of loss channels for the thermal and magnetic energies stored within the reactants into the containment structure, posing a threat for the machine's integrity. In this regard, tokamak design can be well informed by numerical codes modelling the electromagnetic interaction of the MHD plasma with the surrounding conducting structures. The latter provide predictions regarding disruptive plasma instabilities and the ensuing stresses on the walls. The here presented modelling activities have accomplished the **self-consistent** plasma-wall coupling of the induced (eddy) and source-sink (halo) currents flowing in the machine's structures during plasma instabilities; the framework leverages the interplay of the non-linear MHD code JOREK with the 3D wall codes STARWALL (thin) and CARIDDI (volumetric). The first reproduced instabilities are shown.

P 16.67 Thu 13:45 Redoutensaal

Study of finite Larmor radius physics with the gyrokinetic turbulence code GENE-X — •Jose Angel Capitan Garcia[1], Philipp Ulbl[1], Baptiste J. Frei[1], and Frank Jenko[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching bei München, Deutschland — [2]University of Texas at Austin, Austin, Texas 78712, USA

Turbulence is the primary driver of transport losses in magnetically confined plasmas, particularly in tokamaks and optimized stellarators, where it significantly impacts confinement. To optimize energy confinement in a reactor, minimizing turbulent losses is crucial. Achieving a deeper understanding of turbulence in the plasma core as well as the edge and scrape-off-layer (SOL) is essential to this goal.

The GENE-X code, an Eulerian solver of the full-f, collisional, electromagnetic gyrokinetic Vlasov equation, was developed to capture the physics of turbulence in the plasma edge and SOL. Until now, however, it relied on a long-wavelength model, limiting its ability to describe core turbulence and regions with steep gradients, where finite Larmor radius (FLR) effects become essential to capture the physics accurately.

In this work, we present an extension of GENE-X that incorporates FLR effects through Padé-approximated gyro-averaging operators. We will discuss the theoretical basis and first simulations investigating the impact of FLR corrections. This development enables GENE-X gyrokinetic simulations to extend across the entire plasma volume, from edge to core, for the first time in the code.

P 16.68 Thu 13:45 Redoutensaal

Impact of fishbone modes on core microturbulence with global gyrokinetic simulations — •Davide Brioschi[1], Alessandro Di Siena[1], Roberto Bilato[1], Alberto Bottino[1], Thomas Hayward-Schneider[1], Philipp Lauber[1], Alexey Mishchenko[2], Emanuele Poli[1], Alessandro Zocco[2], and Frank Jenko[1,3] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [3]Institute for Fusion Studies, The Univeristy of Texas at Austin, Austin, TX, USA

Fishbone instabilities (FBs) are a class of plasma modes which develop in tokamaks around rational surfaces. They are the energetic particle-driven branch of the n=m kink mode (with n and m toroidal and poloidal mode numbers). Numerical and experimental results show a possible relation between a suppression of (detrimental) turbulent transport inside tokamaks and the trigger of FBs. However, a clear causal relation between the destabilization of FBs and the core turbulent transport reduction has not been found yet. Therefore, it is clear the need for a description of the interaction of FBs with plasma turbulence. Our work aims to study such an interaction via gyrokinetic simulations with the codes GENE and ORB5, including both a FB mode and the ITG branches. These simulations are performed for an AUG discharge characterized by the presence of fishbone activity and plasma temperature peaking. Since the latter can be used as a proxy for core turbulence suppression, studying this case we can explore the physics of the interaction between FB instabilities and turbulence.

P 16.69 Thu 13:45 Redoutensaal

On the Nonlinear Excitation of Zero Frequency Zonal Flows by Alfvén Eigenmodes — •Riccardo Stucchi[1,2], Ph. Lauber[1], X. Wang[1], F. Zonca[3,4], M. V. Falessi[3], N. Chen[1,4], F. Stefanelli[1], and D. Korger[1] — [1]Max Planck Institute for Plasma Physics — [2]Technical University of Munich — [3]Center for Nonlinear Plasma Science and C.R. ENEA Frascati — [4]Institute of Fusion Theory and Simulation, Zhejiang University

As magnetic fusion plasmas move closer to ignition, increasing interest is raised by energetic particles (EPs) and Alfvén eigenmodes (AEs). As hinted by simulations and experiments, the interplay of EPs, AEs and background plasma can potentially lead to regulation of turbulence, and the aim of the present work is to build a reduced model to assess the impact on confinement of one particular mechanism of such interplay: the nonlinear generation of zero frequency zonal flows (ZFZFs) by AEs. The work is currently focused on modelling and un*derstanding the beat-driven generation by AEs of ZFZFs in the context of nonlinear gyrokinetic (GK) theory: on the one hand, we refine previous analytical expressions in the simplified case of well-circulating particles in circular cross section geometry; on the other hand we formulate a semi-analytical approach, presently being implemented in a linear GK eigenvalue code, valid in axis-symmetric toroidal geometry for both trapped and circulating particles. Future work including the comparison with nonlinear GK PIC simulations, the investigation of the nonlinear saturation regime for both AEs and ZFZFs, and the assessment of the impact of ZFZFs on the plasma confinement is foreseen.

P 16.70 Thu 13:45 Redoutensaal

Recent Advances in Efficient Preconditioning Techniques for 3D Nonlinear MHD Simulations in JOREK — •Patrik Rác[1], Omar Maj[1], Vandana Dwarka[2], Eric Sonnendrücker[1], and Matthias Hölzl[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Delft University of Technology, Delft, Netherlands

Enabling next-generation simulations of realistic magnetic confinement fusion devices is crucial for understanding and controlling large-scale plasma instabilities. JOREK is a leading simulation code that simulates plasma dynamics by solving the magnetohydrodynamic (MHD) equations in 3D toroidal geometry using a higher-order isoparametric finite element method in the poloidal plane and a spectral decomposition in the toroidal direction. To effectively address the rising computational demands linked to more detailed simulations, the code must exploit cutting-edge HPC systems in an optimal way to meet current and future needs. The linear systems arising in JOREK are large, sparse, and ill-conditioned. Thus, iterative solvers, such as GMRES, require optimized preconditioning to converge. Current preconditioning techniques rely on the direct factorization of sub-blocks corresponding to the toroidal modes of the global system. However, this approach limits scalability, performance, and portability to accelerated systems. We present recent developments in preconditioning methods for the iterative solution of the reduced MHD models in JOREK. Current research focuses, in particular, on deflation-based methods and novel multiphysics block and equation splitting approaches.

P 16.71 Thu 13:45 Redoutensaal

Statistical Analysis of Plasmoid Properties from Pellet Injections in Wendelstein 7-X — •Edgardo Villalobos Granados[1], Jügen Baldzuhn[1], Naoki Tamura[1], Ameer Mohammed[2], Larry Baylor[3], and Nerea Panadero[4] — [1]Max Planck Institute for Plasma Physics, Greifswald, MV, Germany — [2]Princeton Plasma

Physics Laboratory, Princeton, New Jersey, United States — [3]Oak Ridge National Laboratory, Oak Ridge, TN, USA — [4]Laboratorio Nacional de Fusión, CIEMAT, Madrid, Spain

Hydrogen pellet injection is essential for core fueling in magnetic confinement fusion devices, such as stellarators. In particular, the Wendelstein 7-X (W7-X) stellarator aims to achieve steady state operation and demonstrate long pulse operation at high performance, which includes continuous particle fueling with the use of cryogenic hydrogen pellets. Understanding the dynamics of pellet ablation and the resulting plasmoid characteristics is a fundamental step for optimizing fueling strategies and improving plasma confinement. A statistical analysis of plasmoid properties generated during pellet injection in the W7-X. Plasmoid properties were inferred from visible range spectroscopic measurements of the hydrogen Balmer series. A dataset of over 2000 pellet injections across multiple magnetic configurations was analyzed to extract statistical distributions of plasmoid temperatures (typically 1-2 eV), densities on the order of 1e24 m-3, and corresponding pressure. The correlation between these properties and pellet and background plasma conditions was investigated. These results provide important experimental constraints for modeling pellet-plasma interactions

P 16.72 Thu 13:45 Redoutensaal

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

The study of runaway electrons (RE) dynamics 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. For this purpose, the multispectral imaging system MANTIS consisting of 6 filtered cameras is being commissioned in AUG.

Technical considerations, such as filter wavelength, view port location, neutron flux, among others, have to be taken into account for the installation of the system. Synthetic images for the corresponding wavelengths and views are simulated using the SOFT synthetic diagnostic framework.

To validate the system performance and resilience in real conditions, a first commissioning phase was pursued. The first images of a RE synchrotron spot using a multispectral imaging system in AUG are presented.

P 16.73 Thu 13:45 Redoutensaal

Observed toroidal radiated power variations in Wendelstein 7-X — •Anastasios Tsikouras[1], Felix Reimold[1], Gabriele Partesotti[1], Kevin Andrea Siever[1], Takashi Nishizawa[2], Maciej Krychowiak[1], and Daihong Zhang[1] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]Kyushu University, Kasuga, Japan

An accurate total radiated power (P_{rad}) proxy is important for the efficient and safe operation of a nuclear fusion device. Specifically in 3D devices such as the Wendelstein 7-X stellarator (W7-X), the P_{rad} distribution varies toroidally [1]. This poses a challenge in precise calculation the total P_{rad}. Although shown with synthetic data [1], the distribution of the radiation needs to be validated experimentally. This contribution presents the observed asymmetries on different P_{rad} proxies from different bolometer systems in W7-X. Data from different cross-sections reveal up to 8-fold increase in toroidal asymmetries for low plasma densities. The effect reduces with the increase in the density. For higher input powers the asymmetry increases. Furthermore, configurations with higher field line pitch and reduced plasma wall interaction exhibit a decrease in the asymmetries. In seeded cases, the asymmetries decrease with the increase in the fraction of radiated power which is directly linked with the impurity content in the machine. These results support the formulation of a more precise P_{rad} proxy.

[1] G. Partesotti, PhD thesis (Greifswald 2025)

P 16.74 Thu 13:45 Redoutensaal

ECRH power deposition measurements using ECE radiometers at W7-X — •Vaishnavi Murugesan, Matthias Hirsch, Gavin Weir, Torsten Stange, Juan Fernando Guerrero Arnaiz, Melina Arvanitou, Neha Chaudhary, Robert C Wolf, and the W7-X Team — Max Planck Institute for Plasma Physics

Electron Cyclotron Resonance Heating (ECRH) is a prominent heating scheme in many modern fusion devices. The narrow deposition width of ECRH makes it an effective tool for plasma profile shaping and turbulence control. The experimental validation of said narrow power deposition, however, has proved to be challenging, limited by the diagnostic capabilities and heat diffusion. ECRH modulation and switching experiments offer a unique way of deriving power deposition profiles in magnetically confined plasmas. ECRH modulation initiates perturbations in local electron temperature (Te) that are observed as an immediate response in the Electron Cyclotron Emission (ECE) signals. The instantaneous response of the ECE channels probing the magnetic flux surfaces in the vicinity of heating is used to derive power deposition profiles. This work presents narrow ECRH power deposition profiles measured using standalone calibrated ECE radiometers at Wendelstein 7-X (W7-X). Experimental results are discussed alongside mathematically derived ray-tracing profiles for plasma discharges from the experimental campaign 2.3 at W7-X.

P 16.75 Thu 13:45 Redoutensaal

Advancing Tokamak Edge Stability Predictions with Extended-MHD Modelling — •Michael Sieben[1], Michael Dunne[1], Jonas Puchmayr[1], Roxana Takacs[1], and the ASDEX Upgrade Team[2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]See author list of H. Zohm et al 2024 Nucl. Fusion 64 112001

The high-confinement mode (H-mode) is an operational regime achieved in many present tokamaks, including ASDEX Upgrade (AUG), and is expected to be accessed in the future by ITER. In H-mode, a transport barrier, the so-called pedestal, forms at the plasma edge, where steep temperature and density gradients can drive magnetohydrodynamic (MHD) instabilities and trigger rapid heat and particle losses that can be hazardous for plasma-facing components. Predicting pedestal stability limits is therefore essential for H-mode operation. MHD models combined with an assumption on the transport in the pedestal, such as IPED [1], can be used to predict the pedestal structure prior to such events. Here, we present three extensions to IPED that improve edge stability predictions: (1) high-precision equilibrium reconstruction using the GVEC code [2]; (2) inclusion of extended-MHD physics through integration of CASTOR3D [3]; and (3) a robust growth-rate prediction based on an iterative search in the complex eigenvalue space. We demonstrate how these extensions affect predicted stability limits in both predictive and interpretive analyses of H-mode plasmas at AUG. [1] Dunne M.G. et al. 2017, [2] Hindenlang F. et al. 2019, [3] Strumberger E. et al. 2016.

P 16.76 Thu 13:45 Redoutensaal

Investigation of boron transport in the pedestal of ASDEX Upgrade — •Lucas Räss[1], Rachael McDermott[1,2], Tabea Gleiter[1], Dirk Stieglitz[1], Thomas Pütterich[1,2], Kiera McKay[3], Ralph Dux[1], Elisabeth Wolfrum[1,4], and The ASDEX Upgrade Team[5] — [1]Max-Planck-Institut für Plasmaphysik — [2]Ludwig- Maximilians-Universität München — [3]University of Seville — [4]TU Wien — [5]See author list of H. Zohm et al, 2024 Nucl. Fusion

Impurity transport across the edge of the confined plasma (pedestal) is of special interest for future fusion reactors, as it sets boundary conditions for the core impurity concentration. The transport is generally determined by a combination of collisional (neoclassical) and anomalous contributions, where neoclassical predictions for future reactors result in favourable hollow impurity density profiles.
This study investigates pedestal impurity transport between type-I edge localised modes (ELMs) in the high confinement regime (H-mode) at ASDEX Upgrade across a wide range of plasma parameters. For this purpose, a database of suitable discharges was established and for a subset the ratio of drift velocity to diffusion coefficient is inferred from experimental boron measurements and compared to neoclassical predictions. Our results support prior findings of transport near neoclassical levels in the steep gradient region, with most discharges agreeing well with neoclassical predictions while singular outliers, that occur in particular at low collisionality, are present. Due to uncertainties in these discharges, however, further analysis is needed to prove or disprove significant anomalous transport at low collisionality.

P 16.77 Thu 13:45 Redoutensaal

Flight-Simulators for the ASDEX Upgrade Tokamak: De-

velopment of a New Software-In-the-Loop Tool and Controller Design for Advanced Divertor Configurations — •Marco Biasizzo[1,2], Pierre David[1], Matthias Gehring[1], Renat Kermenov[1], Mariano Ruiz[2], Bernhard Sieglin[1], Wolfgang Treutterer[1], Hartmut Zohm[1], and the ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Grupo de Investigación en Instrumentación y Acustica Aplicada, Universidad Politécnica de Madrid, 28031 Madrid, Spain

Flight-simulators (FS) for tokamaks ingest a discharge program and return the time evolution of plant and plasma variables, enabling rapid testing of scenarios and control algorithms. The current ASDEX Upgrade (AUG) FS, Fenix, uses a physics-based model for the plasma and a Simulink model of the tokamak control system. An alternative software-in-the-loop (SIL) version is under development; it runs an exact replica of the control system, removing modelling limits and reducing execution time. Synchronization and communication between the control system and the plasma and plant models are presented.

The SIL simulator will be used to implement and test a novel controller to regulate desired advanced divertor configurations (ADCs) and key plasma shape geometric descriptors. Model-based controller synthesis has begun with ADCs data obtained from the current FS. Fenix results were benchmarked against recent AUG experiments, showing quantitative agreement. This integrated approach promises faster, reliable controller development while saving experimental time.

P 16.78 Thu 13:45 Redoutensaal

Modelling the Pellet-Produced Plasmoid Dynamics in Stellarators with JOREK — •Carl Wilhelm Rogge[1], Ksenia Aleynikova[1], Pavel Aleynikov[1], Rohan Ramasamy[2], Matthias Hoelzl[1], and Nikita Nikulsin[1] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald and Garching — [2]Proxima Fusion, München

Cryogenic pellet injection is expected to be a key technique for refuelling future fusion reactors based on the stellarator concept. While this technique is more mature in tokamak experiments, the departure from axisymmetry in stellarators introduces unique challenges and opportunities that remain insufficiently explored.

Here, we employ the stellarator extension of the 3D nonlinear MHD code JOREK to study the radial drift of a fully ionised plasmoid. Since this drift depends on the pressure evolution within the pellet-produced plasmoid, the parallel expansion has a strong impact on the final deposition profile of the injected material. Consequently, particular attention must be paid to accurately modelling the reheating of the plasmoid by hot background plasma particles, which drives the parallel expansion. Because the mean free path of background electrons in core-fuelling scenarios is very long, non-local heat transport effects need to be incorporated into the fluid description.

Two non-local heating schemes have been newly implemented in JOREK and verified against analytical theory. These new schemes are then applied to stellarator geometries, where the radial drift following complete pellet ionisation is investigated.

P 16.79 Thu 13:45 Redoutensaal

Investigating drift effects in island divertors with the mean-field Braginskii model — •Tobias Tork[1,2], Felix Reimold[1], David Bold[1], Ben Dudson[3], Andreas Stegmeir[4], and Peter Manz[2,1] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Institute of Physics, University of Greifswald, 17489 Greifswald, Germany — [3]Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore CA 94550, USA — [4]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

The inclusion of drifts has been shown to be critically important for the boundary physics of tokamaks and has a significant impact on the predictions of divertor heat loads and impurity transport. Current state-of-the-art stellarator boundary simulations like EMC3-Eirene do not include drifts, but experiments in W7-X already show numerous indications of drift effects. Such effects could significantly alter the heat loads on the divertors or redistribute the plasma profiles.

In this contribution, we present the development of a 3D simulation for island diverted stellarators. The model is derived from the Hermes-2 physics model by parameterizing the divergence of the polarization drift with a set of anomalous diffusion coefficients. The simulation tool allows for the analysis of potential and current distributions in stellarators.

We will show results of drift effects in an island divertor. Stagnation points of the parallel ion flow demonstrate a significant poloidal shift which depends on the magnetic field direction.

P 16.80 Thu 13:45 Redoutensaal

Analysis on the plasma edge fluctuations in the X-point radiator regime in ASDEX Upgrade — •Yu-Chih Liang[1,2], Ou Pan[1], Matthias Bernert[1], Tim Happel[1], Ulrich Stroth[1,2], Gustavo Grenfell[1], Sebastian Hörmann[1], Alessandro Mancini[1], Konrad Eder[1], Mate Szuecs[1,2,3], and the 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]ITER Organization, 13067 St. Paul Lez Durance Cedex, France

The power exhaust problem in large-scale fusion reactors necessitates operational regimes that can avoid extreme heat fluxes onto the plasma-facing components. One promising regime is the X-point radiator (XPR), featuring a highly radiative plasma volume forming above the X-point. Additionally, suppression of edge localized modes (ELMs) can be achieved when the XPR moves inside the confined region.

This contribution focuses on the plasma edge, where the complexity arises from the turbulence around the XPR volume, the interactions between the edge modes and the XPR, and the influence of the XPR on the edge turbulence transport. Using the thermal He beam diagnostics, the diode bolometry, and the magnetic coils in ASDEX Upgrade, the edge fluctuations in the XPR regimes both with and without large ELMs are studied. Furthermore, the presented analysis on the fluctuation measurements is extended from the outer midplane to the XPR volume, aiming to improve understanding on the interactions between the outer midplane plasma profile and the XPR.

P 16.81 Thu 13:45 Redoutensaal

Operational space of the ASDEX Upgrade tokamak and its proximity to that of future devices with burning plasma — •Daniela Kropáčková, Emiliano Fable, Ondřej Kudláček, Hartmut Zohm, and ASDEX Upgrade Team — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, Garching, D-85748, Germany

Present-day tokamaks are unable to capture the dynamic interaction between alpha heating and the plasma operational scenario during changing operating conditions as expected in future reactors. To enable these investigations, a method for emulating dominant alpha heating in existing tokamak experiments was introduced in [FableNF2023].

In this contribution, a database of operational scenarios of ASDEX Upgrade (AUG), covering ELM-free regimes such as EDA and QCE, scenarios with ELM suppression via resonant magnetic perturbations (RMPs), flux-pumping scenarios, and operation with a X-point radiator (XPR), is presented. The interesting operational space is characterized in terms of key non-dimensional parameters, e.g., $\nu_{\rm eff}$, β_N, ρ^*, and q_{95}. These parameters are compared with the expected values for a few considered fusion reactors, and the conditions under which relevant physical parameters can be matched are identified.

The selected scenarios are then used to calibrate the alpha heating power proxy through simulations performed with the flight simulator Fenix. Experimental validation of the obtained results is planned for a future campaign, followed by burn control studies.

P 16.82 Thu 13:45 Redoutensaal

Comparison of experimental radiation dynamics in the scrape-off layer of Wendelstein 7-X with transport simulations — •Kevin Andrea Siever[1], Felix Reimold[1], Satoshi Togo[2], Gabriele Partesotti[1], Takashi Nishizawa[3], Daihong Zhang[1], Nassim Maaziz[1], Anastasios Tsikouras[1], Valeria Perseo[1], Victoria Winters[1], Masahiro Kobayashi[4], Byron Peterson[4], and Kiyofumi Mukai[4] — [1]Max Planck Institute, Greifswald, Germany — [2]Plasma Research Center, University of Tsukuba, Tsukuba, Japan — [3]Kyushu University, Kasuya, Japan — [4]National Institute for Fusion Science, Toki, Japan

At Wendelstein 7-X (W7-X) the strongly 3D topology of the scrape-off layer (SOL) leads to a complex behavior of the impurity radiation structure. In this context, the 3D transport code EMC3-Eirene is often used to assess its SOL. This contribution aims at the validation of such simulations with experimental data, focusing on the radiation distribution. In the work [S. Togo et al (submitted) Plasma Phys. Control. Fusion], density scans have been simulated with EMC3-Eirene for 5 configurations corresponding to different radial positions of the islands. Matching W7-X density scan-experiments are chosen and data from the 3 available bolometry systems analyzed. In order to compare the simulated radiation structure to the experimental data, synthetic diagnostic data generation and 2D tomographic inversions are employed.

This allows to compare with the simulations the experimental poloidal evolution of the emissivity localization as density is increased, for the different geometries.

P 16.83 Thu 13:45 Redoutensaal

Modelling of Island Divertor Topology and Edge MHD Instabilities in Stellarators with JOREK — •Orin Varley[1], Rohan Ramasamy[2], Jonas Puchmayr[1], Samet Kocbay[1], and Matthias Hoelzl[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Proxima Fusion, Munich, Germany

Large-scale MHD dynamics shape key aspects of stellarator performance, especially island divertor geometry and edge instabilities. This work examines these phenomena and summarizes recent advances in modelling capabilities.

Island divertors are the leading concept for particle and heat exhaust in stellarators, but their performance is highly sensitive to magnetic topology. Increasing plasma β can shift island position and width, enhance chaos, and, in some optimized quasi-isodynamic configurations, even induce phase transitions within the island structure. Using JOREK, we model these β-driven transitions, compare with HINT, and investigate the mechanisms that reshape island topology.

We also study MHD-driven edge instabilities with improved physics models, supported by ongoing developments in the JOREK stellarator framework, including a no-wall boundary condition and diamagnetic drift effects.

This poster presents an overview of these model improvements and their first applications to island divertor physics and edge instability studies, forming a basis for future work on plasma exhaust, detachment, and wall loading in stellarators.

P 16.84 Thu 13:45 Redoutensaal

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 not only because of the large in vessel forces involved, but also because they may lead to the acceleration of some electrons to relativistic speeds. These so-called runaway electrons (REs) can exponentially multiply due to large-angle collisions with thermal electrons during the RE avalanche. As the RE avalanche is exponentially sensitive to the pre-disruption plasma current, this can lead to multi-MA RE beams in large future devices, which may cause severe localized wall damage. Therefore, 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 3D nonlinear MHD code JOREK contains a hybrid fluid-kinetic model that describes the REs with a full-f relativistic particle in cell (PiC) approach using either full-orbit or drift kinetic RE descriptions. We present the implementation of the relativistic large-angle collision operator and a resampling technique needed to limit the number of markers, along with first applications.

P 16.85 Thu 13:45 Redoutensaal

Radiative power exhaust in Alternative Divertor Configurations at ASDEX Upgrade — •Alessandro Mancini, Matthias Bernert, Tilmann Lunt, Dominik Brida, Felix Albrecht, and the ASDEX Upgrade team — Max Planck Institute for Plasma Physics (IPP Garching)

Power exhaust is a major challenge in the development of tokamaks as fusion reactors. The unmitigated power flux in a reactor is expected to be several orders of magnitude higher than the heat load limit for tungsten plasma facing components (PFCs).

Alternative Divertor Configurations (ADCs) feature an increased flux expansion and/or secondary X-Points to lower the heat load on the PFCs by easing the access to detachment, where the plasma recombines before reaching the wall. Therefore, ADCs may be taken into consideration for future tokamak reactors. The ASDEX Upgrade tokamak was recently upgraded with a new upper divertor that can produce ADCs, like X-Divertor (XD), Snowflake Minus (SF-), super Compact Radiative Divertor (sCRD). This work focuses on the power exhaust capabilities of ADCs, in particular on the radiated power distribution. Bolometer data is complemented by Langmuir probe data to characterize the detachment.

It is observed that ADCs highly modify the radiation distribution. The SF- configuration facilitates X-Point Radiators (XPR), even at low impurity seeding levels. Fast transitions in the radiation pattern are observed even with a slow variation of the ADC configuration.

P 16.86 Thu 13:45 Redoutensaal

Equilibrium reconstruction and toroidal current density analysis for high-β Wendelstein 7-X plasmas — •E. Hausten[1], K. Rahbarnia[1], H. Thomsen[1], L. van Ham[1], C. Brandt[1], T. Andreeva[1], C. Büschel[1], M. Kelly[1], P. Pons-Villalonga[1], S. Vaz Mendes[1], S. Lazerson[2], and the Wendelstein 7-X Team[1] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Gauss Fusion GmbH, Parkring 29, 85748 Garching bei München, Germany

Accurate knowledge of the magnetohydrodynamic equilibrium is essential for interpreting diagnostics and inferring non-measurable plasma parameters in fusion experiments such as the Wendelstein 7-X (W7-X) stellarator. Equilibria can be reconstructed from experimental data using the STELLOPT code [1], which employs optimization methods to find equilibria that best match diagnostic measurements. A key challenge in reconstructions is determining the toroidal plasma current density, for which only limited experimental information is directly accessible. This becomes particularly relevant in high-β scenarios, where increased pressure gradients can drive stronger currents. In this contribution, we present reconstructed current density profiles for high-β plasmas obtained in W7-X experiments. We analyze the influence on rotational transform and Shafranov shift and compare with predictions from the current-evolution code THRIFT [2].

[1] S. A. Lazerson, 2015, Nucl. Fusion 55
[2] L. van Ham et al, 2025, Nucl. Fusion 65

P 16.87 Thu 13:45 Redoutensaal

On the role of density-potential coupling in the interplay of zonal-flow and intermittency formation — •Lilian Harumi Yoshida, Mirko Ramisch, and Ralph Sarkis — IGVP, University of Stuttgart, Germany

The destabilization of density perturbations in drift-wave turbulence is based on the decoupling of density ($\tilde{n}$) and potential ($\tilde{\phi}$) fluctuations. This decoupling mechanism is promoted by electron collisionality, which in turn tends to change the turbulent behaviour from adiabatic into a hydrodynamic one, where density becomes passively advected and resembles the intermittent vorticity. Decoupling is also intrinsic to the interchange drive of filamentary, intermittent density structures - so-called blobs - in the scrape-off layer (SOL). In contrast to blobs, strong coupling is essential for the Reynolds-stress drive of zonal-flows (ZF). However, recent studies showed a causal link between blob detachment from the bulk plasma and ZF generation inside the separatrix. In this experimental work, multiple Langmuir-probe arrays are used at the TJ-K stellarator to untangle the interplay of $\tilde{n}-\tilde{\phi}$ coupling with ZF and intermittency formation. Conditional sampling reveals a temporal correlation between net turbulent particle flux and zonal intermittency levels, which is in-line with the associated drift-wave destabilization. Furthermore, the coupling and intermittency dynamics across the separatrix is examined, shedding light on the role of blobs in ZF formation.

P 16.88 Thu 13:45 Redoutensaal

ECRH as a candidate for electron temperature and -density profile shaping towards confinement improvements in W7-X — •Melina Arvanitou, Matthias Hirsch, Kai Jakob Brunner, Neha Chaudhary, Golo Fuchert, Juan Fernando Guerrero Arnaiz, Vaishnavi Murugesan, Miklos Vecsei, Gavin Weir, Robert Wolf, and The W7-X Team — Max Planck Institute for Plasma Physics

At present T_i gradient clamping inhibits the establishment of high-confinement regimes in Wendelstein 7-X (W7-X) plasmas. Overcoming this constraint requires finite density gradients at mid-radius, which are believed to suppress ITG turbulence. Although achievable with deep fueling by Neutral Beam Injection (NBI) and pellets, both methods pose challenges for reactor-scale implementation. Since Electron Cyclotron Resonance Heating (ECRH) is already envisaged as the primary heating system in future reactor-scale stellarator concepts, any intrinsic profile-shaping capability would represent a built-in advantage for optimizing confinement. ECRH is well known to provide control over the T_e-profile while simultaneously impacting particle and impurity transport through mechanisms such as density pump-out. On- and off-axis application of localized X2 ECRH has been conducted to investigate its profile-shaping properties, with the resulting density and temperature profiles provided by Thomson scattering (TS) and alkali metal beam spectroscopy. Small heat-wave-like temperature perturbations in the Electron Cyclotron Emission (ECE) traveling away from the ECRH deposition zone indicate an associated transport effect.

P 16.89 Thu 13:45 Redoutensaal

Core neutral density measurements from Balmer-α emission at Wendelstein 7-X — •Lucas Nitzsche[1], Sebastian Bannmann[1], Oliver Ford[1], Felix Reimold[1], and Robert Wolf[1,2] for the w7-x team-Collaboration — [1]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [2]Technical University of Berlin, Strasse des 17.Juni 135, 10623 Berlin, Germany

Wendelstein 7-X (W7-X) is a current state-of-the-art magnetic confinement fusion device of the stellarator type.

It was shown at W7-X, that the energy confinement time of its plasmas depends strongly on their density profile shape. This in turn is linked directly to controlling and knowing the particle-transport. Although the particle fueling of recycling neutrals into the confined region is an important quantity in corresponding calculations, it is not routinely measured and must be approximated by simplified modeling. Accessing this particle fueling is possible by measuring the density of neutral particles n_0 inside the plasma and combining it with ionization rates.

In this work, passive Balmer-α emissions from the confined region are analysed to estimate n_0-profiles along each measured line-of-sight (LOS). The previous modeling of the emissions was improved by including charge-exchange-reactions in the emission coefficients. From the evaluations, the n_0-distributions inside W7-X plasmas were estimated and compared to modeling with EMC3-EIRENE. Results are compared for two spectrometers at different toroidal positions at W7-X.

P 16.90 Thu 13:45 Redoutensaal

hybrid kinetic-MHD simulations of energy-dependent effects of runaway electron beams on MHD Instabilities — •Shijie Liu, Hannes Bergstroem, Haowei Zhang, and Matthias Hoelzl — Max Planck Institute for Plasma Physics,Garching b.m., Germany

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 a cold plasma with a high-energetic runaway beam, the equilibrium cannot be force-free, and the RE curvature drift introduces an energy-dependent outward shift of magnetic flux surfaces. We investigate how these RE-induced orbit shifts affect both linear and nonlinear MHD instabilities, with a particular focus on tearing modes. A poloidal mode coupling mechanism is now observed due to (1,0) component of the RE curvature drift. Future work will extend efforts by comparing the resistive layer width with the characteristic width of RE orbits.

P 16.91 Thu 13:45 Redoutensaal

Turbulent Transport Mechanism in Island Divertors — •Ralph Sarkis[1], Mirko Ramisch[1], and Peter Manz[2] — [1]IGVP, University of Stuttgart, Germany — [2]Institute of Physics, University of Greifswald, Germany

Island divertors have demonstrated strong promise in controlling particle and heat exhaust. Considering the long parallel and short binormal connection lengths at the island divertor, it becomes clear that transport in the binormal direction plays an important role. This can broaden perturbations and modify the convective and diffusive transport, ultimately determining the divertor heat and particle flux pattern. In this contribution, we present an overview of an envisaged research project dedicated to the understanding of the fundamental dynamics in island divertors. This objective will be pursued through an integrated experimental and computational approach, jointly carried out by research groups at the University of Stuttgart and the University of Greifswald, thereby combining complementary expertise in diagnostics, modeling, and theoretical analysis to achieve a comprehensive understanding of transport in the island divertor.

P 16.92 Thu 13:45 Redoutensaal

Influence of Flow Shear Modulation on Turbulent Transport Regulation — •Carmen Sofia Vergara Interian, Mirko Ramisch, and Ralph Sarkis — IGVP, University of Stuttgart, Germany

In magnetically confined toroidal plasmas, zonal flows play a crucial role in regulating the cross-field turbulent transport. While this relation has been widely established, the detailed interrelation of transport with flow shear modulation has yet to be clarified. Hence, the spatiotemporal evolution of turbulent particle transport, together with the scale-resolved density and potential power distributions, is experimentally investigated with respect to modulation in the zonal potential as measured by a Langmuir probe array at the TJ-K stellarator. Contrary to positive zonal potential amplitudes, negative potentials are found to be associated with an increased particle flux, pointing to a weakened shear effect. Moreover, the density power spectrum reveals a cascading-like redistribution of power from small to large scales. This could indicate a mechanism in which turbulence both drives and responds to modulation in zonal potential. The effects of negative and positive zonal potential events are compared on the basis of their characteristic time scales and their influence on density-potential coupling with respect to the turbulent particle flux in magnetically confined fusion plasmas.

P 16.93 Thu 13:45 Redoutensaal

Study of boronization history effects on impurity control in Wendelstein 7-X — •Pei Ren[1,3], Yunfeng Liang[1,3], Shuai Xu[1], Frederik Henke[2], Alexander Knieps[1], Maciej Krychowiak[2], Birge Buttenschön[2], Alice Bonciarelli[2], Sebastijan Brezinsek[1], Dorothea Gradic[2], Daihong Zhang[2], Carsten Killer[2], Luo Yu[1,3], Marcin Jakubowski[2], Petra Kornejew[2], and Erhui Wang[1] for the w7-x team-Collaboration — [1]Institute of Fusion Energy and Nuclear Waste Management, Forschungszentrum Jülich GmbH, Jülich, Germany — [2]Max Planck Institute for Plasma Physics, Greifswald, Germany — [3]Faculty of Mathematics and Natural Science, Heinrich Heine University Düsseldorf, Düsseldorf, Germany

Boronization is routinely applied for wall conditioning on W7-X, significantly improving plasma performance. This work investigates the history effects on impurity control using visible and UV spectroscopy. Results show that boronization strongly suppresses oxygen impurities, and although this effect gradually weakens, overall impurity control remains robust. Spearman correlation analysis indicates that, over time, oxygen impurity radiation becomes decoupled from total radiation, while carbon sputtering reaches a steady state. Analysis of OP2.2 data under identical conditions 1 day, 2 days, and 2 weeks after fresh boronization shows consistent trends: oxygen radiation slightly increases over time but remains within controlled levels. These findings confirm that multiple boronizations effectively maintain good wall conditioning.

P 16.94 Thu 13:45 Redoutensaal

Measurement of electron-temperature dynamics in TJ-K plasmas — •Rimae Lamara Mhend, Alf Köhn-Seemann, and Mirko Ramisch — IGVP, University of Stuttgart, Germany

Heat-flux analyses for energy confinement studies in magnetized plasmas require the resolution of the fast plasma-temperature dynamics. While the electron temperature T_e can be deduced from swept Langmuir probes, extending this procedure to time scales in the microsecond range is experimentally challenging. A simple approach using a triple probe diagnostic system, measuring the potential of a biased double probe against that of a single floating probe, provides direct access to fluctuations in T_e. In this work, a triple probe is set up for use in the magnetized plasmas of the torsatron TJ-K and tested against swept single-probe characteristics. Statistical properties of T_e fluctuations measured along radial profiles are presented and characterized under variation of the drift scale $\rho_s = \sqrt{T_e M_i}/eB$ for ion masses M_i ranging from hydrogen over helium to argon.

P 16.95 Thu 13:45 Redoutensaal

Preliminary study of boronization effect on divertor density regime in the standard configuration on W7-X — •Muzhi Tan[1,2], Shuai Xu[1], Yunfeng Liang[1,2], Yu Luo[1,2], Pei Ren[1,2], Yuhe Feng[3], Detlev Reiter[1], Daihong Zhang[3], Arun Pandey[3], and Golo Fucher[3] for the w7-x team-Collaboration — [1]Forschungszentrum Jülich GmbH, IFN-1 Plasma Physics, Jülich, Germany — [2]HHU Düsseldorf, Faculty of Mathematics and Natural Sciences, Düsseldorf, Germany — [3]Max-Planck-Institute für Plasmaphysik, Greifswald, Germany

Boronization is widely applied in magnetic confinement devices to sustain high-performance, steady-state plasma operation. In this work, we present a preliminary study of the boronization effect on divertor density regimes by comparing two density-ramp discharges with identical ECRH heating power (3 MW). Experimental observations show that boronization significantly suppresses intrinsic oxygen impurity sources. Before boronization, the downstream ion saturation current (Isat) increases slightly with rising radiated power; after boronization it rises much more rapidly and exhibits a clear roll-over when the radiation fraction exceeds 50%. Motivated by these experimental trends, EMC3-EIRENE simulations were performed to assess the impact of boronization on divertor density regimes. By comparing impurity transport at the same radiated power, simulations illustrate how oxygen influences the transition of divertor density regime. Simulations without oxygen impurities reproduce the Isat roll-over and highlight the beneficial role of boronization on modifying transport in W7-X.

P 16.96 Thu 13:45 Redoutensaal

First L-Mode experiments in Alternative Divertor Configurations in ASDEX Upgrade — •Felix Albrecht[1,2], Dominik Brida[1], Ou Pan[1], Tilmann Lunt[1], Michael Faitsch[1], Bernhard Sieglin[1], and ASDEX Upgrade Team[3] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technical University of Munich, Physics Department, Garching, Germany — [3]see author list of H. Zohm et al. 2024 *Nucl. Fusion* **64** 112001

All fusion devices need to exhaust the plasma heating power in a separate region from the core plasma called the divertor. There, most of the heat flux must be radiated away through plasma-neutral interactions, typically by seeded impurities, to protect the divertor target plates. If the impurity concentration is high enough, a favorable state of detachment can be reached, where the plasma recombines in front of the target. However, the required impurity concentrations might be too high for good core performance. Recent hardware upgrades in the tokamak ASDEX Upgrade enable access to alternative divertor configurations (ADCs), a possible solution to facilitate detachment with less impurities. Through increased flux expansion at the target (X-divertor, XD) or the introduction of another X-point in the divertor plasma (snowflake minus, SF^-), ADCs have been shown in other machines to be favorable for detachment *[Theiler NF 2017]*.

We present the first L-Mode experiments in ASDEX Upgrade with ADCs. In XD and SF^-, an earlier detachment of the primary strikepoint compared to single null was found. The results are interpreted with the plasma and neutral transport code SOLPS-ITER.

P 16.97 Thu 13:45 Redoutensaal

Towards the Application of the Gyrokinetic Code GENE-X to Tokamak and Stellarator Scrape-Off Layer Turbulence — •Yantong Tao[1], Philipp Ulbl[1], and Frank Jenko[1,2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]University of Texas at Austin, Austin, TX 78712, USA

Predicting heat loads in the scrape-off layer (SOL) is a major challenge for future fusion divertors, largely due to the complex interplay between turbulence and boundary plasma physics. Gyrokinetic simulations provide a powerful tool for investigating SOL turbulence; however, their predictive capability critically depends on the incorporation of plasma sheath physics at the divertor targets. The plasma sheath plays a key role in regulating turbulent transport and heat exhaust, and its proper treatment is therefore crucial for reliable heat flux predictions and divertor design.

In this work, we will apply sheath boundary conditions to the full-f gyrokinetic turbulence code GENE-X in full tokamak and stellarator geometry, and present some preliminary results. Since the sheath structure cannot be fully resolved in gyrokinetic simulations, we start from a reduced sheath model that captures the essential physics while omitting the sheath complexity at the same time. Then we will study the impact of sheath boundary conditions and compare the results with TCV-X21 validation case.

P 16.98 Thu 13:45 Redoutensaal

Neural network surrogate-assisted Bayesian inference for input parameter of edge plasma simulations — •Yu Luo[1,2], Shuai Xu[1], Yunfeng Liang[1,2], Erhui Wang[1], Jianqing Cai[1], Yuhe Feng[3], Detlev Reiter[2], Alexander Knieps[1], Sebastijan Brezinsek[1,2], Derek Harting[1], Maciej Krychowiak[3], Dorothea Gradic[3], Pei Ren[1,2], Daihong Zhang[3], Yu Gao[3], Golo Fuchert[3], Arun Pandey[3], and Marcin Jakubowski[3] for the w7-x team-Collaboration — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany — [2]Faculty of Mathematics and Natural Science, Heinrich Heine University Düsseldorf, 40225 Düsseldorf, Germany — [3]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany

We present a neural network-accelerated workflow to efficiently infer EMC3-EIRENE input parameters from measurements on Wendelstein 7-X. A database of 3D EMC3-EIRENE edge-transport simulations is generated by varying key inputs, and a feed-forward neural-network surrogate is trained to map parameters to synthetic diagnostic signals. Embedded in a Bayesian inference framework with Dynamic Nested Sampling, the surrogate enables fast likelihood evaluations, explicitly incorporates diagnostic uncertainties, and yields posterior distributions and maximum a posteriori (MAP) estimates. EMC3-EIRENE simulations at these MAP parameters reproduce the measurements while greatly reducing computational cost and manual tuning, and the approach is transferable to other modeling tools.

P 16.99 Thu 13:45 Redoutensaal

Transient non-equilibrated plasma phases in the Wendelstein 7-X stellarator — •Christian Brandt, Charlotte Büschel, Edith Victoria Hausten, Kian Rahbarnia, Henning Thomsen, Sara Vaz Mendes, Tamara Andreeva, Martin Clifton Kelly, Ulrich Neuner, and Pedro Pons Villalonga — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

Selected Wendelstein 7-X stellarator plasmas are investigated far away from an equilibrium state in certain experimental scenarios. A stable plasma phase was actively perturbed, e.g. by heating power steps, the injections of cryogenic pellets or impurities. Moreover, internal events temporarily destabilized the plasma, triggered by MHD instabilities. Analysis of highly spatiotemporally resolved soft X-ray (SX) tomographic measurements help to understand these transient phases by studying the topologic evolution of the SX emissivity in a poloidal cross section. An experimental survey of several types of transient phases analyzed by SX tomography is presented. Besides details of the plasma startup phase – sometimes accompanied by mode activity – we focus on the stability of high energy plateau phases.

P 16.100 Thu 13:45 Redoutensaal

High Frequency Dispersion Interferometry for Alfvén Mode Studies — •Vineeta Nair — Max Planck Institute for Plasma Physics, Greifswald

Dispersion interferometry is emerging as a preferred diagnostic for measuring line-integrated electron density in many fusion devices, offering a robust alternative to the traditional dual-color interferometers because its phase measurements are inherently immune to mechanical vibrations of optical components. At Wendelstein 7-X (W7-X), a phase-modulated dispersion interferometer based on a continuous-wave CO2 laser (10.6 μm) serves as the standard electron density diagnostic. Phase modulation in the current diagnostic setup is performed using a photo-elastic modulator, which offers a good modulation depth (ρ), but is limited to modulation frequencies (ωm) of only a few kHz due to its mechanical resonance based modulation. With the current diagnostic, fluctuations in electron density can be measured only up to 50 kHz. To investigate several instabilities*such as MHD modes, kinetic ballooning modes, and fast-ion*driven Alfvén modes*it is essential to extend the capabilities of the standard single-channel dispersion interferometer to a high-frequency, multi-channel system capable of localized electron density measurements. To achieve higher modulation frequency, a 40 MHz GaAs electro-optical modulator is planned for implementation. Using multiple plasma sightlines together with appropriate inversion techniques will allow spatially resolved, high-frequency electron density fluctuation measurements. This poster will outline the project plan, present the current status, and discuss the main technical challenges.

P 16.101 Thu 13:45 Redoutensaal

Quantification of tungsten content in Wendelstein 7-X — •Birger Buttenschön, Daihong Zhang, Christian Brandt, Felix Reimold, and W7-X Team — Max Planck Institute for Plasma Physics, Greifswald, Germany

The high-Z material tungsten (W) is one of the most promising candidates for the use as first wall material in magnetic confinement fusion devices. Its capability to bear high particle and energy loads makes it ideal for the first wall. However, plasma-wall interaction can release W into the confined plasma, where even small impurity concentrations give rise to significant radiative power losses. Especially in a stellarator, which tends to accumulate impurities in relevant scenarios, the knowledge of tungsten sources and transport and the control of total tungsten concentration is crucial for reliable high performance operation.

In this contribution, we present our current knowledge about the W content in Wendelstein 7-X (W7-X) plasmas. The evaluation comprises deliberate impurity injections, interpretation of the radiation structures observed by bolometry and x-ray tomography, and finally an estimate of the background intrinsic tungsten concentration during standard W7-X operation.

P 16.102 Thu 13:45 Redoutensaal

JANUS: a composite HTS tape for improved magnetic field performance — •Titouan Atane, Paul Huslage, and Eve Stenson — Max-Planck-Institut für Plasmaphysik, Garching b. München, Germany

ReBCO (Rare-earth barium copper oxide) high-temperature superconducting (HTS) tapes are a promising technology for the generation of strong magnetic fields (with potentially reduced cryogenic cooling requirements). Due to anisotropy of the crystal lattice however, the critical current (I_c) is strongly dependant on the magnetic field angle (θ) as well as magnetic field strength ($|\mathbf{B}|$), which puts challenging constraints on coil optimization and manufacturing, particularly for non-planar coils (often used, e.g, in stellarator design). To solve this problem, the proposed JANUS composite tape consists of two HTS tapes (with different I_c vs θ orientations) soldered together. This concept can allow for a higher critical current, and it can make JANUS more robust against coil manufacturing errors. It is planned to further develop initial feasibility calculations to get a reliable description of the tape's response in a coil winding pack, then validate these experimentally.

P 16.103 Thu 13:45 Redoutensaal

Electric Field Reconstruction via Impurity-Induced Rotation in Wendelstein 7-X — •Thomas Wegner, Henning Thomsen, Christian Brandt, and the W7-X Team — Max-Planck-Institute for Plasma Physics, Greifswald, Germany

In stellarators, a self-generated radial electric field arises to fulfill ambipolarity and strongly shapes neoclassical transport by modifying particle orbits through the resulting ($E \times B$) drift. In this contribution, we present an experimental method to infer the radial electric field from the dynamics of impurities injected via laser blow-off and analyzed through tomographic inversion of line-integrated soft-X-ray measurements. The analysis of the poloidal motion of the resulting radiation pattern, driven by the ($E \times B$) drift, enables a reconstruction of the radial electric field. This method is applied and compared across similar plasma scenarios with forward and reversed magnetic field configurations.

P 16.104 Thu 13:45 Redoutensaal

Localized probe measurements across magnetic islands: implications for divertor operation in W7-X — •Alice Bonciarelli[1], Carsten Killer[1], Olaf Grulke[1], Alexander Knieps[1,2], Yu Gao[1], Sebastian Thiede[1], Marcin Jakubowski[1], Arun Pandey[1], and W7-X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management, Plasma Physics, 52425 Jülich, Germany

The optimized stellarator Wendelstein 7-X (W7-X) employs an island divertor. In this configuration, the scrape-off layer (SOL) is organized by a chain of resonant magnetic islands, which intersect the divertor targets placed accordingly. The latter act as a heat and particle exhaust system. The energy and particle transport processes are particularly challenging to disentangle in the complex three-dimensional magnetic geometry of the island divertor SOL. To investigate these complex edge regions, a suite of diagnostics is used, including a multi-user platform for reciprocating Langmuir probe measurements, that provides highly localized measurements of electron temperature and density as well as floating potential with high temporal resolution. The measurements indicate a complex distribution of plasma parameters in the island SOL, with well-localized features that presumably correlate to the island geometry and connection length distribution. By tracing magnetic field lines from the reciprocating probe sampling region to the divertor targets, local SOL measurements can be directly linked to divertor heat fluxes and plasma parameters.

P 16.105 Thu 13:45 Redoutensaal

Development of a Synthetic Helium Beam Diagnostic at ASDEX Upgrade — •Pietro Pecchini, Michael Griener, Sebastian Hoermann, Wladimir Zholobenko, Kaiyu Zhang, and Ondrej Grover — Max Planck Institute for Plasma Physics, Garching

Turbulent plasma behavior in the edge and scrape-off layer is a key factor for magnetic confinement fusion. Physics-based plasma boundary codes like GRILLIX, based on a two-fluid description of the plasma, can model these dynamics by simulating fundamental plasma parameters, such as electron density and temperature. However, experimental diagnostics - such as the helium beam diagnostic - measure derived quantities like spectral line emission intensities, making a direct comparison of measurement and simulation outputs challenging. To quantitatively validate the code output with experimental data, a synthetic helium beam diagnostic that translates simulation outputs into experimentally accessible signals is developed. A first implementation of this synthetic diagnostic for ASDEX Upgrade GRILLIX simulations is presented, and its performance is evaluated by comparing it with simplified models to quantify the impact of key effects. The importance of computing the ionization of the helium, considering simultaneously the time evolution of both helium particles and plasma, is investigated. The synthetic emission profile is decomposed to illustrate its dependence on electron density, helium density, and photon emissivity coefficients, for both an individual spectral line and the ratio between two spectral lines.

P 16.106 Thu 13:45 Redoutensaal

Absorption of high-intensity laser pulses in plasma gratings — •Sophie Opara and Götz Lehmann — Heinrich-Heine-Universität, Düsseldorf

Plasma transmission gratings are transient, periodic density structures in underdense plasmas that enable the manipulation of high-intensity laser pulses beyond the damage threshold of conventional solid-state optics. They are generated by the ponderomotive force of interfering driving pulses and can be reproducibly created on a shot-to-shot basis. With lifetimes on the picosecond timescale, they are well suited for controlling high-power femtosecond laser pulses. Potential applications include polarizers, wave plates, Bragg-type mirrors, and holographic lenses, among many others.

The optical response of these gratings is governed by their grating period, modulation depth, and plasma parameters, which in turn determine their transmission, reflection, and absorption characteristics. At sufficiently high intensities, a probe laser pulse can modify the density modulation and excite collective plasma dynamics, leading to energy absorption. This work investigates the absorption mechanisms in plasma transmission gratings and their dependence on laser and plasma parameters such as wavelength and plasma density. The results provide guidelines for their use either as efficient beam blockers or as low-loss, damage-free optical elements for high-intensity laser systems.

P 16.107 Thu 13:45 Redoutensaal

Laser pulse duration as a key parameter in plasma grating formation — •Götz Lehmann and Karl-Heinz Spatschek — Heinrich-Heine-Universität, Düsseldorf

Prompted by early experimental realizations of plasma-optical components, we examine how finite formation times affect the quality and scaling behavior of a plasma grating induced by the ponderomotive potential of two counter-propagating pump laser beams. Besides the plasma density, the ratio of thermal to ponderomotive pressure is known to be an important factor. Via full Vlasov simulations we show that the ratio of the laser pulse duration to the characteristic ion reaction time is another important parameter. These simulations also reveal that (linearized) kinetic models for electron-temperature-dependence need to be extended in order to recover the correct behavior for gratings generated by short laser pulses. A generalized simple hydrodynamic model allows to study the dependence of the grating amplitude on the pump laser amplitude a_0.

P 16.108 Thu 13:45 Redoutensaal

Particle Acceleration and Emission Signatures in Relativistic AGN Jets — •Nikita Nikita, Frank Rieger, and Frank Jenko — Max Planck Institut für Plasmaphysik

Relativistic jets from active galactic nuclei (AGNs) are among the most energetic phenomena in the universe, extending over kilo-parsec scales and interacting with their surrounding environment in highly complex ways. These jets develop complex structures through different MHD instabilities and turbulence, which strongly influence non-thermal particle acceleration in these systems. Using 3D RMHD simulations with PLUTO, we investigate jet-driven turbulence as a site for stochastic (second-order Fermi) acceleration in regimes where strong shocks are absent and magnetization is sufficient for stochastic processes to become relevant . We explore a semi-analytical treatment of turbulent acceleration and examine how different prescriptions for momentum diffusion coefficients and escape timescales shape the particle energization and the resulting spectra. By coupling these models to synthetic synchrotron emission, we aim to examine how variations in diffusion physics manifest in observable radio signatures from active galaxies, providing new constraints on the physical processes underlying particle acceleration in large-scale AGN jets.

P 16.109 Thu 13:45 Redoutensaal

energy dissipation in collisionless shocks: MMS observations — •Valentina Villaflor, Artem Bohdan, and Frank Jenko — Max Planck Institute for Plasma Physics, Garching, Germany

Collisionless shocks play a key role in space and astrophysical plasmas, enabling the conversion of large-scale kinetic energy into heat and non-thermal particle populations without relying on binary Coulomb collisions. Instead, these shocks are sustained by collective effects such as wave-particle interactions that are inherently kinetic and nonlinear. Despite significant observational and theoretical efforts, the precise mechanisms of energy dissipation in collisionless shocks remain debated. While it is widely accepted that dissipation occurs within the shock ramp, observations have shown that energy conversion may also extend involving other shock structures.

We analyze high-resolution measurements from the Magnetospheric Multiscale (MMS) mission across multiple quasi-perpendicular bow shock crossings. We quantify energy contribution of different particle species within a vicinity of the shock ramp to analyze energy transfer among electrons, ions. By correcting the measured ion and electron distribution functions for instrumental effects, we isolate the energy contributions of each species and examine how they vary throughout the shock structure. We calculate the theoretically expected values for thermal energy from mass conservation principles and Rankine-Hugoniot conditions to analyze the observed deviation from adiabatic behavior in collisionless shocks. Finally, we discuss how energy transfer between species depends on various shock parameters.

P 16.110 Thu 13:45 Redoutensaal

First interpretative local ERO2.0 modelling of tungsten erosion experiments at W7-X — •Claudio Maria De Simone[1], Chandra-Prakash Dhard[1], Dirk Naujoks[1], Juri Romazanov[2], and Sebastijan Brezinsek[2] — [1]Max-Planck Institute for Plasma Physics, Wendelsteinstrasse 1, 17491 Greifswald, Germany — [2]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics, 52425 Jülich, Germany

Tungsten has been chosen as the most promising material for plasma-facing components (PFCs), in future fusion devices, due to its favorable thermo-mechanical properties, low fuel retention, and low sputtering. While in tokamak devices tungsten erosion, deposition and transport has been extensively investigated, in stellarators such studies remain limited. This work aims to extend PWI knowledge for W7-X with the use of ERO2.0 developed by FZJ. This 3D Monte-Carlo is used to model local W erosion and migration for some baffle modules equipped with W tiles. Different 3D plasma solutions and scenarios as generated by EMC3-EIRENE will be used as an input for ERO2.0 modeling. A material-mixing model will be applied to consider the change of W surface concentration due to the impact of carbon impurity ions. The results of these simulations will be validated against in-situ spectroscopy and post-mortem analysis of exposed samples.

P 16.111 Thu 13:45 Redoutensaal

Evaluation of wall boiling models for plasma facing components — •Ahmet Kilavuz[1,2], Jeong-Ha You[2,3], Bosjan Koncar[4,5], and Rudolf Neu[1,2] — [1]Technical University of Munich — [2]Max Planck Institute for Plasma Physics — [3]University of Ulm — [4]Jožef Stefan Institute — [5]University of Ljubljana

Subcooled flow boiling in fusion-device cooling channels can occur under conditions far beyond those of conventional nuclear applications, with plasma-facing components exposed to heat fluxes up to 40 $\mathrm{MW\,m^{-2}}$ and mass fluxes approaching 20,000 $\mathrm{kg\,m^{-2}\,s^{-1}}$. This study compares several wall-boiling models, including the Rensselaer Polytechnic Institute (RPI) model and the Massachusetts Institute of Technology Boiling (MITB) model, together with multiple bubble-parameter correlations, against fusion-relevant high heat- and mass-flux experiments. The RPI model shows intrinsic limitations at high mass fluxes, producing non-physical negative boiling-curve slopes within the partially developed nucleate boiling regime. It is suggested that this behaviour cannot be corrected by adjusting bubble-parameter correlations. The MITB model mitigates these issues through a sliding-conduction mechanism that scales with flow velocity, which is particularly important at high mass fluxes. This leads to more physically consistent behaviour and reduces the mean absolute error by approximately 65% compared to generic wall-boiling formulations.

P 16.112 Thu 13:45 Redoutensaal

Testing of Tungsten-Copper Joints for Plasma-Facing Components by Means of Cyclic High Heat Flux Loading — •Simone Cocchi[1,2], Alexander von Müller[2], David Dellasega[1], Robert Lürbke[2,3], Ahmet Kilazuv[2,3], Julien Schachter[2], Johann Riesch[2], and Bernd Böswirth[2] — [1]Politecnico di Milano, 20156 Milan, Italy — [2]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [3]Technical University of Munich , 85748 Garching, Germany

In magnetic-confinement fusion devices, plasma-facing components (PFCs) have to face extreme heat loads. Decades of plasma-wall interaction research point to a design with plasma-facing tungsten tiles joined to a copper (Cu)-based heat sink. In so-called ”flat-tile” configurations, thermal gradients and the coefficient of thermal expansion (CTE) mismatch between W and Cu induce critically high stresses at the material interface, often leading to component failure. To mitigate this, tailored W-Cu interfaces represent a possible solution to improve PFCs durability - now possible due to developments in additive manufacturing technologies. An experimental design was devised to test relevant W-Cu joint specimens under high heat loads. FEA simulations were conducted to model thermomechanical loading at the flat-tile joint, aiding design of a dedicated mock-up joint geometry for testing under thermal cycling in the high heat flux test facility GLADIS. Results were obtained for DEMO-relevant tile dimensions with different interface architectures.

P 16.113 Thu 13:45 Redoutensaal

Investigation of Grain Boundary Transport in Tungsten by Hydrogenography — •Fahrudin Delic[1,2], Armin Manhard[2], and Udo von Toussaint[2] — [1]Technical University of Munich, Munich, Germany — [2]Max Planck Institute for Plasma Physics, Garching, Germany

The permeation of deuterium through grain boundaries in tungsten was studied on recrystallized foils using the hydrogenography method, employing tungsten trioxide as a hydrogen indicator. The temperature dependence of grain boundary transport was analyzed on 50 μm foils up to 700 K, revealing an overall increase in permeation activity with rising temperature. At around 630 K, a distinct *halo* structure forms around several grain boundaries, indicating the onset of deuterium desorption from the boundaries and the gradual transition toward bulk-dominated permeation. To investigate geometrical influences on permeation behavior, the 50 μm results were compared with measurements on 25 μm foils. In thinner foils, the grain geometry facilitates bulk transport, and a depletion region of hydrogen permeation around certain grain boundaries becomes visible. The hydrogenography analysis is furthermore complemented by grain orientation mapping via EBSD.

P 16.114 Thu 13:45 Redoutensaal

Exploiting Tungsten Fibre-Reinforcement for Plasma-Facing Component Design — •Thomas Fox[1,2], Alexander von Mueller[1], and Rudolf Neu[1,2] — [1]Technical University Munich, Boltzmannstr. 15, 85748 Garching — [2]Max Planck-Insitute for Plasma Physics, Boltzmannstr. 2, 85748 Garching

The divertor of a magnetic confinement fusion device has extreme requirements for materials design due to the high heat fluxes combined with plasma erosion and neutron flux considerations. Current leading designs centre around tungsten (W) surface armouring joined to a copper (Cu)-based heat sink. The mismatch in coefficient of thermal expansion (CTE) between these base materials leads to high thermomechanical stresses during heat loading that can cause cracking and delamination of the W armouring. This can significantly hamper the performance and shorten the service lifetime of a divertor plasma-facing component (PFC).

In this work, a design will be presented, in which W-fibre reinforcement will be utilised to mitigate the CTE mismatch while also strengthening and toughening the W/Cu joint with cross-interface connections. By taking advantage of textile processes, complex fibre preforms can be constructed out of ductile, potassium-doped W fibres. These preforms can first undergo chemically vapour infiltration of W and then melt infiltration of Cu or Cu-based alloys for creating a highly damage resistant fibre-reinforced composite PFC design. The overall goal of this work is to design, manufacture and test a scalable concept that meets the extreme requirements of a fusion reactor divertor.

P 16.115 Thu 13:45 Redoutensaal

Dynamic evolutions of radiation and divertor target behavior during detachment with an island divertor configuration on J-TEXT — •Yutong Yang[1], Yunfeng Liang[1,2], Wei Yan[2], Jiankun Hua[2], and Song Zhou[2] — [1]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management Plasma Physics, Jülich, Germany — [2]International Joint Research Laboratory of Magnetic Confinement Fusion and Plasma Physics, Huazhong University of Science and Technology, Wuhan, China

On J-TEXT, the temporal evolution of the heat flux distribution on the divertor plate has been measured using an infrared camera with an island divertor configuration. In previous experiments employing this configuration, partial detachment was achieved by SMBI gas fuelling when the radiation front approached the last closed flux surface (LCFS). This observation is consistent with the results obtained on the W7-X stellarator. We conducted a series of experiments under different island divertor configurations to further validate this conclusion. By reconstructing the 2D radiation profile using AXUV arrays, we investigated the dynamic characteristics of edge radiation, heat and particle fluxes on divertor target during the detachment. The results highlight the critical role of magnetic topology in the onset and development of detachment, providing important insights into realizing stable detachment under 3D boundary conditions.

P 16.116 Thu 13:45 Redoutensaal

Additive manufacturing for tailored tungsten copper joints in plasma-facing components — •Alberto Ambrogini[1,2], Alexander von Müller[1], and Rudolf Neu[1,2] — [1]Technical University of Munich — [2]Max Planck Institute for Plasma Physics

Additive manufacturing (AM) technology has progressed significantly in recent years and holds the potential to become a decisive technology for the fabrication of plasma-facing components (PFCs). In highly heat loaded divertor PFCs, issues regarding the joining of plasma-facing tungsten materials with copper based heat sink materials represent a major engineering challenge, considering the differing thermomechanical properties of these two materials. Under heat flux loadings in magnetic confinement fusion devices, this leads to stress concentrations at the joining interface, that in turn can lead to undesired failure of PFCs. One possible solution for improving such material joints is the tailoring of the interface between the two materials with the help of AM that enables control of the geometry, composition, and microstructure at the interface. This allows the creation of a tailored interfacial region where common failure mechanisms, like joint delamination, might be avoided. The contribution will present relevant AM technologies considered to be suitable for the realisation of tailored tungsten-copper interfaces and approaches to the design of such joints. Furthermore, plans for their testing under relevant loading situations will be outlined.

P 16.117 Thu 13:45 Redoutensaal

Quantum kinetic methods for dense quantum plasmas in nonequilibrium — •Christopher Makait and Michael Bonitz — Institute of Theoretical Physics and Astrophysics, Christian-Albrechts-Universität zu Kiel, 24098 Kiel, Germany

Standard kinetic approaches to plasma dynamics, such as the Boltzmann equation and the Lenard-Balescu equation (LB), face severe limitations when interaction energies, quantum effects, and ultra-short time scales - e.g. induced by intense laser pulses - become relevant [1]. These limitations can be overcome by non-Markovian quantum kinetic approaches such as nonequilibrium Green functions [2], reduced density matrices [3], or quantum fluctuations [4], each with their own advantages and disadvantages, in terms of accuracy and computational effort. Here, we systematically compare Markovian (LB) and non-Markovian results for electrical conductivity and stopping power in dense plasmas, and quantify the impact of non-Markovian memory effects.

[1] H. Haberland et al, Phys. Rev. E 64, 026405 (2001)

[2] G. Stefanucci, R. van Leeuwen, “Nonequilibrium Many-Body Theory of Quantum Systems: A Modern Introduction”

[3] M. Bonitz, “Quantum Kinetic Theory”, 2nd ed. Springer 2016

[4] E. Schroedter et al, Condensed Matter Physics, 2022, vol. 25, No. 2, 23401

P 17: Plasma Wall Interaction II

Time: Thursday 16:15–18:15 Location: KH 02.016

Invited Talk P 17.1 Thu 16:15 KH 02.016

Energetic proton damage for simulating fusion relevant neutron damage on reactor materials — •Rahul Rayaprolu — Forshungszentrum Jülich, Jülich, Germany

As fusion research progresses from experimental devices to reactors, it is imperative to comprehend the effects of fusion neutron damage and its impact on plasma-facing materials (PFMs). At present, the study of neutron damage is predominantly conducted through the use of fission reactors, which exhibit a distinct neutron-energy flux spectrum. Hence, the fission neutron damage leads damage ingrowth as compared to that of a fusion reactor. Ion irradiation is a well-established method and is frequently used as a surrogate for neutron damage. It is a more accessible method than nuclear reactors and simultaneously offers superior control over experimental conditions. Until recently, the focus has been on the use of heavy ions to replicate the displacement effects of neutron damage on the PFMs lattice. However, the heavy-ion irradiation method has a very shallow damage depth and is unable to take macroscopic effects into consideration. Energetic protons offer a solution and have been shown to deliver damage in depths ranging from 500 um to 1 mm. They produce a combination of displacement and nuclear-transmutation damage that is comparable to fusion neutrons. However, the irradiated area is constrained to the beam spot size, and the samples like fission irradiations are radioactive. In the absence of a fusion neutron source, this method can be used to study the development and influence of fusion relevant neutron damage in PFMs.

P 17.2 Thu 16:45 KH 02.016

Influence of the presence of deuterium on damage evolution in tungsten — •Zeqing Shen[1,2], Thomas Schwarz-Selinger[2], Mikhail Zibrov[2], Armin Manhard[2], and Martin Balden[2] — [1]Technische Universität München, 85747 Garching, Germany — [2]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany

A systematic investigation was conducted to examine the effects of ion flux during deuterium (D) exposure of self-ion-damaged tungsten (W). The samples were heated to four temperatures within the range of 470–770 K during the plasma loading process. Two plasma conditions were applied during annealing: a low flux of 6e19 D/m2/s and a high flux of 5e20 D/m2/s, both using an ion energy of 5 eV/D. For comparison, annealing experiments were also carried out in vacuum. The depth distribution of deuterium was determined by 3He nuclear reaction analysis (NRA), while its total inventory was evaluated using both NRA and thermal desorption spectroscopy (TDS). Morphological modifications at the surface were analysed by confocal laser scanning microscopy (CLSM). For the flux condition of 6e19 D/m2/s, the results revealed a decrease in deuterium retention with increasing annealing temperature for both plasma annealing and vacuum annealing. The presence of D during annealing has only a small stabilizing effect on the defects. In contrast, exposure to a higher flux of 5e20 D/m2/s induces additional damage, producing micrometer-wide blisters only a few tens of nanometers high.

P 17.3 Thu 17:10 KH 02.016

Hydrogen Isotope Exchange in Tungsten Displacement Damaged at High Temperature — •Laurin Hess[1,2] and Thomas Schwarz-Selinger[2] — [1]Technical University Munich, Munich, Germany — [2]Max-Planck-Institute for Plasma Physics, Garching, Germany

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 increases significantly due to displacement damage produced by 14 MeV fusion neutrons. Over the last years, a basic understanding of the behaviour of hydrogen in point defects was acquired. However, damage at high temperatures can also produce nm-sized voids. To gain 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 <5 eV deuterium (D) from a low-temperature plasma. The retained deuterium was then exchanged for protium (P) using the same plasma loading process. D depth profiles were measured after D loading and periodically during P loading using ^{3}He-NRA. After the loading, the retained hydrogen isotopes were measured using TDS. This showed that hydrogen in voids does not exchange at temperatures up to 370 K. At higher temperatures exchange starts to happen, with almost all hydrogen exchanged within hours during exposure at 460 K. The results were compared to the model proposed by Zibrov and Schmid [1].

[1] M. Zibrov, K. Schmid, Nucl. Mat. Eng. 30 (2022) 101121

P 17.4 Thu 17:35 KH 02.016

Effect of high displacement damage at different dose rates and temperatures on Deuterium retention in Eurofer97 — •Abdulrahman Albarodi[1,2], Thomas Schwarz-Selinger[2], Dina Mergia[3], and Dimitrios Papadakis[3] — [1]Technical University of Munich, Garching, Germany — [2]Max Planck Institute for Plasma Physics, Garching, Germany — [3]NCSR Demokritos, Athens , Greece

Open-volume defects in irradiated metals are attributed to increased gas retention. In this study, deuterium (D) retention was used as an indicator for the evolution of open-volume defects at different temperatures and dose-rates. EUROFER97 samples were irradiated with a defocused continuous 11.6 MeV Au beam with a dose rate of 2.5-16.5 dpa/hr using ions to peak displacement damage doses of 50-100 dpa at 100-400°C. Rutherford-backscattering (RBS) with 4 MeV helium was used on aluminum surrogates to characterize the Au implantation profile. The Au depth profile showed a region of high displacement damage of 500 nm that is gold-free for uncontaminated defect analysis. X-ray diffraction showed clear differences in the lattice constant and the width of the Bragg peaks between damaged samples and undamaged reference. The samples were subsequently exposed to D-plasma at 100°C and low energy (<5 eV/D) until full D defect decoration. D depth profiles were measured using 3He nuclear reaction analysis. D-retention results are comparable with previous low-dose (0.6 dpa) irradiated samples at 100°C. For the sample damaged at 300-400°C, it is comparable to undamaged EUROFER97. NRA and XRD results show recovery of open-volume defects at 400°C.

P 17.5 Thu 18:00 KH 02.016

Developing Tritium Diffusion Barrier Materials for Plasma-Facing Components in Fusion Reactors — •Markus Hermanski[1,3], Liang Gao[1], Arkadi Kreter[1], Jan Willem Coenen[1], Rongxing Yi[1], Sebastijan Brezinsek[1,2], and Christian Linsmeier[1,2] — [1]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management — Plasmaphysics (IFN-1), Jülich 52425, Germany — [2]Ruhr-Universität Bochum, Faculty of Physics and Astronomy, Bochum 44801, Germany — [3]RWTH Aachen University, Faculty of Georesources and Materials Engineering, Aachen 52072, Germany

Fuel permeation and retention in wall materials of fusion reactors, especially Tritium (T), are important aspects to be prevented to achieve commercial viability of fusion power in the future. For this reason, T diffusion barrier materials have been developed, however, focusing on applications at the coolant side. Preventing T permeation into the coolant, they cannot address the degradation of wall materials induced by H isotopes from plasma. Here, a diffusion barrier made of tungsten carbides (WxC) is proposed and will be developed for applications at plasma-facing surfaces.

WxC coatings will be fabricated via field assisted sintering technique (FAST) on W and G91 steel substrates, followed by deuterium (D) plasma exposure, where laser induced breakdown spectroscopy (LIBS), nuclear reaction analysis (NRA) and thermal desorption spectroscopy (TDS) measurements will be employed to measure the D depth profile after plasma exposure.

P 18: High Energy Density Physics III

Time: Thursday 16:15–17:30 Location: KH 01.020

Invited Talk P 18.1 Thu 16:15 KH 01.020

High-energy-density and high-pressure states investigated with x-ray imaging at HED-HiBEF — •Alejandro Laso Garcia — Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany

The High Energy Density - Helmholtz International Beamline for Extreme Fields (HED-HiBEF) at the European XFEL combines the x-ray beam, with unparalleled spatial and temporal coherence and brilliance, with powerful optical drivers to probe and study extreme states of matter.

With the high-intensity short-pulse laser, ReLaX, reaching intensities of 10^{20} W/cm^2 on target, is used to isochorically heat matter and generate blastwaves in materials. It can also generate high-pressure states via cylindrical compression in micrometer-sized wires. Thanks to the narrow energy bandwidth of the XFEL beam, the energy can be tuned to be resonant with the transition energy between the K- and L- shell of specific charge states in the plasma.

The DiPOLE-100X, the high-energy nanosecond pulse duration laser is used to generate planar shocks in materials and study equation-of-state of highly compressed matter via shock compression.

All these experiments make use of the x-ray imaging platform developed at HED-HiBEF. In this talk we will provide a description of the platform and the spatial resolution achieved (better than 500 nm) as well as its application to all the cases mentioned above.

P 18.2 Thu 16:45 KH 01.020

A Megajoule Experiment at an XFEL: High-repetition Rate XRTS Measurements in Shock Compressed Plastics — •Thomas Gawne[1,2], Oliver S Humphries[3], Tobias Dornheim[2,1], and Thomas R Preston[3] — [1]CASUS, Görlitz, Germany — [2]HZDR, Dresden, Germany — [3]European XFEL, Schenefeld, Germany

The properties of plastics under laser compression are of broad importance due to their prevalence as ablators in shock-compression experiments and laser-driven inertial fusion energy schemes. Accurate measurements of their equation of state and electronic structure are therefore of paramount importance for predicting achievable conditions in laser-driven systems. Here we report on results from a recent experiment at the European XFEL, where the DiPOLE-100X laser was used to shock compress plastics at a repetition rate of 1 Hz with ~30 J laser energy in 2ω. In the three day experiment, more than 34,000 laser shots were collected, and more than 1 MJ of laser energy fired at the targets. The systems were probed using simultaneous forward and backwards XRTS. Ultrahigh resolution measurements of the elastic feature in backscattering reveal the shock dynamics via the combined thermal Doppler broadening and shock-driven Doppler shift. Forward scattering measurements at multiple scattering angles show pronounced changes in the shape of the plasmon scattering between the different plastics, providing insights into the differences in their electronic properties and structures under shock compression. The setup and results presented here represent an important development for future laser compression experiments at XFEL facilities.

P 18.3 Thu 17:00 KH 01.020

Hydrodynamic equations for strongly coupled plasmas — •Daniels Krimans, Hanno Kählert, and Michael Bonitz — Institute of Theoretical Physics and Astrophysics, Christian-Albrechts-Universität zu Kiel, 24098 Kiel, Germany

In strongly coupled plasmas, particle correlations dominate the dynamics, making theoretical descriptions challenging. To provide an alternative to computationally intensive particle-based methods, we present a hydrodynamic model obtained from the least action principle [1, 2]. In this approach, the pair distribution function is included directly into the Lagrangian, allowing correlation effects to be treated consistently while conserving energy and momentum.

We apply this framework to Coulomb [1] and Yukawa [2] one-component plasmas and analyze the linearized hydrodynamic equations by computing longitudinal and transverse modes. The obtained dispersion relations agree closely with molecular dynamics simulations over a wide range of coupling strengths and screening parameters, up to finite wavelengths comparable to the interparticle spacing.

We also outline how this variational framework may be extended to the quantum regime, thereby generalizing earlier formulations of quantum hydrodynamics [3] to strongly coupled systems. The resulting equations are expected to be relevant for inertial confinement fusion.

[1] D. Krimans and S. Putterman, Phys. Fluids **36**, 037131 (2024).
[2] D. Krimans and H. Kählert, arXiv:2506.23006v1 (2025).
[3] Zh. A. Moldabekov, M. Bonitz, and T. S. Ramazanov, Phys. Plasmas **25**, 031903 (2018).

P 18.4 Thu 17:15 KH 01.020

Matsubara Local Field Correction of Warm Dense Beryllium — •Maximilian Boehme[1], Tobias Dornheim[2], Jan Vorberger[2], and Zhandos Moldabekov[2] — [1]Lawrence Livermore National Laboratory — [2]Helmholtz-Zentrum Dresden-Rossendorf

Recent studies, including Dornheim et al. [EPL 147, 36001 (2024)], have highlighted the role of dynamical quantum effects encoded in the imaginary-time correlation function of the uniform electron gas in the warm dense matter (WDM) regime. In this work, we extend these efforts by employing the Fourier-Matsubara expansion framework introduced by Tolias et al. [J. Chem. Phys. 160, 181102 (2024)] to compute the Matsubara density-response function of warm dense beryllium using path-integral Monte Carlo simulations. We consider temperatures from 155.5 to 190 eV and densities between 7.5 and 30 g/cc, spanning a representative region of the WDM phase space. This approach provides access to electronic correlations and localization phenomena within the imaginary-time formalism. Furthermore, the resulting Matsubara density-response enables the extraction of the corresponding local field correction (LFC), thereby revealing the imaginary-frequency dependence of exchange-correlation effects in beryllium. Our results offer new insight into the microscopic dynamical behaviour of partially ionized systems and support the development of improved theoretical models for WDM.

P 19: Atmospheric Pressure Plasmas III

Time: Thursday 17:30–18:15 Location: KH 01.020

P 19.1 Thu 17:30 KH 01.020

Upscaling Microwave CO_2 Plasma Torches: Transitioning to 915 MHz Operation — •Marc Bresser, Katharina Wiegers, Irina Semjonov, Andreas Schulz, Matthias Walker, and Günter Tovar — IGVP, University of Stuttgart, Germany

The continuous rise in Earth's surface temperature makes a reduction of the emission of climate gasses essential. The chemical industry, as one of the largest emitters of CO_2, must find new processes to replace fossil routes with renewable alternatives. A promising approach is to use CO_2 as a feedstock and close the carbon cycle. One innovative technology is the activation of CO_2 with an atmospheric microwave plasma torch, which produces CO and O_2. The produced CO can be used together with green hydrogen to form syngas and to be a feedstock for processes like Fischer-Tropsch. One advantage of the microwave plasma is the flexibility of power, small turn on times, and the use of the fluctuations of renewable intermittent energy sources like wind or solar. This work investigates the upscaling of CO_2 splitting with an atmospheric plasma torch from 2.45 GHz to 915 MHz. The process at 2.45 GHz was examined up to 6 kW and gas flow-rates of 74 slm. To improve conversion efficiency, the quenching of the effluent plasma was explored using a gas nozzle and different cooler positions. The cold product gas is analyzed with absorption Fourier-transform infrared spectroscopy and a X-Stream gas analyzer. Based on these findings, a 915 MHz plasma torch was designed and constructed. The first conversions results are presented.

P 19.2 Thu 17:45 KH 01.020

Using the AD8302 phase detector for power measurements of RF-driven plasmas — •Steffen Schüttler[1], Michael Roloff[1], Sven Weller[2], Michael Konkowski[2], and Judith Golda[1] — [1]Plasma Interface Physics, Ruhr University Bochum, Bochum, Germany — [2]Chair for Experimental Physics II - Reactive Plasmas, Ruhr University Bochum, Bochum, Germany

The use of reference standards for plasmas in laboratories guarantees reproducible results. By this, plasma processes can be thoroughly investigated, as the results are comparable and the focus is on plasma physics rather than on comparing different plasma sources. This was the idea behind the design of the COST reference plasma jet [1]. However, the measured values for plasma characterisation are still diverse. Some groups measure the dissipated plasma power while others only provide the applied voltage, as proper power measurements require a high-resolution oscilloscope (expensive and not everywhere available) to measure the phase shift between voltage and current. But the applied voltage is an external parameter that provides poor insights into the plasma itself. For example, the dissipated plasma power differs at the same external voltage for different feed gases and reactive admixtures. In this work, we provide a new method that uses the AD8302 phase detector to measure the phase shift between voltage and current of the COST reference plasma jet. This offers an easy-to-implement and low-cost alternative for measuring the dissipated plasma power of RF-driven plasmas such as the COST reference plasma jet.

[1] Golda et al. J. Phys. D: Appl. Phys. 49 (2016) 084003 (11pp)

P 19.3 Thu 18:00 KH 01.020

Particle Dynamics and Characteristics during In-Flight Iron Oxide Reduction in an Ar-H2 Microwave Plasma — •Jonas Thiel, Lennart Kulik, Moritz Petersen, Marc Böke, and Achim von Keudell — Experimental Physics II - Reactive Plasmas, Ruhr University Bochum, Bochum, Germany

The climate-neutral production of metallic iron from iron ore is an emerging research topic, as the iron and steel industry is one major emitter of CO2. In this work, an atmospheric argon-hydrogen microwave plasma torch is deployed to investigate the in-flight reduction of iron oxide particles. These plasmas provide fast reaction kinetics, a fine control of energy consumption and promising scale-up options. The experimental setup enables a wide range of operating conditions to optimize the process. OES, XRD and spatially resolved RGB pyrometry using two CCD cameras, complemented by a heat transport model and gas-flow simulation, are applied to evaluate parameter variations and the overall reduction efficiency. The resulting phase compositions of the treated particles are correlated with particle size and process parameters, revealing favorable process conditions. Additionally, we observe significant emission trails from the hot particles in the downstream region, which are caused by friction with the much faster gas flow. These formations, which depend on gas-flow dynamics and the particle surface temperature, provide insight into particle size dynamics and evaporation. Overall, the results indicate the potential of in-flight oxide reduction in atmospheric plasmas while also emphasizing challenges such as particle evaporation and surface coatings.

P 20: Members' Assembly

Time: Thursday 18:30–19:30 Location: KS H C

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

P 21: Codes and Modeling II

Time: Friday 9:00–10:30 Location: KH 01.013

Invited Talk P 21.1 Fri 9:00 KH 01.013

Performance Pitfalls and Design Principles of Retarding Potential Analyzers — •Thomas Trottenberg — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

Retarding potential analyzers (RPAs) are standard diagnostics for ion energy distribution measurements, yet their performance is often limited by subtle but critical mechanical design choices. Grid alignment, aperture geometry, grid thickness, and spacing can strongly affect the measured current-voltage characteristics and may introduce non-monotonic behavior and artificial humps.

In this talk, experimental results and trajectory simulations of a four-grid RPA with drilled grids are presented, systematically quantifying the impact of grid orientation and hole geometry. It is shown that certain grid alignments introduce strong correlation effects between adjacent grids, resulting in enhanced transparency and pronounced anomalies close to the falling edge in the characteristics.

These findings reveal fundamental performance pitfalls of RPAs and form the basis for practical design guidelines. Concrete recommendations for grid geometry and alignment are derived, aiming at robust, monotonic characteristics and reliable ion energy distribution functions.

Invited Talk P 21.2 Fri 9:30 KH 01.013

Microwave cavity resonance spectroscopy: a novel approach for spatially resolved electron density measurements — •Jens Oberrath — Modeling and Simulation, South Westphalia University of Applied Sciences, Soest, Germany

Electron density is a critical parameter of plasma. Its non-invasive measurement becomes particularly challenging when spatial resolution is required. A promising technique for this purpose is Microwave Cavity Resonance Spectroscopy (MCRS), where electromagnetic waves are coupled into a plasma-filled cavity to excite resonances. These resonances, which also occur in vacuum, are shifted by the presence of the plasma. MCRS has been known since the 1950s. While significant improvements have been made over the past few decades, a robust approach for measuring spatially resolved electron densities has yet to be fully developed. The scattering behavior of a plasma-filled cavity with a finite number of connected waveguides can be described by the shell-model approach developed by Mahaux and Weidenmüller. Using functional analytic methods, the scattering matrix S for such a cavity can be derived. Assuming a cold plasma model for the electrons, the calculated elements of S (reflection and transmission coefficients) contain the spatially dependent electron density. For a specific type of plasma, a density profile can be assumed and expanded as a function with a certain number of unknown parameters. By comparing the calculated elements of S with the measured ones, these unknown parameters in the density profile can be determined, enabling the spatially resolved measurement of electron densities.

P 21.3 Fri 10:00 KH 01.013

Event-driven simulation of X-ray Thomson scattering for warm dense matter probing — •Uwe Hernandez Acosta[1,2], Thomas Gawne[1,2], Jan Vorberger[1], Hannah Bellenbaum[1,2], and Tobias Dornheim[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]Center for Advanced Systems Understanding, Görlitz, Germany

X-ray Thomson scattering (XRTS) is a central diagnostic for investigating matter under extreme conditions, including laser-driven pump-probe experiments at X-ray free-electron lasers that probe high-energy-density states such as warm dense matter and the compression path of inertial confinement fusion capsules. The analysis of XRTS spectra is often challenging due to low photon counts, evolving sample conditions, and strong geometric and instrumental effects, which are only partially captured by conventional forward-modeling approaches based on convolutions of the dynamic structure factor with simplified source and instrument functions.

We present a proof-of-principle event-driven approach to XRTS modeling that directly connects microscopic electronic-structure physics with realistic detector simulations. Individual scattering events are sampled from the XRTS differential cross section and propagated through a detector model, naturally incorporating instrument response, geometry, and counting statistics. Focusing on non-resonant XRTS in a synthetic diagnostic setup, we demonstrate the technical feasibility and physical consistency of the method and benchmark it against conventional forward models.

P 21.4 Fri 10:15 KH 01.013

Characterising strongly compressed Beryllium using a combined ray tracing and forward-fitting approach — •Hannah Bellenbaum[1,2,3] and Tobias Dornheim[2,1] — [1]Center for Advanced Systems Understanding, Untermarkt 20, 02826 Görlitz, Deutschland — [2]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 DresdenHelmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Deutschland — [3]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23, 18059 Rostock, Deutschland

X-ray Thomson scattering (XRTS) is a commonly used diagnostic in the warm dense matter regime, as it can be used to simultaneously characterise density, temperature and ionisation degree. Extracting these parameters however commonly relies on a forward-modelling approach where a simple model is fitted to experimental data, since the measured spectrum is a convolution of the dynamic structure factor (DSF) describing the plasma conditions and the source-instrument function (SIF) of the detector . This introduces a number of uncertainties and model-dependencies, and fundamentally relies on the model chosen for the SIF. Here, we present a forward-fit using a new open-source XRTS code (xDave) in combination with the ray tracing code HEART to analyse spectra measured for imploding Beryllium capsules at the National Ignition Facility. The coupling of this ray tracing code with a reduced model for the DSF introduces far fewer uncertainties in both the instrument response function and the source spectrum, allowing us accurately study a typical NIF capsule during implosion.

P 22: Plasma Wall Interaction III

Time: Friday 9:00–10:30 Location: KH 01.012

Invited Talk P 22.1 Fri 9:00 KH 01.012

ERO/ERO2.0 modelling for tokamaks, stellarators and linear plasma devices — •Juri Romazanov[1], Henri Kumpulainen[1], Christoph Baumann[1], Sebastian Rode[1], Andriy Tarasenko[1], Andreas Kirschner[1], Georgii Timkovskii[1], Dmitry Matveev[1], Sebastijan Brezinsek[1], JET team[2], and W7-X team[3] — [1]Forschungszentrum Jülich GmbH, IFN-1, 52425 Jülich, Germany — [2]See the author list of "Overview of T and D-T results in JET with ITER-like wall" by C.F. Maggi et al. Nucl. Fusion 64, 112012 (2024). — [3]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

This contribution summarizes PWI research using the ERO2.0 code for erosion and material migration in magnetic confinement fusion devices. Code validation is demonstrated using experiments in the linear plasma device PSI-2, where B sample exposures were analyzed using spectroscopy of atomic B and molecular BD emission. Another validation study was conducted at JET, where interpretative plasma reconstructions were combined with predictive W modelling across all plasma regions and compared with experimental W profiles inferred from multiple diagnostics. Predictive studies are presented for several future devices. These include assessments of replacing C with W PFCs in W7-X, W erosion and prompt redeposition in ITER during limiter ramp-up and diverted operation with neon seeding, and lifetime predictions for diagnostic first mirrors. We conclude with EU-DEMO results and discuss challenges stemming from extrapolating plasma profiles to reactor walls.

P 22.2 Fri 9:30 KH 01.012

Initial predictive modeling of plasma-wall interactions using ERO2.0 for W7-X with tungsten wall divertor — •Georgii Timkovskii[1], Juri Romazanov[1], Sebastijan Brezinsek[1,2], Daniil Ryndyk[1], Henri Kumpulainen[1], and W7-X Team[3] — [1]Forschungszentrum Jülich GmbH, IFN-1 - Plasma Physics, Jülich, Germany — [2]Mathematisch-Naturwissenschaftliche Fakultät, HHU Düsseldorf, Düsseldorf, Germany — [3]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

Plasma-wall interaction (PWI) is a critical aspect of fusion device operation, influencing material lifetime, fuel retention, and overall plasma performance. In addition to interpretive modelling used to analyze and understand physics experiments, predictive modeling with validated codes like ERO2.0 becomes essential for anticipating system behavior and guiding design or operational decisions as required for an exchange of the wall material in Wendelstein 7-X (W7-X). ERO2.0 is a fully kinetic Monte Carlo code dealing with PWI processes at the surface and incorporating phenomena such as drifts, ionization, and impurity-ion collisions in the plasma. While there have been multiple ERO2.0 studies of stellarators - including cases with some tungsten components - no systematic investigation exist for a fully metallic stellarator with a tungsten divertor. In this work, PWI and impurity transport for the W7-X stellarator are studied with focus on the planned wall material exchange from a carbon wall to a tungsten wall. The influence of the resolution of existing 3D grids on the resulting PWI and impurity transport is analyzed.

P 22.3 Fri 9:45 KH 01.012

Spectroscopic Time-of-Flight Spatial Distribution Measurements of Neon-Sputtered Monocrystalline W at the Linear Plasma Device PSI-2 — •Merlin Klein[1], Oleksandr Marchuk[1], Marc Sackers[1], Arkadi Kreter[1], and Sebastijan Brezinsek[1,2] — [1]Forschungszentrum Jülich GmbH, IFN-1 — [2]HHU Düsseldorf, Faculty of Mathematics and Natural Sciences

Tungsten (W) is a plasma-facing material (PFM) for fusion reactors. By erosion W atoms can enter the plasma and cool it through radiation losses. The quantity and spatial distribution of sputtered W atoms from PFMs therefore has a direct impact on reactor performance. For energy impacts in the keV range, the sputtered W atoms follow a cosine angular distribution. For lower energies, as typically exist in the divertor region as well, experimental data shows a discrepancy to existing models.

In this experiment, poly- and monocristalline (111) W is exposed to a linear Neon plasma at kinetic energies of about 100 eV. Further excitations of W atoms sputtered into the plasma column allow for the acquisition of multiple line shapes in a spectroscopic time-of-flight (ToF) measurement. The total sputtering yield can be deduced from multiple acquisitions. In this ToF measurement it is possible to differentiate between angular distributions of sputtered W flux, while all other experimental parameters stay fixed.

These new experimental results show deviations in angular distributions between lattice structures and their orientations which can be used to support modelling of low temperature plasma-wall interactions.

P 22.4 Fri 10:00 KH 01.012

Near-surface hydrogen inventory response to picosecond laser pulses in tungsten. — •Maria Popova, Dmitry Matveev, Sebastijan Brezinsek, Christoph Kawan, and Erik Wüst — Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics, 52425 Jülich, Germany

Tungsten is a leading plasma-facing material; neutron damage creates traps for hydrogen isotopes. Near-surface fuel inventory and release can be probed with LIA-QMS.

A FEniCS/FESTIM framework for picosecond laser pulse trains is presented, addressing depths <1 mm. Transient heat conduction is coupled to a near-surface trapping-detrapping scheme. Coarse ablation is represented as removal of a surface layer, tens of nanometers thick, at the start of each pulse, updating thermal and hydrogen boundary conditions. Per-pulse release is obtained from the desorption-flux integral; initial fuel distributions are taken from NRA depth profiles on proton-irradiated and self-damaged, deuterium-decorated tungsten.

Results indicate that heating-induced release dominates for the first ~10 pulses; subsequent ablation mostly removes a layer partially depleted by prior heating. Including a simple defect-annealing term enables comparison to LIA-QMS depth reconstructions with good agreement.

P 22.5 Fri 10:15 KH 01.012

Fabrication of tungsten fibre-reinforced composites by combining Chemical Vapour Deposition and Field Assisted Sintering — •Patrick Scholz[1], Alexander Lau[1], Jan Willem Coenen[1], and Florian Kleemiss[2] — [1]Forschungszentrum Jülich GmbH, Institut of Fusion Energy and Nuclear Waste Managment - Plasmaphysics (IFN-1), Jülich 52425, Germany — [2]Institut für Anorganische Chemie, RWTH Aachen, Landoltweg 1a, 52074 Aachen, Germany

Many promising materials for high-temperature or oxidizing environments, including chromium aluminium carbide (Cr_2AlC), titanium aluminium carbide (Ti_2AlC), and self-passivating metal alloys with reduced thermo-oxidation (SMART), are limited by their inherent brittleness, restricting their suitability as structural components. Tungsten fibre-reinforced tungsten has demonstrated that embedding ductile fibres in a brittle matrix can produce pseudo-ductile fracture behaviour below the ductile-to-brittle transition temperature (DBTT). To transfer this toughening concept to these alternative matrices, the tungsten fibres must be protected from direct interaction with embrittling species, particularly chromium and carbon. This work investigates sacrificial tungsten coatings deposited by chemical vapour deposition (CVD). These coatings act as controlled sinks for matrix ingress during sintering, ensuring that the fibres remain unaffected. The study focuses on determining the coating thickness required for reliable fibre incorporation into each matrix system and evaluating the resulting mechanical performance.

P 23: Low Pressure Plasmas IV

Time: Friday 11:00–11:30 Location: KH 01.012

P 23.1 Fri 11:00 KH 01.012

Double probe calibration in different plasma regimes using microwave cavity resonance spectroscopy — •Andreas Petersen[1], Johanna Vogt[2], Jens Oberrath[2], Julian Held[3], and Franko Greiner[1,4] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]South Westphalia University of Applied Sciences, Soest, Germany — [3]Eindhoven University of Technology, Eindhoven, Netherlands — [4]KiNSIS, Kiel, Germany

Probe-based diagnostics remain a cornerstone of plasma characterization, offering spatially resolved measurements through precise positioning of the exposed probe tip. But factors like RF compensation and surface contamination can complicate matters. Also, the correct ion current model must be selected: while the ABR theory assumes collisionless, non-orbiting ions, the BRL framework incorporates ion orbiting and weak collisionality. For strongly collisional regimes the modified Talbot-Chou model is an option. This makes model selection nontrivial. We present a comparative study of simultaneous double-probe and microwave cavity resonance spectroscopy (MCRS) measurements, because MCRS is very sensitive and can detect changes in electron density of the order of $10^{10}\mathrm{m}^{-3}$. These results pave the way for future applications in nanodusty and electronegative plasma systems.

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

P 23.2 Fri 11:15 KH 01.012

Numerical studies on extreme-ultraviolet-induced low density hydrogen plasmas — •Adelind Elshani[1], Ahmet Aksoy[1], Linus Nagel[1], Sascha Brose[1,2], Rolf Wester[2], Annika Bonhoff[1], and Carlo Holly[1,2] — [1]RWTH Aachen University TOS, Aachen — [2]Fraunhofer Institute for Laser Technology ILT, Aachen

The interaction of extreme-ultraviolet (EUV) radiation with low-pressure hydrogen gas induces a low-density hydrogen plasma. Understanding the underlying chemical and dynamic processes is essential but complicated due to plasma formation complexity and correlated influencing factors during experiments. Dedicated stand-alone setups using discharge-produced plasma EUV radiation sources allow for reduction of experimental complexity and simplified setups. In addition, experimental parameters can be systematically varied and adjusted leading to controllable boundary conditions. As a result, fundamental dependencies with mostly unbiased parameters can be experimentally investigated, covering intensity or power optimized exposures at 13.5 nm, with narrow to broadband spectral distributions in hydrogen gas atmospheres. An according modeling framework, adaptable to these setups is developed to link the experimental data with theoretical models. The combination of experiment and simulation enables an in-depth understanding of the EUV-induced hydrogen plasma formation. The presentation covers the key components of the modeling framework based on a kinetic approach, along with an analysis of the electron dynamics for high-intensity EUV exposure configurations.

P 24: Laser Plasmas

Time: Friday 11:00–12:00 Location: KH 01.013

P 24.1 Fri 11:00 KH 01.013

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], 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 Delay Dispersion (GDD). 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 ultrashort laser pulses interacting with thin foils reveal prominent spectral shifts across changing GDD 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 Particle-in-Cell codes to simulate these interactions to analyze the underlying mechanisms. By bridging the gap between experimental observations and theoretical predictions, this work aims to advance our understanding of laser-plasma interactions and optimize laser-driven ion acceleration.

P 24.2 Fri 11:15 KH 01.013

Expansion of Nano Rods under Realistic Laser Contrast in 2D PIC Simulations — •Franziska-Luise Paschke-Brühl[1,2] and Thomas Kluge[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Technische Universität Dresden

We present a computational study investigating the pre-expansion of 10 um long, 100 nm thick Silicon nano rods under realistic laser contrast of a 10^20 W/cm^2, 30fs laser pulse. The 2D particle-in-cell simulations give insight into the expansion of the electron density and thus where the laser is getting reflected. Significant expansion under the relativistic intensities in the leading laser ramp cause the peak intensities to be reflected before reaching the solid rod structure. Based on that, we investigate which conditions allow the propagation of the highest intensities into an intact nano rod structure. This allows a coulomb explosion to happen, accelerating Silicon ions to fuel a fusion reaction.

P 24.3 Fri 11:30 KH 01.013

Optical probing of plasma dynamics in laser-driven nanostructured targets — Ankit Dulat[1], Constantin Bernert[1], Thomas Cowan[1], Thomas Kluge[1], Georg Korn[2], Franziska Paschke-Brühl[1,3], Daniel Rivas[2], Hartmut Ruhl[2], Marius Schollmeier[2], Ulrich Schramm[1,3], Karl Zeil[1], •Tim Ziegler[1], and more collaborators[1,2,3] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Marvel Fusion GmbH, Munich, Germany — [3]Technische Universität Dresden, Dresden, Germany

Nanostructured solid targets are of strong interest in high-intensity laser-plasma interactions because they enhance absorption and particle acceleration. However, experimentally accessing the relevant interaction dynamics remains challenging due to their ultrafast and nanoscale nature. In particular, laser pre-pulses can pre-ionize and expand the target, modifying the nanostructure and degrading performance, making these dynamics critical to resolve for reliable modeling and target optimization.

We present an optical pump-probe setup to study pre-plasma dynamics in the interaction of an ultrashort high-power laser with nanostructured targets. Using combined scattering and Doppler spectrometry, we measure target expansion and particle dynamics under different laser contrast conditions, providing insight into how nanostructure modification influences laser-plasma coupling and ion acceleration.

P 24.4 Fri 11:45 KH 01.013

Spin Polarization in Plasma Accelerators — Gudrid Moortgat-Pick[1,2], •Maryam Hamidi[1], Maxence Thevenet[2], and Kristjan Põder[2] — [1]University of Hamburg — [2]Deutsches Elektronen Synchrotron

Plasma based compact accelerators are extremely attractive due to their ultrahigh acceleration gradients. A key property of the electron beam is stable and high spin-polarisation. Spin-polarised beams are substantial for many aspects of fundamental research. However, it is still unclear how a polarised beam behaves in a plasma accelerator. The aim of this project is to study the physics of spin depolarisation in plasma accelerators and to understand the effect of beam parameters on final polarisation. First conceptual ideas for the experimental realization of a spin-polarised plasma accelerator will be discussed. Given a pre-polarised electron source, these spin-aligned electrons must be injected into the plasma accelerator cavity without misaligning the spins to be further accelerated to result in a highly-polarised high-energetic electron beam. A status report of the planned experimental set-up is given and simulations results are discussed.

P 25: Plasma Wall Interaction IV

Time: Friday 11:30–12:00 Location: KH 01.012

P 25.1 Fri 11:30 KH 01.012

Improving The Sinterability Of WfW By Alloying — •Chongyang Liu[1,4], Jan Willem Coenen[1], Yiran Mao[1], Mehrdad Mousapour[1], Tomislav Damjanovic[1], Christian Linsmeier[1,2], and Martin Bram[3,4] — [1]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management, 52425 Jülich, Germany — [2]Ruhr-Universität Bochum, Faculty of Physics and Astronomy, Bochum 44801, Germany — [3]Forschungszentrum Jülich GmbH, Institute of Energy Materials and Devices, 52425 Jülich, Germany — [4]Ruhr-Universität Bochum, Faculty of Mechanical Engineering, Bochum 44801, Germany

In this work, tungsten fiber*reinforced tungsten (Wf/W) composites were modified by adding vanadium (V) to enhance densification while maintaining fiber ductility. W-V powders were produced by mechanical alloying and consolidated by FAST/SPS under varied V contents, temperatures, and holding times. Density was measured by the Archimedes method, and SEM/EDX analyzed microstructure and V diffusion. Three-point bending and fracture observations evaluated fiber behavior. The results show that small V additions, together with reduced sintering temperature and holding time, significantly improve matrix densification while keeping the fibers predominantly ductile. In contrast, higher temperatures or longer holding promote excessive V diffusion and fiber embrittlement. Overall, V alloying with optimized FAST/SPS parameters offers an effective route to improve Wf/W densification without sacrificing fiber integrity.

P 25.2 Fri 11:45 KH 01.012

Design-by-Analysis of Tungsten Fibre-Reinforced Tungsten for Divertor Plasma-Facing Components — •Tomislav Damjanović[1,2], Jan Willem Coenen[1], Yiran Mao[1], Mehrdad Mousapour[1], Christian Linsmeier[1,2], and Ute Wilkinson[3] — [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 — [3]Dr. Fritsch Sondermaschinen GmbH, Fellbach 70736, Germany

Tungsten remains the leading material for plasma-facing components in fusion devices, yet its brittleness, limited thermal shock resistance, and irradiation-induced degradation raise concerns for long-term divertor operation. Embedding ductile tungsten fibres into a tungsten matrix (Wf/W) offers a route toward enhanced toughness and improved damage tolerance.

This contribution presents a design-by-analysis approach to optimize Wf/W composites for divertor-relevant thermo-mechanical loads. The microscale behavior is represented through homogenized material models using rule-of-mixtures and Mori-Tanaka schemes. These effective properties feed into a mesoscale description based on classical laminate theory to explore fiber volume fractions, orientations, and stacking configurations. Optimized composite layouts are then assessed in component-level finite-element simulations with realistic boundary conditions representative of divertor operation.