Plasma Physics Division
Fachverband Plasmaphysik (P)

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Overview of Invited Talks and Sessions

(Lecture halls ELP 6: HS 3, ELP 6: HS 4, and WW 1: HS; Poster ELP 6: Foyer)

Plenary Talks of the Plasma Physics Division

PV II	Mon	9:45–10:30	ELP 6: HS 3+4	**The role of plasma conversion technology in the greening of the chemical industry** — •Richard van de Sanden
PV VIII	Thu	9:45–10:30	ELP 6: HS 3+4	**Achieving target gain > 1 from inertial confinement fusion implosions at the National Ignition Facility*** — •Tilo Döppner

Invited Talks

P 1.1	Mon	11:00–11:30	ELP 6: HS 3	**On the observation of Trapped Electron Modes in W7-X** — •Andreas Krämer-Flecken, Paul Costello, Golo Fuchert, Joachim Geiger, Stèphane Heuraux, Alexander Knieps, Josefine Proll, Kian Rahbarnia, Roland Sabot, Luigui Salazar, Gavin Weir, Thomas Windisch, Haoming Xiang
P 2.1	Mon	11:00–11:30	WW 1: HS	**Interaction of reactive components of non-equilibrium atmospheric plasmas with liquids and surfaces** — •Kerstin Sgonina, Alexander Quack, Christian Schulze, Jan Benedikt
P 3.1	Mon	14:00–14:30	ELP 6: HS 3	**Influence of Nanosecond Pulsed Plasmas in Liquids on Copper Surfaces** — •Pia-Victoria Pottkämper, Oliver Krettek, Katharina Laake, Achim von Keudell
P 4.1	Mon	14:00–14:30	WW 1: HS	**Ab initio calculations of conductivities under planetary interior conditions** — •Martin Preising, Martin French, Maximilian Schörner, Mandy Bethkenhagen, Argha Roy, Uwe Kleinschmidt, Ronald Redmer
P 7.1	Tue	11:00–11:30	ELP 6: HS 3	**Physics of Electrical Currents and Fields in the Scrape-off Layer of Tokamak Plasmas** — •D. Brida, G. D. Conway, J. Adamek, J. Cavalier, H. Bergstroem, G. Grenfell, U. Plank, the ASDEX Upgrade Team
P 8.1	Tue	11:00–11:30	WW 1: HS	**Pulsed Complex Plasma In Microgravity** — •Christina A. Knapek, Daniel P. Mohr, Peter Huber
P 10.1	Tue	14:00–14:30	WW 1: HS	**Filament interaction in dielectric barrier discharges** — •Hans Höft, Ronny Brandenburg, Markus M. Becker, Torsten Gerling
P 11.1	Tue	16:30–17:00	ELP 6: HS 3	**Collaboration on RDM in low-temperature plasma physics** — •Marina Prenzel, Kerstin Sgonina, Markus Becker
P 14.1	Wed	11:00–11:30	WW 1: HS	**Insights into the Non-Thermal Character of Molecular Plasmas from Optical Frequency Comb Spectroscopy** — •Ibrahim Sadiek, Norbert Lang, Jean-Pierre H. van Helden

P 15.1	Wed	14:00–14:30	ELP 6: HS 3	**Particle fueling, profiles and transport in neutral beam heated plasmas at Wendelstein 7-X** — •Sebastian Bannmann, Oliver Ford, Peter Poloskei, Jakob Svensson, Samuel Lazerson, Hakan Smith, Robert Wolf
P 16.1	Wed	14:00–14:30	WW 1: HS	**CO_2 dissociation by microwave plasmas: experimental studies on interfaces in view of industrial applications** — •Rodrigo Antunes, Christian K. Kiefer, Ante Hecimovic, Katharina Wiegers, Arne Meindl, Andreas Schulz, Ursel Fantz
P 17.1	Wed	16:30–17:00	ELP 6: HS 3	**Finite Element Method to Describe Magnetic Measurements of Tearing Modes in ASDEX Upgrade** — •Magdalena Bauer, Hartmut Zohm, Marc Maraschek, Anja Gude, Wolfgang Suttrop, Felix Klossek, Bernhard Sieglin, Louis Giannone
P 18.1	Wed	16:30–17:00	WW 1: HS	**Diffusion of reactive species in aqueous solutions treated by a humid atmospheric pressure plasma jet** — •Steffen Schüttler, Emanuel Jess, Judith Golda
P 20.1	Thu	11:00–11:30	ELP 6: HS 3	**Modelling of tungsten erosion and deposition in fusion devices** — •Andreas Kirschner, Sebastijan Brezinsek, Juri Romazanov
P 20.2	Thu	11:30–12:00	ELP 6: HS 3	**Drift flows in the island divertor of W7-X** — •Carsten Killer, Sean Ballinger, Seung-Gyou Baek, Dario Cipciar, Olaf Grulke, Adrian von Stechow, Jim Terry
P 21.1	Thu	14:00–14:30	ELP 6: HS 3	**The collisionally modified Bohm criterion: Insight or illusion?** — •Ralf Peter Brinkmann
P 22.1	Thu	14:00–14:30	ELP 6: HS 4	**First Results of Laser-Induced Desorption - Quadrupole Mass Spectrometry (LID-QMS) at JET** — •Miroslaw Zlobinski, Gennady Sergienko, Ionut Jepu, et al
P 22.2	Thu	14:30–15:00	ELP 6: HS 4	**Deuterium retention analysis in pre-damaged tungsten using laser-induced breakdown spectroscopy** — •Erik Wüst, Christoph Kawan, Sebastijan Brezinsek, Thomas Schwarz-Selinger
P 23.1	Thu	16:30–17:00	ELP 6: HS 3	**Characterizing electron depleted, nanodusty plasmas recent developments and future outlooks** — •Andreas Petersen, Franko Greiner
P 24.1	Thu	16:30–17:00	ELP 6: HS 4	**Electron surface scattering kernel for plasma simulations** — •Franz Xaver Bronold, Felix Willert

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

See SYPS for the full program of the symposium.

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

Sessions

P 1.1–1.4	Mon	11:00–12:35	ELP 6: HS 3	**Magnetic Confinement I/HEPP I**
P 2.1–2.5	Mon	11:00–12:30	WW 1: HS	**Atmospheric Pressure Plasmas and their Applications I**
P 3.1–3.7	Mon	14:00–16:00	ELP 6: HS 3	**Plasma Wall Interaction I**
P 4.1–4.7	Mon	14:00–16:00	WW 1: HS	**Astrophysical Plasmas/Laser Plasmas**
P 5.1–5.5	Mon	16:30–18:15	ELP 6: HS 3	**Magnetic Confinement II/HEPP II**
P 6.1–6.30	Mon	16:30–18:30	ELP 6: Foyer	**Poster I**
P 7.1–7.5	Tue	11:00–12:30	ELP 6: HS 3	**Magnetic Confinement III**
P 8.1–8.5	Tue	11:00–12:30	WW 1: HS	**Complex Plasmas and Dusty Plasmas I**
P 9.1–9.5	Tue	14:00–16:05	ELP 6: HS 3	**HEPP III**
P 10.1–10.7	Tue	14:00–16:00	WW 1: HS	**Atmospheric Pressure Plasmas and their Applications II**

P 11.1–11.3	Tue	16:30–17:40	ELP 6: HS 3	**Codes and Modeling I**
P 12.1–12.31	Tue	16:30–18:30	ELP 6: Foyer	**Poster II**
P 13.1–13.4	Wed	11:00–12:20	ELP 6: HS 3	**Magnetic Confinement IV/HEPP IV**
P 14.1–14.5	Wed	11:00–12:30	WW 1: HS	**Low Pressure Plasmas and their Application I**
P 15.1–15.5	Wed	14:00–16:10	ELP 6: HS 3	**HEPP V**
P 16.1–16.7	Wed	14:00–16:00	WW 1: HS	**Atmospheric Pressure Plasmas and their Applications III**
P 17.1–17.6	Wed	16:30–18:35	ELP 6: HS 3	**Magnetic Confinement V/HEPP VI**
P 18.1–18.7	Wed	16:30–18:30	WW 1: HS	**Atmospheric Pressure Plasmas and their Applications IV**
P 19	Wed	18:45–19:45	ELP 6: HS 3	**Members' Assembly**
P 20.1–20.5	Thu	11:00–12:45	ELP 6: HS 3	**Magnetic Confinement VI**
P 21.1–21.5	Thu	14:00–15:30	ELP 6: HS 3	**Low Pressure Plasmas and their Application II**
P 22.1–22.4	Thu	14:00–15:50	ELP 6: HS 4	**Plasma Wall Interaction II/HEPP VII**
P 23.1–23.5	Thu	16:30–18:00	ELP 6: HS 3	**Complex Plasmas and Dusty Plasmas II**
P 24.1–24.4	Thu	16:30–17:45	ELP 6: HS 4	**Codes and Modeling II**
P 25.1–25.31	Thu	16:30–18:30	ELP 6: Foyer	**Poster III**

Members' Assembly of the Plasma Physics Division

Wednesday 18:45–19:45 ELP 6: HS 3

P 1: Magnetic Confinement I/HEPP I

Time: Monday 11:00–12:35 Location: ELP 6: HS 3

Invited Talk P 1.1 Mon 11:00 ELP 6: HS 3

On the observation of Trapped Electron Modes in W7-X — •Andreas Krämer-Flecken[1], Paul Costello[2], Golo Fuchert[2], Joachim Geiger[2], Stèphane Heuraux[3], Alexander Knieps[1], Josefine Proll[4], Kian Rahbarnia[2], Roland Sabot[5], Luigui Salazar[3], Gavin Weir[2], Thomas Windisch[2], and Haoming Xiang[6] — [1]Forschungszentrum Jülich GmbH, Jülich, Germany — [2]Max Planck Institut für Plasmaphysik, Greifswald, Germany — [3]Institut Jean Lamour; Université de Lorraine, Nancy, France — [4]Eindhoven Uni- versity of Technology, Eindhoven, The Netherlands — [5]CEA, IRFM, Saint-Paul-Les-Durance, France — [6]Advanced Energy Research Center, Shenzhen University, Shenzhen, PRC

In fusion devices Trapped Electron Modes (TEM) are responsible for particle transport in general. An indication for TEMs are the so called Quasi Coherent (QC)-modes, density fluctuations visible in different diagnostics e.g. Poloidal Correlation Reflectometry (PCR) and observed in a frequency range of 50 kHz to 250 kHz. In case of TEM origin, these QC-modes propagate in electron diamagnetic drift direction and have a poloidal structure size of 20 mm to 30 mm and $k_\perp \rho^* \geq 1$. This presentation reports on the first observation of TEMs and related QC-modes at the stellarator W7-X, as observed by PCR. They show up in low collisionallity ECRH heated plasmas, within a broad frequency range, depending on magnetic configuration and heating power. From the observed frequency of the QC-modes and there poloidal velocity a scaling is developed. Linear gyrokinetic calculation confirm the existence of TEMs within the parameters obtained for these discharges.

P 1.2 Mon 11:30 ELP 6: HS 3

GPU offloading strategies for gyrokinetic edge turbulence simulations with GENE-X via OpenMP and OpenACC — •Jordy Trilaksono[1], Carl-Martin Pfeiler[1], Philipp Ulbl[1], and Frank Jenko[1,2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]University of Texas at Austin, Austin, TX 78712, USA

The GENE-X code simulates plasma turbulence by solving the gyrokinetic equation using a grid-based/Eulerian discretization. The flux-coordinate independent approach allows GENE-X to simulate plasma turbulence anywhere within magnetic confinement fusion (MCF) devices, from the plasma core to the wall. GENE-X is mainly written in object-oriented modern Fortran 2008 fully utilizing MPI+OpenMP parallelization. Here, we present our development strategies and experiences to further accelerate GENE-X on GPU, which is essential for simulations towards larger, reactor-relevant fusion devices. The GPU offloading features are written on an auxiliary C++ layer interoperated by the main Fortran layer. The C++ layer provides broader selections of GPU offloading tools. MPI+OpenMP and MPI+OpenACC parallelizations are chosen to future-proof our solution against the evolution and diversification of modern GPU architectures. We present performance benchmarks and convergence analysis of our OpenMP and OpenACC implementations on GPU. The computational hotspot in GENE-X achieves a significant performance increase on GPU compared to its CPU-equivalent. The readiness of GENE-X compute capability for large-scale production runs on GPU is further investigated.

P 1.3 Mon 11:55 ELP 6: HS 3

Verification of the gyrokinetic code GENE-X for the edge and scrape-off layer of stellarators — •Marion Smedberg[1], Philipp Ulbl[1], Andreas Stegmeir[1], and Frank Jenko[1,2] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]University of Texas at Austin, Austin, TX, USA

A key open question in magnetic confinement fusion research regards plasma turbulence, particularly in the edge and scrape-off layer (SOL). This is especially true for stellarators, since optimization for low neoclassical transport has only recently been proven; the remaining transport is determined to be turbulent [1]. Numerical codes which simulate the plasma turbulence in such devices are critically important to understand the experiments and predict future reactor performance. Here we present `GENE-X`, a full-f, electromagnetic, Eulerian gyrokinetic code designed for the edge and SOL [2], and its generalization to stellarator geometries. We describe the 3D generalization, including the implementation of non-axisymmetric magnetic fields, development of an approximate flux surface label, and the newly generalized data structure. We also discuss the ongoing verification of the 3D-capable code. This includes convergence testing via the method of manufactured solutions, and could include recreating neoclassical transport predictions and a benchmark against the gyrokinetic code `GENE-3D`.

[1] T. S. Pedersen et al, Nucl. Fusion 62 042022 (2022)
[2] D. Michels, et al, Comput. Phys. Commun. 264 (2021)

P 1.4 Mon 12:20 ELP 6: HS 3

Creating a power balance database study on turbulence at Wendelstein 7-X — •Markus Wappl, Marc Beurskens, Sergey Bozhenkov, Tamara Andreeva, Sebastian Bannmann, and Håkan Smith — Max Planck Insitute for Plasma Physics, Greifswald, Germany

Power balance analysis is used to compile a comprehensive database of anomalous transport in various plasma scenarios at the stellarator Wendelstein 7-X. The anomalous transport is attributed to turbulence. As a figure of merit, an effective turbulent transport coefficient χ_{eff} is defined. The database spans a broad parameter range covering different fueling schemes, heating power values and methods as well as different magnetic configurations of W7-X.

Experiments with neutral beam or hydrogen pellet injection allow to increase the central density and ion temperature while creating steep gradients. The database unveils a characteristic dependence of χ_{eff} on the gradient lengths of density and ion temperature, a/Ln and a/LT. This hints at the prevalence of ion temperature gradient (ITG) modes. The critical parameters governing ITG stability, a/Ln_{cr} and a/LT_{cr}, are identified from the database. Based on power and density scan experiments, the scaling behaviour of the effective turbulent transport coefficient is explored. χ_{eff} positively correlates with electron cyclotron heating power, predominantly in the electron channel of turbulent transport.

The benefits of the turbulence database results in a future extrapolation to a stellarator reactor based on W7-X are discussed.

P 2: Atmospheric Pressure Plasmas and their Applications I

Time: Monday 11:00–12:30 Location: WW 1: HS

Invited Talk P 2.1 Mon 11:00 WW 1: HS

Interaction of reactive components of non-equilibrium atmospheric plasmas with liquids and surfaces — •Kerstin Sgonina[1], Alexander Quack[1], Christian Schulze[1], and Jan Benedikt[1,2] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]KiNSIS, Kiel University

Cold atmospheric pressure plasmas (CAP) are a source of reactive species, such as electrons, ions, radicals, excited species, and photons. Typical application fields are surface or liquid treatments, which are based on additive or synergistic effects of these species at solid surfaces or in liquids. However, knowledge about the isolated effect of each plasma component is rare. The isolated interaction of two different reactive components, positive ions and atomic oxygen, with solid surfaces or liquids, respectively, will be presented.

To study the isolated effect of positive ions on substrates at atmospheric pressure, the so-called Vacuum-ultraviolet(VUV)-photoionization chamber has been developed. It uses a helium driven CAP to generate VUV-radiation to photoionize given precursor. With this, an ion-based thin film deposition at atmospheric pressure can be realized.

For atomic oxygen, its effective reaction with organic compounds in liquids is known. However, it was unknown whether these reactions are liquid-surface or volume dominated. Phenol solutions were used as a chemical probe to be treated by the effluent of the COST-Jet as a source of atomic oxygen. The comparison of experimental and modeling results revealed the predominance of reactions of atomic oxygen at the liquid surface.

P 2.2 Mon 11:30 WW 1: HS

Investigation of atmospheric-pressure DBD for thin film deposition in Ar-HMDS mixture — •Marjan Stankov[1], Markus M. Becker[1], Lars Bröcker[2], Claus-Peter Klages[2], and Detlef Loffhagen[1] — [1]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany — [2]Institute for Surface Technology, Technische Universität Braunschweig, Braunschweig, Germany

Although atmospheric-pressure plasma-enhanced chemical vapour deposition processes employing dielectric-barrier discharges (DBDs) as a plasma source are widely explored for diverse surface modifications, a thorough understanding of main aspects of this process is still lacking. This particularly pertains to identify key particle species responsible for the formation of thin films. Here, a study based on modelling and experimental analysis of DBDs in Ar with the addition of hexamethyldisilane (HMDS) as precursor is reported. A single-filament discharge driven by a 19 kHz sinusoidal voltage is investigated using a time-dependent, spatially one-dimensional fluid-Poisson model including an extensive reaction kinetics related to HMDS. The analysis of surface fluxes of particle species indicates that silicon-containing cations play an important role in the film formation process. The contribution of specific cations is investigated and related to the measured average mass of deposited ions. Furthermore, the influence of different chemical processes on the formation of the cations is discussed.

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

P 2.3 Mon 11:45 WW 1: HS

Atmospheric plasma as a source of VUV radiation for particle-free thin film deposition — •Tristan Winzer, Christina Reiser, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

Thin-film deposition using plasma to remotely produce VUV photons for photochemistry is an alternative to direct injection of precursor molecules into a plasma, which often results in generation of particles or strong deposition in the source, compromising the properties of the deposited films and the jet operation. This is especially the case at atmospheric pressure, due to high collision rates. At this pressure, noble gas plasmas are efficient sources of VUV radiation down to 60 nm (helium plasma), which can be utilized to initiate photochemistry with subsequent film deposition in precursor gases.

We present here a study on the photochemistry and ionic thin-film deposition from common precursors using a novel source designed for separation of plasma species, radiation and photochemistry products at atmospheric pressure. Precursors were studied for their use in photochemical vapor deposition by analyzing ionic species formed during VUV-treatment of the precursor with ion mass spectrometry and deposited films with Fourier-transform infrared spectroscopy. Particle formation was checked down to 1 nm diameter using a scanning mobility particle sizer.

P 2.4 Mon 12:00 WW 1: HS

Setup and Investigation of a Plasma Window for Heavy Particle Beam Transmission to High Pressurized Targets — •Andre Michel, Fateme Ghaznavi, Michael Händler, Adem Ates, Bernhard Bohlender, Marcus Iberler, and Joachim Jacoby — Goethe University Frankfurt

With an ever-growing enhancement of particle beam intensities and energies in accelerators around the world, a reliable vacuum to high-pressure-target separation technique is strongly needed where common separation techniques such as differential pumping stages or solid membranes might fail. A plasma window, first introduced by A. Hershcovitch [1], offers the advantage of a membraneless particle beam transmission from low- to high pressurized target areas.

At the plasma physics department of Goethe University Frankfurt, a plasma window was developed and successfully tested during the 2022 GSI UNILAC beamtime, utilizing an 48Ca10+ ion beam at 4.8MeV/u - therefore being the first plasma window setup proving its applicability on the transmission of heavy ion beams.

This talk presents the underlying working mechanisms of the plasma window, its plasma physical properties, electrical parameters, its pressure separating properties as well as the characteristics of the transmitted ion beam.

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

P 2.5 Mon 12:15 WW 1: HS

Spatio-temporal analysis of plasma electrolytic polishing: Insights from optical and electrical diagnostics — •Sehoon An[1], Luka Hansen[2], Thorben Wolff[1], Rüdiger Foest[1], Maik Fröhlich[3], and Holger Kersten[2] — [1]INP Greifswald, Greifswald, Germany — [2]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [3]Leupold Institute of Applied Sciences, University of Applied Sciences Zwickau, Zwickau, Germany

Plasma electrolytic polishing (PEP) has recently gained much attention for its ecological benefits and its ability to enhance the surface quality of intricate metallic components. Understanding the dynamics of the gaseous layer around the workpiece, accompanied with electrical discharges, is crucial for optimal outcomes, as it significantly influences the surface modification effect. Here, we investigate the PEP process using optical and electrical monitoring, utilizing a high-speed camera synchronized with electrical waveform measurements. The temporal development of the temperatures of the workpiece and the surrounding electrolyte is measured and discussed in relation to the discharge characteristics. The experiment involves a WC-Co workpiece immersed in a 10 wt% Na2CO3 solution, anodically polarized at 120 V for 30 s. By high-speed video (1000 fps) a temporally resolved development of the gas layer involving numerous discharges on the workpiece surface is visualized which is correlated to the current signal. We report observations on oscillating discharge currents and characteristic frequencies, analyzed using FFT, in relation to process parameters and the workpiece temperature evolution.

P 3: Plasma Wall Interaction I

Time: Monday 14:00–16:00 Location: ELP 6: HS 3

Invited Talk P 3.1 Mon 14:00 ELP 6: HS 3

Influence of Nanosecond Pulsed Plasmas in Liquids on Copper Surfaces — •Pia-Victoria Pottkämper, Oliver Krettek, Katharina Laake, and Achim von Keudell — Ruhr-Universität Bochum

One application of plasmas in liquids is the modification of metal surfaces. In this project a plasma is ignited in water at an electrode using high voltages, nanosecond pulses and fast rise times. The plasma is then used to modify a coppper surface in contact with the plasma-activated liquid. The plasma causes a dissociation of the water molecules, leading to the creation of many different reactive species with varying lifetimes such as molecular oxygen and hydrogen, solvated electrons and hydrogen peroxyde. The created electric field with a short rise time leads to a fast pressure increase at the ignition site and an expansion of a shock wave which transports the reactive species to the surface. Here different reactions may occur that lead to the modification of the copper. It is possible to reduce the surface or to initiate growth of nanostructures depending on the experimental conditions. The changes are monitored via FTIR spectroscopy, SEM and XPS. The creation of uniform CuxO nanocubes has been observed under certain conditions. One application of these structures is the catalysis of the electrochemical reduction of CO2. During this reaction the activity of these catalysts decreases over time. The in-liquid plasma can cause a re-oxidation and therefore the formation of new CuxO nanocubes. It is postulated that by an in-situ in-liquid plasma treatment the lifetime of the catalytic surfaces can be extended.

P 3.2 Mon 14:30 ELP 6: HS 3

Characterization of boron layers on tungsten substrates by picosecond and nanosecond laser-induced breakdown spectroscopy — •Huace Wu, Sebastijan Brezinsek, Rongxing Yi, Anne Houben, Gennady Sergienko, and Yunfeng Liang — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung * Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany

Boronization is considered in ITER as wall conditioning method for full-W material option. Boron acts primarily as oxygen getter, but can also reduce intrinsic impurity content such as carbon and nitrogen as well as moderately the hydrogen recycling. However, the boron layer thickness, and therefore the lifetime by plasma-induced erosion, is limited, not necessarily toroidal homogeneous, and repetitively boronization needs to be applied to be effective. LIBS as a versatile tool for the investigation of the element composition and is a potential candidate for in-situ investigations of erosion, deposition and material mixing in nuclear fusion devices. At first, we study LIBS in the laboratory on thin boron films (about 100nm) or boron-tungsten layer systems produced by magnetron sputtering on the polished tungsten substrates. Ps (35ps,355nm) and ns (7ns,1064nm) lasers were used to characterize the ablation rate of boron layers as well as matrix effects in the layer system. The ps laser provides a better depth resolution due to the smaller ablation rate. Comparison studies with boron layers (about 10nm) obtained on W substrates in the midplane manipulator of W7-X from boronization will be presented.

P 3.3 Mon 14:45 ELP 6: HS 3

Experimental studies of Hydrogen plasma produced in Pulsed Plasma Accelerator source — •Azmirah Ahmed, Sumit Singha, Pradipta P Kalita, Pallabi Baruah, Nirod K Neog, and Tridip K Borthakur — Centre of Plasma Physics-Institute for Plasma Research (CPP-IPR)

Hydrogen plasma is produced in a Pulsed Plasma Accelerator (PPA) source to simulate the heat loading phenomena of an ELM transient event of fusion devices. A 200 kJ Pulsed Power System (PPS) powers the PPA by delivering a discharge current pulse of 100 kA of half-time period ~ 0.5 ms. An accelerated plasma stream is produced which has a relatively high density and high velocity. An external longitudinal magnetic field of ~ 0.1 T in the observation region is generated using an electromagnet to study its effect on the plasma stream. Calorimetric study, high-speed imaging and OES is carried out for proper optimization of the plasma. The calorimetric study gives the measure of optimized energy density ~ 0.22 MJ/m2 of the hydrogen plasma. The imaging done using a high speed video camera shows the confinement, shape, uniformity and intensity distribution of plasma. The spectroscopic observations shows the emission from Hα and Hβ transitions of hydrogen and also the transitions of different impurity species generated during the plasma production. The interaction of this hydrogen plasma with a fusion relevant tungsten material is then studied by exposing the tungsten target. By using XRD and FESEM techniques, the impact on the material is studied and initial testing shows formation of major and micro cracks on tungsten.

P 3.4 Mon 15:00 ELP 6: HS 3

Laser enhanced copper surface oxide generation by plasma generated reactive oxygen species — •Sascha Chur[1], Robin Minke[1], Marc Böke[2], and Judith Golda[1] — [1]Plasma Interface Physics, Ruhr-University Bochum, D-44801 Bochum, Germany — [2]Experimentalphysik II, Ruhr-University Bochum, D-44801 Bochum, Germany

Copper, a promising catalyst for CO_2 electroreduction, faces challenges of poor selectivity and energy efficiency. Copper oxides enhance selectivity, particularly towards C_{2+} products. Surface morphology significantly influences performance, and our study demonstrates that combined laser and plasma treatment fine-tunes these characteristics for effective functionalization. Treatment with a micro atmospheric pressure plasma jet induces Cu(II) oxides on copper by generating reactive oxygen species. Investigation into prevalent reaction partners produced by the plasma jet revealed atomic oxygen density at 10^{21} m^{-3} (two-photon absorption laser-induced fluorescence). Singlet delta oxygen, at 10^{20} m^{-3} (emission spectroscopy) closely aligned with simulation results, while ozone density, calculated at 10^{21} m^{-3} (absorption spectroscopy), was overestimated by the simulation. X-ray Photoelectron Spectroscopy of treated surfaces demonstrated an increasing Cu(II) oxide ratio with extended treatment. This research provides insights into controlled and precise copper surface modification, applicable in diverse fields requiring tailored material properties. Supported by the DFG within CRC 1316, project B2.

P 3.5 Mon 15:15 ELP 6: HS 3

Data-integrated multiphysics simulations of reactive magnetron sputtering — •Tobias Gergs[1], Luca Vialetto[1,2], Christian Stüwe[1], and Jan Trieschmann[1] — [1]Theoretical Electrical Engineering, Kiel University, Kaiserstraße 2, 24143 Kiel, Germany — [2]Department of Aeronautics and Astronautics, Stanford University, 496 Lomita Mall, Stanford, CA 94305, United States of America

Reactive magnetron sputtering is widely used in science and industry. However, the understanding of the physical kinetics remains incomplete, primarily because the intrinsic length and time scales of the plasma and the surface differ by orders of magnitude. Individual scientific disciplines have frequently concentrated on only one of these aspects in detail (i.e., plasma or surface), while the other aspect may have been considered in a simplified manner. In this work, established and novel methods are combined to adequately describe the coupled plasma and surface physics involved in the sputter deposition of silicon oxide in Ar/O_2 discharges. The dynamics of the plasma are described by 2d3v particle-in-cell simulations with a Monte Carlo transport scheme for charged particles, energetic neutrals, and sputtered atoms. The surface evolution is determined by rate equations for the surface coverage, which account for chemisorption, physisorption, diffusion of adatoms, and physical sputtering. The energy and angular distributions of sputtered particles are incorporated by an integrated machine learning model, which was trained with Monte Carlo simulation data. The influence of process parameters (e.g., admixtures of O_2) on phenomena such as target poisoning is emphasized.

P 3.6 Mon 15:30 ELP 6: HS 3

Low Pressure Plasma Spraying of Tungsten on Plasma Facing Components for Future Fusion Devices — •Gunnar Schmidtmann[1,2], Andrey Litnovsky[1], Jan Willem Coenen[1], Robert Vassen[2], Sebastijan Brezinsek[1], Christian Linsmeier[1], Olivier Guillon[2], and Georg Mauer[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie und Klimaforschung - Plasmaphysik (IEK-4), 52425 Jülich, Germany — [2]Forschungszentrum Jülich GmbH, Institut für Energie und Klimaforschung - Werkstoffsynthese und Herstellungsverfahren (IEK-1), 52425 Jülich, Germany

Tungsten is currently the baseline plasma-facing material (PFM) for future fusion devices. Despite its advantageous properties, tungsten gets damaged under the extreme plasma conditions, which can lead to a reduced lifetime of the plasma facing components (PFC) or the outage of the whole fusion reactor. As repairing is time and resource intense, Low Pressure Plasma Spraying emerges viable as a fast and affordable solution to restore the PFM and repair damages. Pre-heating of the different substrate materials: Carbon fibre composite, tungsten and Eurofer ($T < 740$ °C), helped to mitigate residual stresses caused by the thermal mismatch between coating and substrate. Quality parameters such as porosity below 5 % and number of defects were evaluated using digital image analysis. Further characterization was performed to obtain more information on the surface roughness and a coating thickness of at least 100 *m. In future work, selected coatings will be tested under fusion-relevant conditions to obtain a lifetime prediction and to allow to infer further possible improvements.

P 3.7 Mon 15:45 ELP 6: HS 3

Studies of deuterium retention in pre-damaged tungsten with laser-induced ablation quadrupole mass spectrometry — •Christoph Kawan[1,2], Sebastijan Brezinsek[1], Timo Dittmar[1], Thomas Schwarz-Selinger[3], and Erik Wüst[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]Mathematisch-Naturwissenschaftliche Fakultät, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany — [3]Max-Planck-Institut für Plasmaphysik, D-85748 Garching, Germany

Future fusion devices based on magnetically confined plasma will operate with the hydrogen (H) isotopes deuterium (D) and tritium (T) as fuel gases and tungsten (W) as wall material. The extreme conditions inside the fusion device damage the wall surface and change the H retention properties. T accumulating in the W wall is a high risk in terms of radiation safety. Therefore, in-situ methods are needed to quantify the amount of H isotopes. Laser-induced ablation quadrupole mass spectrometry (LIA-QMS) is a promising method which can provide H isotope depth profiles in the wall material, potentially also in-situ. Here, LIA-QMS depth profiles on targets with different amounts of D with established methods such as laser-induced breakdown spectrometry (LIBS) and nuclear reaction analysis (NRA) are compared. LIA-QMS shows a higher sensitivity than LIBS (<0.1 at% with 150 nm depth resolution). The absolute amount differs compared to NRA (6 at% QMS, 1 at% NRA), thus requiring an optimized calibration.

P 4: Astrophysical Plasmas/Laser Plasmas

Time: Monday 14:00–16:00 Location: WW 1: HS

Invited Talk P 4.1 Mon 14:00 WW 1: HS

Ab initio calculations of conductivities under planetary interior conditions — •Martin Preising[1], Martin French[1], Maximilian Schörner[1], Mandy Bethkenhagen[2], Argha Roy[1], Uwe Kleinschmidt[1], and Ronald Redmer[1] — [1]Universität Rostock, Rostock, Germany — [2]École Polytechnique, Palaiseau, France

We summarize our recent efforts to calculate thermal and electrical conductivities under planetary interior conditions with ab initio simulations.

We applied our method to state-of-the-art models [Mankovich and Fortney, Astrophys. J., 889, 51 (2020)] for the gas giant planets Jupiter [French et al., Astrophys. J. Suppl. Ser., 202, 5 (2012)] and Saturn [Preising et al., Astrophys. J. Suppl. Ser., 269, 47 (2023)]. We found a profound impact of the proposed helium-rich layer above Saturn's core on thermal and DC conductivity profiles. The results will affect future magnetohydrodynamic simulations for Saturn's magnetic field.

The ice giant planets Uranus and Neptune are not too well constrained by observational data. We consider different mixtures of hydrogen and methane. Our results show a steady increase in DC conductivity along Uranus' P-T path [Roy et al., submitted (2024)].

A recent study of fcc and hcp iron over a P-T range covering Earth's core-mantle boundary and inner core boundary resulted in fit formulas for the DC and thermal conductivity [Kleinschmidt et al., Phys. Rev. B, 107, 085145 (2023)], applicable to all rocky planets with an iron core.

P 4.2 Mon 14:30 WW 1: HS

Kinetic simulations of strong non-relativistic shocks propagating in a turbulent medium — •Karol Fulat[1], Artem Bohdan[2,3], Michelle Tsirou[4], and Martin Pohl[1,4] — [1]Institute of Physics and Astronomy, University of Potsdam, D-14476 Potsdam, Germany — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, D-85748 Garching, Germany — [3]Excellence Cluster ORIGINS, Boltzmannstr. 2, D-85748 Garching, Germany — [4]Deutsches Elektronen-Synchrotron DESY, Platanenallee 6, D-15738 Zeuthen, Germany

Strong non-relativistic shocks are known to accelerate particles up to relativistic energies. However, for Diffusive Shock Acceleration electrons must have a highly suprathermal energy, implying a need for very efficient pre-acceleration. Most published studies consider shocks propagating through homogeneous plasma, which is an unrealistic assumption for astrophysical environments. To address this limitation, we have developed a novel simulation technique that provides a framework for studying shocks propagating in turbulent media from first principles. We have performed PIC simulations of non-relativistic high-Mach-number shocks propagating in an electron-ion plasma with a turbulent upstream medium. We have explored the impact of the fluctuations on electron heating and acceleration, the dynamics of upstream electrons, and the driving of plasma instabilities. We will also discuss our recent results from oblique shock simulations.

P 4.3 Mon 14:45 WW 1: HS

First operation of APEX-LD, a levitated dipole trap designed for e+e- plasmas — •Alexander Card — Max-Planck-Institut für Plasmaphysik — Technische Universität München

The mission of the APEX-LD (A Positron-Electron eXperiment - Levitated Dipole) trap is to provide a compact (~10-liter) volume of closed dipole magnetic field lines, to be used for the confinement and study of low-temperature, long-lived e+e- pair plasmas. The requirements for this application posed a number of challenges for experiment design and engineering. (These included, e.g., the need to repeatedly make and break thermal contact with cryogenically cooled components in a vacuum environment; excitation of current in the superconducting "floating coil", followed by long-duration, feedback-stabilized levitation; and a demand for robustness to repeated quenches and possible mechanical shocks). A comparable number of experiment design and engineering solutions have been found and implemented, and APEX-LD has successfully started operation, enabling the first electron experiments to commence in late 2023. This talk will outline the design of the APEX-LD systems, then present the highlights of the experiment commissioning (e.g., efficient current induction to ~0.5 T on axis, levitation times in excess of three hours, and slow/"gentle" quenching of the non-insulated HTS [high-temperature superconducting] coil). Finally, it will describe results from first experiments (i.e., magnetic field line visualizations and e- injection) and next steps for making e- plasmas and later injecting cold, dense pulses of e+.

P 4.4 Mon 15:00 WW 1: HS

Improved Conductivity model for fully ionized hydrogen plasma — •Uwe Kleinschmidt and Ronald Redmer — Universität Rostock, Institut für Physik, Albert-Einstein-Strasse 23-24, D-18059 Rostock, Germany

Electrical and thermal conductivities for matter under extreme conditions are an important input in magnetohydrodynamic simulations to model, e.g., the dynamo action in the deep interior of planets like Jupiter or the Ohmic dissipation rate in the atmosphere of hot Jupiters (see [1]). Such gas giant planets consist mainly of hydrogen and helium so that the calculation of corresponding conductivity data for a wide range of pressures and temperatures is an important task. In addition, the construction of conductivity models, e.g., by solving the Boltzmann equation in relaxation time approximation, as proposed by Lee and More [2] help to keep the computational costs low in such simulations. The Lee-More conductivity model provides reasonable results for weakly coupled high temperature plasmas but deviates strongly from ab initio methods like density functional theory molecular dynamics (DFT-MD) simulations for lower temperatures and stronger coupled plasmas (see [3]). We performed extensive DFT-MD simulations to calculate conductivities for fully ionized hydrogen plasma. We used this data to modify the conductivity model by Lee and More and to provide conductivity data for a wide range of temperature and density.

[1] S. Kumar et al., Phys. Rev. E 103, 063203 (2021)
[2] Y. T. Lee and R. M. More, Phys. Fluids 27, 1273 (1984)
[3] M. French et al., Phys. Rev. E 105, 065204 (2022)

P 4.5 Mon 15:15 WW 1: HS

Chirped plasma density gratings for compression of high-intensity laser pulses — •Götz Lehmann and Karl-Heinz Spatschek — Heinrich-Heine-Universität, Düsseldorf

Modern high-power chirped-pulse (CPA) laser systems are limited in several ways by optical damage thresholds and detrimental nonlinearities. Amplification, compression, and polarization control of intense laser beams is often ultimately limited by the ionization threshold of solid state materials. Hence, plasma-based optical elements, often referred to as damageless optics, are attractive alternatives.

We study the formation and optical properties of plasma density gratings which may act as reflective and transmissive optics for high-power pulses. The plasma gratings themselves are driven via laser pulses to ma- nipulate pulses of higher intensity. Our interest lies in chirped plasma gratings that then can be used for compression of chirped pulses similar to conventional compression gratings in modern high-power CPA systems. We demonstrate via simulations the formation of chirped gratings, discuss their compression capabilities, and outline parameter regimes for applications.

P 4.6 Mon 15:30 WW 1: HS

Nonmetal-to-metal transition in dense fluid nitrogen at high pressure — Armin Bergermann and •Ronald Redmer — Univ. Rostock, Institut für Physik, A.-Einstein-Str. 23, 18059 Rostock

The high-pressure phase diagram of solid nitrogen is extremely rich: 12 molecular phases, two nonmolecular phases, and an amorphous one have been reported so far [1]. Recent molecular dynamics (MD) simulations on dense fluid nitrogen using density functional theory (DFT) predict a first-order liquid-liquid phase transition (LL-PT) at about a megabar, see e.g. [2]. Static experiments using diamond anvil cells as well as dynamic shock-wave experiments have been applied to access the corresponding region.

We calculate the electrical conductivity and the equation of state of dense fluid nitrogen for high pressures up to several megabars by using DFT-MD simulations [3]. We determine the instability region of the first-order LL-PT which results from an abrupt dissociation of nitrogen molecules. This transition is accompanied by a nonmetal-to-metal transition (metallization) of the fluid and corresponding structural changes from a molecular to a polymeric phase. We compare our data with earlier theoretical results and available experiments.

[1] R. Turnbull et al., Nat. Commun. 9, 4717 (2018) [2] B. Boates,

S. A. Bonev, Phys. Rev. Lett. 102, 015701 (2009). [3] A. Bergermann, R. Redmer, Phys. Rev. B 108, 085101 (2023)

P 4.7 Mon 15:45 WW 1: HS

Negative Corona, free Electrons and their Role in the Creation of Ball Lightning — •Herbert Boerner — Mainz

Ball lightning (BL) is still an unexplained phenomenon of atmospheric physics. Until recently, all evidence came from reports by accidental observers, but in the last years, additional information became available, mainly from lightning location systems. In order to make progress in defining suitable experiments and in selecting a theory that is consistent with the observations, it is important to choose from the thousands of anecdotal reports those that are reliable and that also contain information on the physics involved. There are indications, that positive cloud-ground lightning (+CG) has a much higher probability to create these objects that negative CG lightning. Together with the fact that BL objects can be produced far away from lightning channels, this allows a definition of the conditions under which BL is created. The importance of negative corona in air, of Trichel pulses, and the role of free electrons is discussed and an experimental setup is proposed.

P 5: Magnetic Confinement II/HEPP II

Time: Monday 16:30–18:15 Location: ELP 6: HS 3

P 5.1 Mon 16:30 ELP 6: HS 3

Searching for SQuIDs:*Stable Quasi-Isodynamic Designs for Stellarators — •Alan Goodman, Pavlos Xanthopoulos, Gabriel Plunk, Sophia Henneberg, Carolin Nuhremburg, Hakan Smith, Craig Beidler, Gareth Roberg-Clark, and Per Helander — Max-Planck-Institut fur Plasmaphysik, D-17491 Greifswald, Germany

Quasi-isodynamic (QI) stellarators are a uniquely attractive fusion reactor candidate due to their low neoclassical transport, excellent confinement of fusion-borne alpha particles, and vanishingly small bootstrap currents [1]. Due to the complexity of their geometries, QI stellarators must generally be designed through numerical optimization, which requires an objective metric that quantifies the degree to which a given design is QI. While once thought impossible, we recently showed that nearly-perfectly QI geometries can be found using an appropriately-designed objective function [2]. We have since built upon this approach, now finding QI geometries with reduced turbulence, improved MHD stability, and lower surface area-to-volume ratios, which are potential candidates for future stellarator experiments and reactors.

References:

[1] P Helander and J Nührenberg. Bootstrap current and neoclassical transport in quasi-isodynamic stellarators. PPCF (2009).

[2] A Goodman et al. Constructing precisely quasi-isodynamic magnetic fields, JPP (2023).

P 5.2 Mon 16:55 ELP 6: HS 3

Equilibrium and stability of plasma with arbitrary non-neutrality in a levitated dipole trap — •Patrick Steinbrunner[1], Thomas O'Neil[2], and Matthew Stoneking[3] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]University of California San Diego, La Jolla, United States — [3]Lawrence University, Appleton, United States

A purely nonneutral plasma can be confined in a global thermal equilibrium state as well as a local thermal equilibrium along magnetic field lines in a magnetic dipole trap. A plasma consisting of a mixture of electrons and positrons, as it is envisioned by the APEX collaboration (A Positron-Electron eXperiment), can only be confined in a local thermal equilibrium state. While global thermal equilibria are maximum entropy states and hence guaranteed to be stable, local thermal equilibria can be unstable.

One of the dominant instabilities, the diocotron mode, was studied to a great extend in the homogeneous magnetic field of a Penning-Malmberg trap. We will focus on the inhomogeneous magnetic field of a z-pinch, which serves as an approximation of the vicinity of a levitated coil. This implies two differences in comparison to a Penning-Malmberg trap. First, grad-B and curvature drifts influence the instability. Second, plasmas of arbitrary nonneutrality can be confined. We found that in the general case of arbitrary nonneutrality, the stability is governed by an interplay between the diocotron and the interchange instability.

P 5.3 Mon 17:20 ELP 6: HS 3

Direct Construction of Large Aspect Ratio Quasi-isodynamic Stellarators — •Katia Camacho Mata, Gabriel G. Plunk, and Alan G. Goodman — Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

Quasi-isodynamic (QI) stellarators are attractive fusion reactor candidates due to their good confinement properties, inherent steady-state operation, low toroidal currents and favourable turbulence properties. However, optimisation methods traditionally used to find QI fields are highly dependent on the initial guess, often result in complicated geometries and do not offer physical insight into the solution space structure. The near-axis expansion (NAE) method, an expansion of the magnetohydrodynamic equations, can be used to construct exact QI equilibria in the vicinity of the magnetic axis, to first or second order. The NAE method is discussed, and it is shown that configurations with low neoclassical transport and simple boundary shapes can be constructed, even far from the axis, by carefully choosing the initial NAE parameters. The QI solution space structure is investigated using these parameters. The role the helicity of the magnetic axis plays in dividing the space into regions with different confinement properties is described and is used to construct NA QI solutions similar to existing optimised stellarators. The strengths of the NAE are discussed, namely its suitability to provide initial points for traditional optimization, and the ability to perform a systematic and exhaustive search of the QI solution space, aiding in the search of the next generation stellarator designs.

P 5.4 Mon 17:45 ELP 6: HS 3

Stochastic Single-Stage Stellarator Optimization for EPOS and Analysis of Coil Perturbations — •Pedro F. Gil, Jason Smoniewski, Paul Huslage, and Eve V. Stenson — Max-Planck-Institute for Plasma Physics, Garching, Germany

The EPOS (Electrons and Positrons in an Optimised Stellarator) project, as part of the APEX (A Positron Electron eXperiment) Collaboration, aims to build a small-scale stellarator for the confinement of pair plasmas. The magnetic field in EPOS will be quasi-axisymmetric, meaning that the magnetic field amplitude is invariant along a toroidal coordinate. This symmetry ensures the good confinement of trapped particle orbits. The device will receive a limited amount of positrons setting a constraint on its size, leading to unmanageable coil manufacturing and assembly tolerances. An analysis of the perturbations that affect the induced magnetic field is performed in order to guide the optimization towards robust configurations.

Stellarator optimization is usually a two-step process: find a target equilibrium, and design coils to match that desired equilibrium. Stochastic optimization of the coils randomly perturbs the shape of the coils N times and averages the magnetic field. This both broadens the width of the minima allowing to find more robust configurations and reduces the likelihood of getting trapped in local minima. Combined with a single-stage approach it smooths the objective function while searching for both coils and plasma. This method is expected to relax the coil construction constraints for EPOS into the ± 0.3 mm range, making it buildable.

P 5.5 Mon 18:00 ELP 6: HS 3

Optimized HTS Coils for the EPOS Stellarator — •Paul Huslage, Pedro Gil, Jason Smoniewski, and E. V. Stenson — Max-Planck Institue for Plasma Physics

The future EPOS (Electrons and Positrons in an Optimized Stellarator) aims to confine an electron positron pair plasma using non-planar high-temperature superconductor (HTS) coils. The non-planar shape combined with the requirement for compactness results in significant mechanical strain imposed on the HTS tapes, which can cause cracks in their functional ceramic layer and requires careful optimization of the coils. With its small size and moderate magnetic field (R=0.2m, B=2T), EPOS provides an attractive platform for advancing stellarator coil design.

En route to an engineering design for the experiment, we built several non-insulated, superconducting prototype coils, both planar and non-planar and operated them under cryogenic conditions. We use 3D-printed metal frames to wind the superconductor into the desired shape.

We present our prototype coils together with critical current measurements and quench tests both in liquid nitrogen and at 20 K inside a vacuum chamber.

P 6: Poster I

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

P 6.1 Mon 16:30 ELP 6: Foyer

Thermo-Field emission from cathodes made of selected materials — •Margarita Baeva[1], Dirk Uhrlandt[1], Dominik Bratek[2], Carsten Uber[2], Bogdan Barbu[3], and Frank Berger[3] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany — [3]Technische Universität Ilmenau, Germany

Electric discharges in a metal vapour released from the cathode during contact opening are observed in various application fields. In explosion protection, the ignition prediction in flammable gas mixtures is concerned with contact break discharges. The latter represent an ignition source for the gas mixture. In low-voltage switching devices, an electric arc in metal vapour occurs during the so called immobility phase, which is essential for the breaking performance of the device.

This contribution is concerned with the emission of electrons from cathodes made of selected materials (Cu, W, Cd, Zn, Ir) that occurs by collective effects (high temperature in the cathode, high electric field on the cathode surface). These effects characterize the arc regime of operation of electric discharges. In order to obtain the electron emission current for operation with cathodes of the aforementioned materials, the transferred matrix method is applied. This method is applicable to arbitrary shapes of the surface potential barrier. The selected materials considered in this work represent both refractory and non-refractory cathodes.

P 6.2 Mon 16:30 ELP 6: Foyer

Deducing line-integrated density, collision frequency and density profile of an atmospheric plasma torch from microwave diagnostics — •Christos Vagkidis, Eberhand Holzhauer, Walter Kasparek, Alf Köhn-Seemann, Stefan Merli, Mirko Ramisch, Andreas Schulz, and Günter Tovar — IGVP, University of Stuttgart, Germany

Microwaves are crucial in plasma applications, either as a heating mechanism or diagnostics tools. In this work we are utilizing high-frequency microwaves to deduce fundamental information of an atmospheric plasma torch. A network analyzer is used in order to measure the phase shift and the attenuation of a microwave that transverses the plasma torch. These measured quantities are directly related to the line-integrated density and the electron-neutral collision frequency of the torch through the plasma index of refraction. Additionally, the microwave is scattered due to the interaction with the plasma and this scattering depends on the plasma density profile. By moving the receiving antenna of the network analyzer, perpendicularly to the plasma torch, the beam scattering profile can be measured. Numerical full-wave simulations in a 3D domain have been carried out, which allow a variation of the density profile over a wide parameter range. Direct comparison of the experimental scattering profile against the simulations enables a precise estimation of a 2D density profile of the plasma torch.

P 6.3 Mon 16:30 ELP 6: Foyer

Kinetic Modeling of the Chemical and Physical Mechanisms in a Rf Plasma Combined with a Catalyst — •Fatma-Nur Seferoglu[1], Dirk Reiser[1], Achim Von Keudell[2], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich Gmbh, Jülich, Germany — [2]Ruhr-Universität Bochum, Bochum, Germany

Plasma driven catalysis is a promising method for addressing environmental challenges, particularly in the removal of volatile organic compounds (VOC), the reduction of nitrogen oxides and the oxidation of hydrocarbons. The oxidation of n-butane is often used as a benchmark for the efficiency of a catalytic system to remove VOC. However, the description of the chemical and physical mechanisms of plasma catalytic processes can be very challenging due to the high number of possible reaction pathways. On the one hand, the plasma changes the surface coverage of the catalyst and on the other hand, the catalyst influences the variety of the plasma species, i.e. due to desorption of species from the catalytic surface.

This work presents an approach to model the species concentration in a radiofrequency atmospheric pressure plasma combined with a manganese dioxide catalyst and to identify the most effective reaction pathways. In the experiment, the plasma channel is filled with different admixtures of carbon dioxide diluted in helium to investigate the dissociation and recombination of molecules using fourier-transform infrared spectroscopy. For better understanding of the chemical and physical mechanisms in the plasma catalytic system, more gas phase and surface reactions will be tested.

P 6.4 Mon 16:30 ELP 6: Foyer

Silicon nitride membrane as entrance window for plasma-induced VUV radiation — •Görkem Bilgin[1], Luka Hansen[1,2], and Jan Benedikt[1,2] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Kiel Nano, Surface and Interface Science KiNSIS, Kiel University, Kiel, Germany

The measurement of vacuum-ultraviolet (VUV) radiation generated by atmospheric pressure plasmas is restricted by the cutoff-wavelength of typical VUV window materials around 100 nanometers as the VUV radiation has to be transfered into the vacuum to avoid absorption [1]. Silicon nitride membranes originally designed for applications in transmission electron microscopes offer the possibility to be used as entrance windows in monochromators. First measurements show that these membranes are capable of withstanding the forces generated by the pressure gradient while being much thinner (20 nm to 200 nm membrane thickness) than typical VUV window materials.

Two different non-thermal atmospheric pressure plasma sources, based on a capillary jet [2] and a DC microplasma [3], were used to generate He-excimer-radiation in the VUV range. Results of the vacuum resistance as well as the VUV absorption measurements of the silicon nitride membranes are presented for different membrane thicknesses.

[1] J. Golda *et al.*, 2020 *Plasma Process. Polym.* **17** 201900216
[2] T. Winzer *et al.*, 2022 *J. Appl. Phys.* **132** 183301
[3] L. Hansen *et al.*, 2022 *Plasma Sources Sci. Technol.* **31** 035013

P 6.5 Mon 16:30 ELP 6: Foyer

Overcoming He: Towards a more sustainable plasma-driven biocatalysis — •Steffen Schüttler[1], Tim Dirks[2], Sabrina Klopsch[2], Jannis Kaufmann[1], Niklas Eichstaedt[1], Julia E. Bandow[2], and Judith Golda[1] — [1]Plasma Interface Physics, Ruhr-University Bochum, Universitätsstraße 150, 44801 Bochum, Germany — [2]Applied Microbiology, Ruhr-University Bochum, Universitätsstraße 150, 44801 Bochum, Germany

In plasma-driven biocatalysis, an RF atmospheric pressure plasma jet operated with humid He is used to generate and deliver H2O2 into a liquid in which biological enzymes act as catalysts [1]. Promising total turnover numbers were found, showing that this approach is competitive with other approaches presented in literature. However, 99% of the operating costs of the process are due to the use of He as feed gas. Therefore, in order to achieve a more sustainable approach, Ar was used as a feed gas because it can be extracted from air and is less expensive than He. A less stable plasma operation and a lower H2O2 production were found, which counterbalances the lower cost of Ar compared to He. To obtain a more stable plasma with Ar, a kHz plasma jet was also tested, which could also be used well in biocatalysis. N2 or air as feed gas are the most cost-effective gases. Therefore, the operation of the kHz plasma jet in humid N2 has also been tested for plasma-assisted biocatalysis, enabling a wider range of applications.

This work is supported by the DFG within CRC1316 (Subproject

B11, project number 327886311).

[1] A. Yayci et al., ChemCatChem 12, 5893-5897 (2020)

P 6.6 Mon 16:30 ELP 6: Foyer

Investigation of the morphology of a pulsed discharge in water using stereoscopic images — •Robert Werberger[1,2], Raphael Rataj[2], and Klaus-Dieter Weltmann[1,2] — [1]Universität Greifswald — [2]Leibniz-Institut für Plasmaforschung und Technologie e. V.

In the past, the morphology of streamer discharges in water was mainly analysed using 2D imaging systems, which resulted in measurement uncertainties due to the loss of depth information on the structure of the discharges. To take the spatial information into account, 3D images of the discharges are required. This study utilised a stereoscopic camera system to determine the disparity between two images resulting from different viewing angles. An automated analysis procedure was used to determine the corresponding points between the images, which was then used to create a 3D reconstruction of the discharges, thereby obtaining spatial information. The streamer discharges were generated at a needle-to-plate electrode with a positive, pulsed voltage signal with an amplitude ranging from 35 to 45 kV and a pulse duration of 100 ns. In the study, effects of voltage amplitude and liquid conductivity on the spatial positions of discharge channel branches and their splitting angles were investigated. Additionally, a comparison between two- and three-dimensional results will be presented.

P 6.7 Mon 16:30 ELP 6: Foyer

Experimental studies on H_2 addition to a CO_2 atmospheric microwave plasma torch — •Marc Bresser, Sophie Wahl, Katharina Wiegers, Andreas Schulz, Matthias Walker, and Günter Tovar — IGVP, University of Stuttgart, Germany

Man-made climate change, caused for example by an increased concentration of carbon dioxide (CO_2) in the atmosphere, is causing a switch from fossil fuels to renewable energy sources. The chemical industry is searching for new renewable ways to synthesize hydrocarbons. One way is to utilize the resulting CO_2 as a reactant and create a cycle process. CO_2 can be activated by a microwave plasma and split into carbon monoxide (CO) and oxygen (O_2). The big advantage is, that this technology enables the use of intermittent energy from wind and sun. The resulting CO can be further processed into hydrocarbons. One idea is to add other gases to the CO_2 plasma in order to utilize the energy and produce higher value products. In this work, the addition of "green" hydrogen (H_2) to a CO_2 plasma is investigated. The CO_2 gas is introduced tangentially in a reverse vortex flow of a microwave plasma torch. On top of the plasma torch a 13 mm restriction nozzle is mounted to quench the plasma and prevent the reverse reaction. The position of the H_2 addition is varied. After cooling to room temperature, the product gas is analyzed using a Fourier transform infrared (FTIR) absorption spectrometer. The influence of microwave power, gas flow and gas composition on the product gas is studied.

P 6.8 Mon 16:30 ELP 6: Foyer

Impact of CO_2 on the metastable atom density in the COST Reference Microplasma Jet — •Alexander Schicke, Sebastian Burhenn, and Judith Golda — Plasma Interface Physics, Ruhr-Universität Bochum, 44801 Bochum, Germany

In the plasma community, the dissociation of CO_2 has become a growing topic over the last years. Many applications include decarbonising the atmosphere and producing carbon for chemicals and fuels. Typical degrees of dissociation of about 45% can be achieved by adding CO_2 to e.g. a helium rf-plasma. The degree of dissociation can be increased by adding argon to the helium discharge gas stream. In previous works, it was assumed that two of the main reaction pathways responsible for the dissociation of CO_2 are electron impact dissociation and dissociation via Penning collisions with metastable atoms.
Therefore, to quantify how big of a role the metastable atoms play in the COST Reference Microplasma Jet, we changed the He/Ar ratio in the feed gas while simultaneously measuring the Ar and He metastable atom densities via tunable diode laser absorption spectroscopy (TDLAS). Additionally, the density profiles were measured as 2D maps, which gives us information about the spatial distribution of the metastable atoms in the discharge channel.

P 6.9 Mon 16:30 ELP 6: Foyer

Construction and test of a (micro-)hollow cathode assembly regarding hydrogen production via methane — •Marcel Margraf — Goethe Universität Frankfurt, IAP

A (Micro-)Hollow cathode assembly was designed with purpose of finding an efficient method to separate Methane into Hydrogen and Carbon. Compared to other discharges a hollow cathode discharge (HCD) allows for higher current densities at same conditions. Due to this higher dissociation degrees can be expected and thus possibly better efficiencies. A cylindrical cathode with a diameter of 0,8mm was used, separated from the anode by a 0,5mm thick MICA isolator. The assembly was powered by a DC high voltage generator and measurements were conducted from 0,2 to 0,9 mA under pressures of 300 to 800 mbar. Discharge voltage and current were measured with an oscilloscope and the conversion rate was measured with a gas analyzer. No correlation between pressure and efficiency was found in this test, however the efficiency went up with higher input currents. The best efficiency of 6,26% +/- 2,62% was achieved with 0,9mA at the highest pressure. This is a promising result for the idea to use such assemblies at atmospheric pressure and a basis for further tests.

P 6.10 Mon 16:30 ELP 6: Foyer

Imaging Spectrography at the Plasma Liquid Interface — •Kai Bröking[1,2], Daniel Tasche[1,2], and Christoph Gerhard[1,3] — [1]HAWK Hochschule für angewandte Wissenschaft und Kunst, Fakultät Ingenieurwissenschaften und Gesundheit, Göttingen — [2]Technische Universität Clausthal, Fakultät für Natur- und Materialwissenschaften, Clausthal-Zellerfeld — [3]Politecnico di Milano, School of Industrial and Information Engineering, Milano, Italy

Imaging spectrographs preserve spatial details imaged onto a spectrograph slit throughout the whole of their optical system. This grants access to spatially resolved spectral information, in our case about both plasma induced processes and, concurrently, to properties of the plasma. We have implemented a fast direct vision spectrograph for imaging in near real time, which allows access to process parameters in near real time as well. This is of marked interest for studying processes near the plasma liquid interface in the plasma induced formation of silver nanoparticles (AgNP). Taking spatially resolved absorption spectra of the AgNP simultaneously with the emission spectra of the plasma permits local process parameters to be observed in real time and investigated with a view to adjusting conditions of the reaction accordingly.

P 6.11 Mon 16:30 ELP 6: Foyer

Investigation of a plasma window arc discharge for particle beam transmission to high pressure targets — •Fateme Ghaznavi — Goethe University, Frankfurt am Main, Germany

A Plasma window [1] is a device which can be used to separate two different pressure levels, allowing for an unperturbed transmission of ion beams from the accelerator vacuum to high pressure targets. This sealing effect is provided by an arc discharge, burning along the ion beam transmission axis. At Goethe University Frankfurt, we constructed a plasma window, featuring an aperture of 5mm, using an 98%Ar-2%H_2 working gas compound and currents between 60-120 A with a flow rate between 1-4 slm. The aim of this study is to investigate the plasma physical characteristics of this arc discharge. A spectroscopic system is adjusted along the discharge axis to allow for a simultaneous estimation of the electron temperature and density at 4 different positions. They were found to range between 1-1.5 eV for the electron temperature and $0.6\text{-}3.8\cdot10^{16}$ cm^3 for the electron density, reaching 30% higher pressures compared to previous measurements utilizing the same aperture with lower currents [2].

[1] Hershcovitch, A. High-pressure arcs as vacuum-atmosphere interface and plasma lens for nonvacuum electron beam welding machines, electron beam melting, and nonvacuum ion material modification J. Appl. Phys., AIP Publishing, 1995, 78, 5283

[2] B. F. Bohlender Characterization of a plasma window as a membrane free transition between vacuum and high pressure Physical review accelerators and beams 23, 2020

P 6.12 Mon 16:30 ELP 6: Foyer

Comparison of the finite element and spectral element methods in modelling of streamer discharges. — •I. L. Semenov, A. P. Jovanovic, and M. M. Becker — Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany

Numerical modelling of streamers at atmospheric pressures is a challenging problem due to the multiscale nature of this discharge type. The current need to simulate streamers in realistic geometries and model the streamer-surface interaction drives the development of novel computational approaches to this problem. One of the key challenges is the development and implementation of efficient methods for solving large-scale electrostatic problems. As it was shown in [I. L. Semenov, K. D. Weltmann, J. Comput. Phys. 465, 111378 (2022)], the use of the hierarchical Poincaré - Steklov (HPS) scheme can be a promising approach to improve the computation efficiency of solving elliptic problems in streamer simulations. The HPS scheme is a multidomain spectral collocation method that has a number of attractive features. In this contribution we compare the streamer simulation scheme based on the HPS method with that based on the conventional finite element method (implemented using FEDM within the FEniCS framework). A number of test problems is considered and the efficiency of both methods is assessed in terms of the required computational time and the number of discrete unknowns being involved.

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P 6.13 Mon 16:30 ELP 6: Foyer

Benefits and perspectives of semantic data acquisition in low-temperature plasma physics — Ihda Chaerony Siffa[1], Hidir Aras[2], Harald Sack[2], Markus Stocker[3], and •Markus M. Becker[1] — [1]Leibniz Institute for Plasma Science and Technology (INP) — [2]FIZ Karlsruhe - Leibniz Institute for Information Infrastructure — [3]TIB - Leibniz Information Centre for Science and Technology

The scientific communities have recognized that structured storage and provision of data and technical information according to the FAIR data principles can represent a tremendous added value for research and development. This is reflected by the establishment of metadata schemas, ontologies, and knowledge graphs within the framework of the National Research Data Infrastructure (NFDI) in Germany and other projects in the field of research data management, where researchers from various fields work closely with computer scientists to develop sustainable infrastructures and tools. In this contribution, we present a basic ontology for low-temperature plasma (LTP) physics and show how a knowledge graph for LTP is created, which allows for easier reuse of data by providing a structured and interconnected representation of information. An application example demonstrates the development of an infrastructure for the simplified search of context-related information in patents, scientific literature and research data. Furthermore, we present how this can also support data-driven research and utilize the benefits of open-access publications.

The work was supported by the DFG (project 496963457) and by the BMBF (projects 16QK03A-B and 16KOA013A-B).

P 6.14 Mon 16:30 ELP 6: Foyer

Research data management with eLabFTW and Adamant — •Markus M. Becker[1], Ihda Chaerony Siffa[1], Robert Wagner[1], Nick Plathe[1], Kerstin Sgonina[2], and Marina Prenzel[3] — [1]Leibniz Institute for Plasma Science and Technology (INP) — [2]Institute of Experimental and Applied Physics, Kiel University (CAU) — [3]Research Department Plasmas with Complex Interactions, Ruhr-University Bochum (RUB)

The practical implementation of present requirements of the funding organizations with regard to the collection of standardized metadata and compliance with the FAIR data principles presents scientists and institutes with new challenges. Research data should be documented in a structured way and provided with identifiers to keep both data and metadata findable, accessible, interoperable and reusable. Electronic laboratory notebook (ELN) systems can support the implementation of these requirements. This contribution introduces the open-source ELN system eLabFTW (https://www.elabftw.net) and demonstrates its practical application in several groups in the field of low-temperature plasma physics. Furthermore, it is shown how the open-source tool Adamant (https://github.com/plasma-mds/adamant) can help to collect and store metadata in structured formats supporting the implementation of automated workflows for metadata acquisition, storage and publication on the basis of eLabFTW.

The work is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under the National Research Data Infrastructure – [NFDI46/1] – 501864659 and project 327886311.

P 6.15 Mon 16:30 ELP 6: Foyer

Characterization of millimeter-sized low-pressure plasmas in multi-scale aeromaterials — •Karin Hansen[1], Julian Held[2], Jonas Lumma[3], Lena Marie Saure[3], Fabian Schütt[3], Rainer Adelung[3], and Franko Greiner[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Department of Mechanical Engineering, University of Minnesota, Minneapolis, USA — [3]Institute for Materials Science, Kiel University, Kiel, Germany

Environmental protection is pivotal in our daily lives, and catalysis, particularly plasma catalysis, stands as a promising avenue to address these challenges. The efficiency of chemical processes hinges on the interplay between the plasma and catalyst surface. Nanodusty plasmas, comprising nanometer-sized particles spaced at micrometer intervals in a low-pressure plasma, exhibit notable attributes - a high surface-to-volume ratio and exceptional plasma permeability with a filling factor $f \approx 10^{-5}$. Multi-scale aeromaterials, micron-sized tetrapodal frameworks with nano-sized walls, share a comparable filling factor. These highly porous and lightweight aeromaterials remain solid and deployable within a plasma environment.

Our investigation centers on probing the interaction between these aeromaterials and low-pressure, radio-frequency argon plasmas. The plasma is ignited in a system of millimeter-sized aeromaterial cylinders with cylindrical cavities, providing a large aeromaterial-surface to plasma-volume ratio. Optical emission spectroscopy and electrostatic double probes as key techniques have been tailored to this millimeter-sized system. Our preliminary studies focus on aeroglass (t-SiO2).

P 6.16 Mon 16:30 ELP 6: Foyer

Langmuir probe measurements in a dual-frequency capacitively coupled rf discharge — •Viktor Schneider[1], Jessica Schleitzer[1], Ihor Korolov[2], Gerrit Hübner[2], Peter Hartmann[3], Julian Schulze[2], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics (IEAP), Kiel University — [2]Chair of Applied Electrodynamics and Plasma Technology, Faculty of Electrical Engineering and Information Sciences, Ruhr University, Bochum, Germany — [3]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Hungary

A dual-frequency capacitively coupled rf argon plasma has been investigated using a passively compensated Langmuir probe. The discharge is driven by two different excitation frequencies (13.56 MHz and 27.12 MHz) simultaneously with variable phase angle θ between them, utilizing the electrical asymmetry effect (EAE). With a passively compensated Langmuir probe the floating potential, plasma potential, electron temperature and electron density are measured for different phase angles in two different geometrically asymmetric discharges. Similar to the dc self-bias, the plasma parameters show a pronounced dependence on the phase. However, the measured profiles of the density and temperature as a function of phase in both experimental setups are not symmetric around $\theta = 90°$, unlike the dc self-bias. This observation is confirmed by PIC/MCC simulations, which reveal asymmetrical electron excitation/ionization dynamics at the corresponding phases. This implies that the observed trends are a property of the 2f discharge in combination with a geometric asymmetry of the discharge.

P 6.17 Mon 16:30 ELP 6: Foyer

Seagull - A compact helicon discharge — •Stefan Knauer, Nils Fahrenkamp, Sebastian Haag, and Peter Manz — Felix-Hausdorff-Str 6, 17489 Greifswald

The Seagull experiment is a radio-frequency powered plasma experiment with a planar double spiral antenna. The plasma forms in a cylindrical high-vacuum, within a volume of about $1\mathrm{dm}^3$. It was used to study capacitively (CCP) and inductively (ICP) coupled radio-frequency discharges, e.g. by means of a microwave interferometer, electron detachment and a set of Langmuir probes. Phase transitions and instabilities in electro-negative gases were investigated, as it aims to provide insight in industrial relevant coating processes. We plan to upgrade the experiment with copper coils to add a static magnetic field to the discharge area. A static magnetic field is required for helicon discharges, which are known for their height densities. Since Seagull exhibits unusual small vessel dimensions compared to other helicon experiments (sometimes multiple meters long), a comparatively short wavelength should be sufficient and thus a low magnetic field. This parameter and diagnostic set-up might enable well diagnosed helicon discharge measurements at the size of a table-top experiment.

P 6.18 Mon 16:30 ELP 6: Foyer

Development and application of low energy plasma treatments for steel surfaces — •Gustav Gürtler[1,2], Wolfgang Burgstaller[1], Markus Valtiner[2], and Friedrich Aumayr[2] — [1]voestalpine Stahl Gmbh, voestalpine Straße 3, 4020 Linz, Austria — [2]Institute of Applied Physics, TU Wien, Wiedner Hauptstraße 8-10/E134, 1040 Wien, Austria

Plasma cleaning can be an efficient way of preparing metallic surfaces for subsequent coating procedures by removing oxides and other contaminants and consequently enhancing the adhesion of deposited coating layers [1]. This study investigates the efficiency of low-pressure plasma treatments of steel batch samples. Plasma monitoring via optical emission spectroscopy (OES) is performed on a pulsed-DC argon plasma discharge. A successful removal of sample material is confirmed by Fe atomic emission, while an estimation of electron density Ne and electron temperature Te is attempted by exploiting intensity ratios of neutral argon Ar (I) emission lines via a modified Boltzmann plot and a Te-dependent neutral Ar (I) emission line ratio [2]. A possible correlation of Te and Ne values and the amount of detached material is investigated.

[1] H. C. Barshilia et al, 2012, Vacuum, 86 1165-1173
[2] J. B. Boffard et al, 2012, J. Phys. D: Appl. Phys. 45 045201

P 6.19 Mon 16:30 ELP 6: Foyer

Helicon wave physics for the development of a helicon plasma cell for particle-driven wakefield accelerators — •Alf Köhn-Seemann[1], Luis Herrera[1], Oliver Lass[2], and Peter Manz[2] — [1]IGVP, University of Stuttgart, Germany — [2]Institute of Physics, University of Greifswald, Germany

Plasma wakefield accelerators provide significantly higher gradients in the electric field to accelerate particles than linear particle accelerators, thereby significantly reducing their overall size. High electric fields require high electron plasma densities. Helicon plasma discharges are known to provide the highest electron densities. In this contribution we will give an overview of our newly started DFG-funded project to understand the helicon wave propagation and dissipation in the plasma based on a joint experimental and numerical approach between the University of Stuttgart and the University of Greifswald.

P 6.20 Mon 16:30 ELP 6: Foyer

Investigation of charge exchange collisions in an ion beam — •Philipp Georg Johannes Kropidlowski, Leo Zeidler, Thomas Trottenberg, and Holger Kersten — IEAP, Christian-Albrechts-Universität zu Kiel

Charge exchange collisions (CEX) play an important role in operation of ion beam sources for industrial applications and electric propulsion systems for space travel. CEX collisions convert part of the ions into a beam of fast neutral atoms.

Several diagnostic methods can be used to measure this phenomenon, like a combination of force probe [1] and Faraday cup [2]. In this contribution, we use a Faraday cup to measure the spatial electric current density of the beam ions. In addition, a force probe measures the momentum flux density of all energetic beam particles, including the neutrals generated by charge exchange collisions, which cannot be detected by a Faraday cup.

We present measurements in the beam of an inductively coupled plasma (ICP) gridded ion source.

[1] T. Trottenberg, A. Spethmann, and H. Kersten, EPJ Techn. Instrum. 5, 3 (2018)
[2]J. Benedikt, H. Kersten, and A. Piel, Plasma Sources Sci. Technol. 30, 033001 (2021)

P 6.21 Mon 16:30 ELP 6: Foyer

Transport Across an X-Point in HiPIMS plasmas — •Martha Finke[1], Achim von Keudell[1], Dennis Krüger[2], and Marc Böke[1] — [1]Fakultät für Physik und Astronomie, Bochum, Germany — [2]Fakultät für Elektrotechnik und Informationstechnik, Bochum, Germany

Magnetized low pressure plasmas have a wide range of applications such as sputter deposition of metals and oxides or plasma thrusters for small satellites. In case of High Power Impulse Magnetron Sputtering (HiPIMS) the plasma currents may affect the magnetic fields. By combining two magnetrons with their magnets facing each other one obtains a specific topology of the magnetic field with an X-point, where we seek to find signatures of magnetic recinnection events. We investigate in the time-resolved behaviour of the plasma during the HiPIMS pulse using an ICCD camera and observe that the plasma igniting in front of the driven targen is strongly influenced by the magnetic field of the opposite magnetron.

P 6.22 Mon 16:30 ELP 6: Foyer

Multidimensional effects in low-pressure discharges — •Jonas Thiel, Tsanko V. Tsankov, and Uwe Czarnetzki — Ruhr-University Bochum, Faculty of Physics and Astronomy

The transport in low-pressure discharges, such as the ones commonly used in many industrial applications, is governed by diffusion. Most of the insights on the behavior of these plasmas is obtained through the use of one-dimensional models. Such a treatment forces equality of the ion and electron fluxes and leads to the well-known ambipolar diffusion. However, in realistic systems with metal walls, flux balance has to be satisfied only globally but not locally. This leads to a peculiar behavior, with regions where the ion flux to the walls exceeds the electron flux and vice versa. In this contribution, the effect is investigated experimentally for a large area rectangular discharge chamber, which provides a simple geometry. The plasma is generated by inductive coupling provided by the recently developed INCA configuration. An array of wall-mounted planar probes allows the measurement of the spatial profiles across one of the major walls. The spatial distributions of the electron and ion fluxes, as well as of the plasma potentials, the densities and the electron temperature are measured and analyzed. The results demonstrate the expected deviation from local equality of the fluxes.

P 6.23 Mon 16:30 ELP 6: Foyer

Formation of ammonia in a surfaguide discharge assisted by catalysis — •Vinzenz Wolf[1], Roland Friedl[1], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Ammonia (NH_3) is an important chemical widely used as fertiliser and in the chemical industry. Plasma-catalysis has attracted great interest in the last years as an alternative for the energy intensive thermal-catalytic synthesis of ammonia via the Haber-Bosch process. The plasma generates photons, radicals, excited and metastable states which lead to and additional activation of the precursor hydrogen and nitrogen molecules, thereby lowering the activation energy needed for the generation of NH_3.

In this contribution, the effect of changes in pressure in the range of 3 Pa to 1000 Pa, the hydrogen-nitrogen gas composition, and the presence and position of a commercial Ruthenium catalyst (2 wt% Ru on γ-Al_2O_3 pellets) on ammonia production are investigated in a microwave (2.45 GHz) plasma discharge by means of mass spectrometry. The calibration of the mass spectrometer and the influence of considering the background water are described. Additionally, optical emission spectroscopy is used to determine the vibrational and rotational temperatures of the molecules in the plasma.

P 6.24 Mon 16:30 ELP 6: Foyer

Effect of low-pressure plasma treatment on triboelectric properties of polypropylene (PP) and polylactic acid granules (PLA) — •Alina Bachmann — Hessen, Germany

This study evaluates the effect of low-pressure plasma treatment of approximately spherical polypropylene (PP) and cylindrical polylactic acid granules (PLA) on triboelectric properties. Using low-pressure plasma, various process gases and treatment durations, surfaces of the polymer materials were modified.

Within the experimental procedure these process parameters were varied to achieve saturation charge for PP and PLA. The charge-to-mass ratio and surface charge density serve as crucial parameters for characterising the treated surfaces.

The results of the study find application in the electro-sorting of plastics based on triboelectricity. Since this phenomenon is not scientifically understood to a full extent, the generated data contributes to a more optimised implementation in the technical field.

P 6.25 Mon 16:30 ELP 6: Foyer

Stokes-Einstein Relation for Binary Mixtures — •Yang Liu and Dietmar Block — IEAP, Christian-Albrechts-Universität, D-24098 Kiel, Germany

The Stokes-Einstein (SE) relation connects the diffusion coefficient (D) of Brownian particles in liquids to their temperature (T) and the shear viscosity (η) [1]. Extensive evidence has confirmed the validity of the SE relation in ordinary liquids and dusty plasmas, except for systems near the melting temperature and for the gaseous behavior [2]. However, for binary mixtures, i.e. dusty plasmas consisting of two particle species with different charges, an explicit validation of SE is lacking.

In this paper, a Langevin simulation code is used to generate 2D binary systems whose structural and dynamical properties match the experimental conditions [3]. The obtained η and D in monodisperse and binary systems are analyzed and compared. Finally, the applicability of the SE relation to 2D finite binary mixtures is tested. Our results show that, even in finite systems the SE relation holds. Further, the transport properties of monodisperse and binary systems can be combined in a generalized SE relation if properly defined coupling strengths and screening parameters are used.

References
[1] A. Einstein, Investigations on the Theory of the Brownian Movement (Courier Corporation, 1956).
[2] N. Ohtori, et al., Phys. Rev. E 95 (2017) 052122.
[3] F. Wieben, et al., Phys. Plasmas 24 (2017) 033707.

P 6.26 Mon 16:30 ELP 6: Foyer

Plasma processing of Ag nanoparticles for resistive switching applications — •Arthur Fabritz[1], Florian Ziegler[2], Blessing Adejube[2], Alexander Vahl[2,3], Franz Faupel[2,3], and Jan Benedikt[1,3] — [1]Institute of Experimental and Applied Physics, Kiel University — [2]Institute of Materials Science, Kiel University — [3]KiNSIS, Kiel University

Given their negative charge when inserted or formed in plasma, nanoparticles can be stored in the positive plasma potential and can be effectively modified inside a plasma, which allows for applications in various fields such as opto-electronics, sensors, or medicine. A large area of study are their electric characteristics, where especially their utilization in memristive devices is still largely unexplored. Memristic devices allow for the simulation of complex neuronal systems, and could therefore contribute to a vast improvement in the functionality of electrical components.

In this work, silver nanoparticles generated in a gas aggregation source are injected into low pressure plasma and coated with thin films (hydrocarbons, SiOx) to form core-shell nanoparticles. Injection of additional silver nanoparticles and extraction of the trapped particles onto non-conducting substrate can prepare mixed nanoparticle films with the density of uncoated particles on the percolation limit, the condition needed for the successful construction of a device with memristive properties. The experimental setup, in-situ diagnostics with UV-Vis absorption spectroscopy, nanoparticle extraction and measurements of their electrical properties will be discussed.

P 6.27 Mon 16:30 ELP 6: Foyer

On the use of configurational temperature for an ion focus measurement — •Natascha Blosczyk and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

Complex plasmas -especially those using micronsized dust grains- allow to study fundamental physical processes. Due to the particle size they attain a large negative charge and allow to study strongly coupled systems in a fluid and crystalline state. However, in the plasma sheath the negatively charged dust grains perturb the ion flow, resulting in a positive space charge region downstream of each particle which modifies the interparticle interaction force. This positive space charge region is called the ion focus and has a non-negligible effect on interaction strength as its charge is comparable to a significant portion of particle charge and its distance to the particle layer is of the order of interparticle distance. However, to determine the strength and position of the ion focus is a difficult task. In this contribution the configurational temperature method will be used to estimate the focus properties. If the particle charge and the screening length are known, the contribution of ion focus in terms of focus strength and position can be estimated from force equilibrium and a configurational temperature fit. The method is tested for results of MD-simulations as well as experimental data.

P 6.28 Mon 16:30 ELP 6: Foyer

The charging of nonspherical particles in a dusty plasma — •Isabel König, Armin Mengel, and Franko Greiner — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

For the most part, studies focus on the charging of spherical particles in a plasma, and only a few experiments were performed studying the charging of nonspherical particles. Nonspherical particles have a varying surface potential, which complicates the calculation of the equilibrium particle charge and also affects dust dynamics. One ansatz to determine the charge of nonspherical particles is the smallest enclosing sphere approximation [Asnaz, Phys.Plasmas 2018].

To analyze the charging of micrometer-sized nonspherical particles we use a combination of long-distance microscopy and the phase-resolved resonance method. We compare the nonspherical particles with spherical SiO_2 particles which levitate at the same position in the sheath. Measurements for different kinds of nonspherical particles are performed: clustered microparticles (doublets and triplets), cylinders, tetrapods, MgO and sapphire crystals, multiscale aeromaterials and MOFs.

P 6.29 Mon 16:30 ELP 6: Foyer

COMPACT – the future complex plasma facility for the ISS — •Daniel P. Mohr[1], Christina A. Knapek[1], Stefan Schütt[1], Daniel Maier[1], André Melzer[1], and COMPACT Collaboration[2] — [1]University of Greifswald, Institute of Physics, Greifswald, Germany — [2]International: CA, US, SE, DE

Complex, or dusty, plasmas consist of micrometer-sized grains that are injected into a low-temperature noble gas discharge. The grains become charged and interact with each other via a screened Coulomb potential. On ground, gravity compresses the system and prevents the formation of larger, three-dimensional particle clouds.

The future complex plasma facility COMPACT will allow the investigation of large three-dimensional complex plasmas under microgravity conditions aboard the International Space Station (ISS). Its technology is based on preliminary studies (Ekoplasma, PlasmaLab), including a novel plasma chamber with adaptive internal geometry, a four-electrode radio-frequency system for plasma generation, and a stereoscopic particle diagnostic that enables the 3D particle dynamics to be recorded in real time. COMPACT is a project with international scientific contributions, funded by space agencies (DLR, NASA). A phase 0/A study is currently underway in collaboration with the space industry and will be finished until 02/2024.

We will present the scientific objectives of COMPACT, scientific and technological progress and the project status.

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

P 6.30 Mon 16:30 ELP 6: Foyer

Oxygen dependent size evolution of PMMA particles in the plasma sheath — Franziska Reiser, •Sören Wohlfahrt, and Dietmar Block — Kiel University, Kiel, Germany

Microparticles are the essential component of complex (dusty) plasmas. The forces affecting the particles, as well as their accumulated charge, depend prominently on their size. However, dependent on the particle material, the size and surface morphology of the particle will change when exposed to the plasma. Polymethymethacrylat (PMMA) particles show a strong plasma-particle interaction, resulting in a significant size reduction, or etching of the particle. In addition, a heavily modified surface structure with crests and trenches that has a reduced mass density of up to 50 % was reported. Compared to melamine formaldehyde (MF) particles, which show only a moderate response to the surrounding plasma, PMMA particles are an excellent research object to investigate the material dependent plasma-particle interaction itself, as well as the possible influence of the surface morphology on charging processes. An enhanced light scattering diagnostic based on Lorentz-Mie-theory is used to determine and track size and optical properties of the particle and thus the evolution of the plasma-particle interaction. The time resolved evolution of size and the optical properties of single PMMA particles for a systematic variation of oxygen admixture to the argon plasma are presented in this contribution. The results are compared to MF particles and complimented with levitation height measurements, which act as an indicator for particle charge.

P 7: Magnetic Confinement III

Time: Tuesday 11:00–12:30 Location: ELP 6: HS 3

Invited Talk P 7.1 Tue 11:00 ELP 6: HS 3

Physics of Electrical Currents and Fields in the Scrape-off Layer of Tokamak Plasmas — •D. Brida[1], G. D. Conway[1], J. Adamek[2], J. Cavalier[2], H. Bergstroem[1], G. Grenfell[1], U. Plank[1], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching/Greifswald, Germany — [2]Institute of Plasma Physics of the CAS, Prague, Czech Republic

The outermost layer of tokamak plasmas, the so-called Scrape-Off

Layer (SOL), exhibits strong electric fields and currents, which affect the plasma transport in the SOL and possibly also the confinement of the overall plasma. Understanding the physics governing SOL electric fields and currents and having accurate models describing them is therefore potentially crucial to operate and design future fusion devices. The validation and improvement of these models requires detailed comparisons to measurements obtained in present-day tokamaks, such as ASDEX Upgrade in Garching.

This contribution provides an introduction to the physics of SOL electric fields and currents and presents recent experimental studies conducted at ASDEX Upgrade and other tokamaks. The dependence of the electric field on the divertor conditions, measured by Langmuir probes, is analyzed for different plasma states. Using an analytical model, based on Ohm's law, it is shown how the divertor conditions are related to the electric field further upstream. The studies highlight the pivotal role of the divertor state in determining the electric field and show how currents can lead to substantial heat fluxes onto the divertor target.

P 7.2 Tue 11:30 ELP 6: HS 3

Edge current density distributions in the island divertor configurations on the J-TEXT tokamak — •Jiankun Hua[1,2], Yunfeng Liang[1,2,3], Qinghu Yang[2], Jie Yang[2], Song Zhou[2], and Yutong Yang[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung Plasmaphysik, 52425 Jülich, Germany — [2]International Joint Research Laboratory of Magnetic Confinement Fusion and Plasma Physics, Huazhong University of Science and Technology, Wuhan, 430074, China — [3]Institute of Plasma Physics, Chinese Academy of Sciences, 23003 Hefei, China

The island divertor configuration was recently operated on the J-TEXT tokamak, and the magnetic field structure can vary with the edge safe factor (qa), amplitude and phase of the island divertor coil current. A set of probes called the Directional Electron Probe (DEP) was developed to measure edge plasma current density distributions in different configurations. The qa scan was performed by increasing the total plasma current from 80kA to 110kA with a fixed toroidal magnetic field (1.6T) and island divertor coil current (+5kA or -5kA). At the same time, the m/n=3/1 magnetic island will move from the inside of the last closed flux surface (LCFS) to the outside. In this experiment, the DEP remains at the same position in the plasma, and the dynamic of plasma current density distribution can be measured as the m/n=3/1 magnetic island moves. Preliminary experimental results show that the edge current density distribution has a strong correlation with the length of the magnetic field lines and the edge magnetic configuration (such as magnetic island).

P 7.3 Tue 11:45 ELP 6: HS 3

Machine learning based fast optimization of free parameters in W7-X edge plasma modeling with EMC3-EIRENE — •Y. Luo[1,3], S. Xu[1], Y. Liang[1,3], E. Wang[1], J. Cai[1], Y. Feng[2], D. Deiter[3], A. Knieps[1], S. Brezinsek[1,3], D. Harting[1], M. Krychowiak[2], D. Gradic[2], E. Flom[2], F. Henke[2], Y. Gao[2], R. König[2], A. Pandey[2], M. Vecsei[2], and A. Dinklage[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany — [2]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [3]Faculty of Mathematics and Natural Science, Heinrich Heine University Düsseldorf, 40225 Düsseldorf, Germany

EMC3-EIRENE is a powerful tool for simulating edge plasma transport, capable of providing insights into transport parameters based on limited local experimental measurements. However, achieving a closer match between simulations and actual experiments often requires extensive scanning of input-free parameters. To address this challenge, we have developed a machine learning model that, by learning from a simulation database, can predict optimal edge cross-field transport coefficients, based on multiple edge measurements. To quantify the performance of the trained model, we calculate mean squared error in the test set, resulting in an error magnitude of 0.024. Moving forward, our plan is to expand the range of learned parameters and significantly enhance the simulation database, thus trying to employ the machine learning technique for directly forecasting plasma information of all EMC3-EIRENE cells based on local experimental measurements.

P 7.4 Tue 12:00 ELP 6: HS 3

Fast 2D n_e and T_e profile measurements with the divertor helium beam at ASDEX Upgrade — •Sebastian Hörmann[1,2], Marco Cavedon[3], Michael Griener[1], Daniel Wendler[1,2], Ulrich Stroth[1,2], and The ASDEX Upgrade team[4] — [1]Max-Planck-Institut für Plasmaphysik, Garching — [2]Physik-Department E28, Technische Universität München, 85747 Garching, Germany — [3]Dipartimento di Fisica "G. Occhialini", Università di Milano-Bicocca, Milano, Italy — [4]See author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

The divertor is an important element to achieve magnetic confinement fusion, reducing the impurity content of the core plasma and increasing the pumping efficiency. Too high heat loads on the target plates of the divertor can be mitigated by a layer of neutral gas which forms in front of the target plates, such a state is called detachment. To study the condition of the divertor and the detachment process, a new thermal helium beam diagnostic with high spatiotemporal resolution has been installed in the outer divertor of ASDEX Upgrade. It is capable to measure two-dimensional electron density, temperature and hence pressure profiles by means of a collisional radiative model. This makes it possible for the first time to observe the change in these profiles from an attached to a partially detached divertor state on a fast time scale and therefore contribute to the understanding of the dynamics during this transition. In particular, the movement of the detachment front and divertor plasma oscillations during the transition to detachment are presented within this contribution.

P 7.5 Tue 12:15 ELP 6: HS 3

Electromagnetic particle-in-cell simulation of the tokamak scrape-off layer — •Annika Stier[1], Alberto Bottino[1], David Coster[1], Thomas Hayward-Schneider[1], Andreas Bergmann[1], Frank Jenko[1], and Laurent Villard[2] — [1]Max-Planck Institute for Plasma Physics, Boltzmannstrasse 2, Garching, 85748, Bavaria, Germany — [2]Ecole Polytechnique Federale de Lausanne (EPFL) Swiss Plasma Center (SPC), Rte Cantonale, Lausanne, CH-1015, State Two, Switzerland

The particle-in-cell code PICLS is a full-f finite element tool intended to simulate turbulence in the tokamak scrape-off layer using gyrokinetic ions and drift-kinetic electrons. Up until now however, PICLS has been a purely electrostatic code with a prescribed background magnetic field. This approach is not perfectly suited to represent unstable regimes occurring in the scrape-off layer, since although $\beta = 2\mu_0 p/B^2$ can be small, turbulence there is still dominated by electromagnetic effects [1]. In order to capture those effects, an Ampère-solver is added to the code and the evolving magnetic field is taken into account in the particle pusher stage. In order to combat the Ampère-cancellation problem that arises from the Hamiltonian canonical Lagrangian formulation that PICLS is based on, we combine the newly added Ampère-solver with a pullback scheme akin to the one used in ORB5 [2]. This improved version of PICLS opens up possibilities in simulating β-dependent ITG-KBM transitions like illustrated in ref. [3] for the codes GENE, GKW, EUTERPE and ORB5, shear Alfvén waves, microtearing modes and more.

P 8: Complex Plasmas and Dusty Plasmas I

Time: Tuesday 11:00–12:30 Location: WW 1: HS

Invited Talk P 8.1 Tue 11:00 WW 1: HS

Pulsed Complex Plasma In Microgravity — •Christina A. Knapek[1,2], Daniel P. Mohr[1,2], and Peter Huber[2] — [1]Institute of Physics, University of Greifswald, 17489 Greifswald, Germany — [2]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt, 51147 Köln, Germany

A new experimental method for creating void-free complex plasmas under microgravity conditions is presented. The method is based on a pulsed operation mode of a four-channel radio-frequency generator for plasma generation. A dust cloud of micrometer-sized particles can be immersed in the bulk of a low temperature plasma under microgravity conditions. It typically contains a central volume depleted of particles – the void – that prevents the generation of large, continuous clouds. Experiments performed at different neutral gas pressures and discharge volumes during the microgravity phase of a parabolic flight show that the central void is closed completely once the pulsed operation mode is applied. The particle cloud shape, and the density distribution within the cloud, are practically independent on the pulse period within the investigated parameter range. The proposed method has great potential for future application in experimental facilities dedicated to fundamental studies of large three-dimensional, homogeneous complex plasma systems in microgravity. Prospective ongoing studies are outlined that are dedicated to investigate the underlying physical processes for the observed void closure.

This work is funded by DLR/BMWi (FKZ 50WP0700, 50WM1441, 50WM2161) and StMWi.

P 8.2 Tue 11:30 WW 1: HS

A full Stokes imaging polarimeter for nanodusty plasma applications — •Alexander Schmitz, Andreas Petersen, and Franko Greiner — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

Full Stokes imaging Mie polarimeters are required to study the detailed dynamic of particle growth in reactive plasmas. Various concepts exist, which often rely on the rotation or switching of optical components. Our setup, constructed from two divisions of focal plane CMOS cameras, presents a new imaging polarimeter with high spatial resolution that does not require moving optics.

The accuracy of the polarimeter has been carefully investigated. The performance of the new polarimeter is demonstrated by visualizing two-generation layered particle growth in a reactive Argon-Acetylene plasma.

P 8.3 Tue 11:45 WW 1: HS

Three-dimensional investigation of dust flows around obstacles under microgravity — •Stefan Schütt, Christina Knapek, Daniel Maier, Daniel Mohr, and André Melzer — University of Greifswald, Greifswald, Germany

Dust flows around a tungsten wire in three-dimensionally extended dusty plasmas have been investigated on parabolic flights. A fixed wire has been installed in the midplane between the electrodes of a parallel plate rf discharge. The dust particles were captured three-dimensionally with a stereoscopic four-camera system. The dust flow around the wire was investigated during the pull-out phase at the end of each parabola, when gravity sets in and the dust cloud moves downward past the wire. Additionally, a periodic dust motion was generated by superimposing a low-frequency ($f \approx 1\,\mathrm{Hz}$) modulation on the electrodes. The repetitive nature of the dust motion in the latter case allows to stroboscopically overlay dust trajectories from multiple modulation periods and to accurately obtain fluid properties in three dimensions.

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

P 8.4 Tue 12:00 WW 1: HS

Electrostatic probes in high Havnes nanodusty plasmas — •Franko Greiner[1] and Julian Held[2] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Department of Mechanical Engineering, University of Minnesota, Minneapolis, USA

Invasive diagnostics, such as Langmuir probes, pose challenges when employed in nanodusty plasmas with high dust density. When a floating probe is utilized, it establishes a dust-free 'probe void' around itself. Applying a more negative probe voltage expands this void, while a more positive probe voltage results in a significant dust flow toward the probe upon reaching the plasma potential. Since the plasma potential is unknown, probe contamination and the disruption of the nanodusty plasma become inevitable.

Double probes, which inherently float below the plasma potential at zero voltage bias, appear to be the preferred choice for probes. This choice helps in avoiding probe contamination, and the impact on dust density is minimal across all probe voltages. In our study, we present measurements of ion density and electron temperature in a nanodusty, strongly electron-depleted argon plasma.

P 8.5 Tue 12:15 WW 1: HS

Surface modification and core-shell structure of MF particles in the plasma sheath — •Sören Wohlfahrt, Franziska Reiser, and Dietmar Block — Kiel University, Kiel, Germany

Complex (dusty) plasmas consist if micrometer sized particles in addition to the typical plasma species of ions, electrons and neutrals. Dependent on the particle material, they show a distinct plasma-particle interaction that leads to a modification of the particles surface and even a decrease of the particle size in a process commonly referred to as 'etching'. In case of the widely used melamine formaldehyde (MF) particles, there is a strong connection between the surface reactivity and the etch process itself, which can be explained in the framework of an increasingly roughened surface shell and an unmodified particle core. We use a polarization resolved light scattering technique based on Lorentz-Mie theory to investigate the size and size evolution of single MF-particles in the plasma sheath. Our scattering-model assumes a coated sphere, which is analogous to a core-shell structure. Thus, the optical properties of the particle surface become directly accessible in the experiment. We will present time resolved measurements of single MF particles whose core is unaffected by the etch process, while the shell shows a steep increase in the imaginary part of the refractive index. Although the shell is only 100 nm thick ($< 5\%$ of particle size), this increase has a significant influence on the overall scattering- and absorption cross section of the particle and affects the particle dynamics as well.

P 9: HEPP III

Time: Tuesday 14:00–16:05 Location: ELP 6: HS 3

P 9.1 Tue 14:00 ELP 6: HS 3

Integrated modelling of impurity transport in ASDEX Upgrade — •Daniel Fajardo[1], Clemente Angioni[1], Ralph Dux[1], Emiliano Fable[1], Giovanni Tardini[1], and the ASDEX Upgrade Team[2] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]see author list of Stroth *et al* 2022 *Nucl. Fusion* **62** 042006

Impurities play crucial roles in fusion devices, from the deleterious fuel dilution and radiative cooling of the core to the beneficial edge cooling for safe power exhaust. Predicting their behavior and effects becomes essential as tokamaks approach reactor operation. We present an integrated framework that demonstrates multi-species, multi-channel modelling capabilities for the prediction of impurity density profiles and their feedback on the main plasma through radiation and dilution. It combines all presently known theoretical elements in the local description of quasi-linear turbulent and collisional transport.

The workflow reproduces ASDEX Upgrade experimental results in L-mode and H-mode, with full-radius and core simulations, respectively. In particular, predictions of a radiative L-mode with one seeded (Ar) and two intrinsic (B, W) impurities match its measured radiated power and H-mode-like confinement. Likewise, the control of W accumulation with ECRH and ICRH in NBI-heated H-mode plasmas is studied in dynamical simulations of experiments featuring wave heating power steps, finding good agreement with the measured W peaking.

P 9.2 Tue 14:25 ELP 6: HS 3

Shattered pellet injection experiments performed at ASDEX Upgrade — •Paul Heinrich[1], G. Papp[1], M. Bernert[1], P. de Marné[1], M. Dibon[2], S. Jachmich[2], M. Lehnen[2], T. Peherstorfer[3], N. Schwarz[1], U. Sheikh[4], B. Sieglin[1], J. Svoboda[5], and the ASDEX Upgrade team[6] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]ITER, St. Paul-lez-Durance, France — [3]TU Wien, Wien, Austria — [4]EPFL, Lausanne, Switzerland — [5]IPP CAS, Prague, Czech Republic — [6]See author list of U. Stroth et al. 2022 NF 62 042006

Future fusion devices like ITER, which are based on the tokamak concept, require a disruption mitigation system (DMS) to ensure machine protection. While the fusion reactions will naturally come to a hold within a fraction of a second in an unforeseen event causing a disruption, this can cause large forces and heat loads on the structure which might damage the device. In order to support the design of the ITER disruption mitigation system, a highly flexible shattered pellet injection (SPI) system was installed at the tokamak ASDEX Upgrade. Hereby, frozen pellets of deuterium, neon or a mixture thereof, are injected into the plasma to isotropically radiate the confined energy. Optimized mitigation is investigated by variation of the pellet parameters (e.g. size, velocity) or shatter geometry. The injection parameters are found to have a stronger impact on material assimilation, while the radiation characteristics are dominated by the pellet composition. A system overview as well as first analysis results for the experimental campaign – with focus on the radiation characteristics – are presented.

P 9.3 Tue 14:50 ELP 6: HS 3

Exploring the influence of plasma triangularity on pedestal stability and structure in ASDEX Upgrade — •Lidija Radovanovic[1], Elisabeth Wolfrum[2], Mike Dunne[2], Tobias Görler[2], Georg Harrer[1], Facundo Sheffield Heit[2], Friedrich Aumayr[1], and The ASDEX Upgrade Team[3] — [1]Institute of Applied Physics, TU Wien, 1040 Vienna, Austria — [2]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [3]See author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

The confinement and the performance of a tokamak plasma in the high confinement regime are closely related to the structure of the pedestal. One possible factor limiting the pedestal width is the onset of instabilities, kinetic ballooning modes (KBMs), at the top of the pedestal, which we approximate by local ideal ballooning modes (IBMs). The stability of these modes can be altered by varying the plasma shape. To determine the role of local IBMs at the pedestal top, other possible instabilities present in the pedestal top are analysed with the local linear version of the gyro kinetic code GENE and compared with the shearing rate. The results show that different physical mechanisms influence the pedestal width of the electrons and ions with respect to their density and temperature. Particularly, the electron pressure pedestal top strongly correlates with the minimum in ballooning stability. The objective of this study is to link physical processes in frameworks of MHD, transport and gyro kinetics with the experimentally observed pedestal structure.

P 9.4 Tue 15:15 ELP 6: HS 3

Properties of Tungsten Particles Produced by Arcing — •Albertto Castillo Castillo[1,2], Martin Balden[2], Volker Rohde[2], Peter Siemroth[3], Michael Laux[3], Heinz Pursch[3], Juergen Sachtleben[3], and Rudolf Neu[1,2] — [1]Technische Universität München, 85748 Garching, Germany — [2]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [3]retired, was with Arc-Precision GmbH, 15711 Königs Wusterhausen, Germany

Metal droplet emission by arcing is one of the mechanisms generating dust in a magnetic confinement fusion device. Tungsten droplet production is of particular interest for full tungsten wall devices. The potential of a droplet to introduce impurities in the plasma depends on its velocity, diameter, and angle. The distributions of these parameters has been measured in a dedicated device with multiple independent methods in order to provide useful data to evaluate their effect on plasma operation.

In a addition to a time-of-flight detection system based on light scattering by droplets to measure their size, velocity and angle, a high-speed camera was added to record videos of the flying droplets. Dedicated software was developed to track the trajectories in the video, and fitting the thermal radiation curves to a model of the cooling of particles allows measurement of diameter and initial temperature. This first measurement of initial temperatures reveals that a significant fraction of particles are ejected in a solid state. This is supported by microscopy analysis of the particle deposition showing non-spherical particles.

P 9.5 Tue 15:40 ELP 6: HS 3

Spectroscopy based inference of impurity transport at the plasma edge in different tokamak confinement regimes — •Tabea Gleiter[1,2], Ralph Dux[1], Francesco Sciortino[3], Tomáš Odstrčil[4], Thomas Hayward-Schneider[1], Daniel Fajardo[1], Ulrich Stroth[1,2], and the ASDEX Upgrade Team[5] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Physik-Department E28, Technische Universität München, Garching, Germany — [3]Proxima Fusion GmbH — [4]General Atomics, San Diego, USA — [5]Authors of U. Stroth et al. 2022 Nucl. Fusion 62 042006

We present the inference of radial impurity diffusion and convection profiles in steady state discharges. The experimental basis are customized charge exchange recombination spectroscopy (CXRS) measurements, yielding line radiances from multiple impurity charge states. A forward model based on the impurity transport solver Aurora is able to generate synthetic CXRS-data for given transport coefficients. It requires additional inputs, such as neutral beam and thermal deuterium densities, kinetic profiles and atomic rate data. This model is used for a Bayesian inverse inference of transport coefficent probabilities. Due to the complexity, the selection of suitable free parameter sets, prior distributions and data likelihoods is important.

The framework is mostly suitable for the plasma edge, i.e. where impurities are not fully ionized. Since the pedestal impurity transport in tokamaks is crucial for energy confinement and radiative power exhaust, we compare various confinement regimes at ASDEX Upgrade, including promising reactor scenarios without large ELMs.

P 10: Atmospheric Pressure Plasmas and their Applications II

Time: Tuesday 14:00–16:00 Location: WW 1: HS

Invited Talk P 10.1 Tue 14:00 WW 1: HS

Filament interaction in dielectric barrier discharges — •Hans Höft[1], Ronny Brandenburg[1], Markus M. Becker[1], and Torsten Gerling[1,2] — [1]Leibniz Institute for Plasma Science and Technology (INP), Felix-Hausdorff-Str. 2, 17489 Greifswald, Germany — [2]Competency centre for diabetes (KDK), Greifswalder Str. 11, 17495 Karlsburg, Germany

The formation and interaction of individual filaments in dielectric barrier discharges (DBDs) are essential for the efficiency and efficacy of DBD reactors. In most DBD arrangements, multiple filaments are formed, since the power input per filament is limited. Therefore, the impact of O_2 concentration and high-voltage operation (pulsed vs. sinusoidal) on the number of filaments per period and their ignition pattern is studied. The spatially 1D multi-filament arrangement had a length of about 10 mm while the gap distance was set to 1.0 mm. The working gas was a binary mixture ranging from 0.1 to 20 vol% O_2 in N_2 at 1 bar. The DBDs were characterised by iCCD camera imaging determining the filament number and the discharge development by a streak camera to obtain the filament positions during different phases of one HV period. Simultaneously, electrical measurements using fast probes were performed. The results clearly show the different effects of the performed parameter variations on pulsed and sine-driven discharges, particularly regarding the spatial stability and number of filaments. Finally, the findings for the multi-filament arrangement are linked to single-filament DBDs under the same experimental conditions.

Funded by the DFG – project number 466331904.

P 10.2 Tue 14:30 WW 1: HS

Electric field components within a micro scaled dielectric barrier discharge measured by Stark shift and splitting of helium lines — •Henrik van Impel, David Steuer, Robin Labenski, Volker Schulz-von der Gathen, Marc Böke, and Judith Golda — PIP & EP2, Ruhr-University Bochum, D-44801 Bochum

Atmospheric pressure dielectric barrier discharges (DBDs), such as the micro cavity plasma array (MCPA) [1], have emerged as promising technologies for the conversion of volatile gases. These conversion processes' effectiveness can be enhanced by integrating catalytically active surfaces. To deepen the understanding of the plasma-catalyst interaction, it is crucial to investigate the transport dynamics of reactive species to the catalytic surface. The transport is in particular affected by the electric field perpendicular to the catalytic surface. However, experimental data on the component-wise electric field strength within DBDs are rare. To address this issue, we performed polarized optical emission spectroscopy on the shifting and splitting of the allowed 492.19 nm ($^1D \rightarrow ^1P^0$) and forbidden 492.06 nm ($^1F^0 \rightarrow ^1P^0$) helium line pair. This diagnostic approach requires a non-radially symmetric geometry, which leads to an adapted reactor design of the MCPA allowing the side-on observation of the discharge. The discharge operates in pure helium at atmospheric pressure, utilizing a triangular excitation voltage with a frequency of 15 kHz and an amplitude of 600 V. Field components reveal differences of approximately 5 kV cm^{-1} or 20 %. The project is funded within project A6 of the SFB 1316.

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

P 10.3 Tue 14:45 WW 1: HS

Time-resolved ion mass spectrometry to investigate the ion chemistry of a dielectric barrier discharge — Nils Dose[1], •Luka Hansen[1,2], Tristan Winzer[1], Christian Schulze[1], and Jan Benedikt[1,2] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Kiel Nano, Surface and Interface Science KiNSIS, Kiel University, Kiel, Germany

The ion chemistry plays a crucial role for many plasma chemical processes ranging from particle or thin film growth to the production of biomedical relevant species [1]. Ion mass spectrometry allows a direct measurement of the formed ions with the drawback of a limited temporal resolution due to the flight time of ions from the plasma through the filtering optics of the mass spectrometer to the detector [2].
To overcome this issue the ion mass spectrometer was equipped with a multi channel scaler which allows to measure the incoming ions with up to 10 ns resolution. The mass dependent ion flight times were determined using a (pulsed) dielectric barrier discharge usually utilized for deposition processes [3] and compared with SIMION simulations. The derived connection between flight times and mass can be used to correct the time-resolved ion measurements, therefore allowing to gain inside into the production and conversion of ions.
The diagnostic will be presented and its potential demonstrated on first measurements with N_2 and O_2 admixtures.

[1] P. Tosi *et al.*, 2009 *Plasma Sources Sci. Technol.* **18** 034005
[2] J. Benedikt *et al.*, 2012 *J. Phys. D: Appl. Phys.* **45** 403001
[3] L. Bröcker *et al.*, 2023 *Plasma Process. Polym.* e2300177

P 10.4 Tue 15:00 WW 1: HS

Tunable laser absorption spectroscopy of all four Ar*(3p⁵4s) states in a pulsed-driven dielectric barrier discharge with short gas-residence times — •Levin Krös, Hans Höft, Andy Nave, Jean-Pierre van Helden, and Ronny Brandenburg — Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany

Dielectric Barrier Discharges (DBDs) can be applied for plasma enhanced chemical vapour deposition processes, i.e. for the deposition of thin functional films. In case of short gas-residence times realised by e.g. high working gas flows, ions play an important role in the deposition process. A significant production channel for ionic species is provided by excited argon species, especially the metastable states, via Penning ionisation. Therefore, tunable laser absorption spectroscopy is utilized to measure absolute number density of the four lowest energetic excited states of argon. The ability to determine the number density all four Ar*($3p^5 4s$) states as a function of the operation parameters, like gas flow and characteristics of the applied high-voltage pulse, is especially valuable for a comparison with numerical models. As a starting point, the number densities of these states will be measured in a pulsed-driven DBD with 3 mm gas gap flushed with pure argon at atmospheric pressure.

P 10.5 Tue 15:15 WW 1: HS

Fluid Simulation of Streamer Dynamics in Nanosecond Pulsed Surface Dielectric Barrier Discharges — •Dominik Filla, Gerrit Hübner, Nils Schoeneweihs, Ihor Korolov, Thomas Mussenbrock, and Sebastian Wilczek — Department of Electrical Engineering and Information Science, Ruhr-University Bochum

The efficient conversion of airborne pollutants, such as volatile organic compounds (VOCs) and nitrogen oxides, is not only crucial for environmental protection but also holds great scientific interest. Within this scope, surface dielectric barrier discharges (sDBD) driven by nanosecond pulses emerge as promising tools for energy-efficient gas conversion. This study delves into the streamer dynamics in sDBD systems, utilizing the 2D plasma simulation code nonPDPSIM. We demonstrate how key process parameters – such as pressure, voltage pulse amplitude, and pulse rise time – significantly influence streamer behavior, affecting its length, propagation speed, and direction. Our numerical results show a qualitative alignment with experimental data obtained from time-resolved optical emission spectroscopy. This correlation underscores the practical relevance of our simulations in advancing the understanding of plasma-based pollutant conversion.

**The authors thank a) Mark Kushner (University of Michigan) for providing nonPDPSIM and b) the DFG for financial support via SFB 1316.

P 10.6 Tue 15:30 WW 1: HS

Electrical Characterization and Imaging of the Discharge Morphology in a Small Scale Coaxial Packed Bed Dielectric Barrier Discharge — •Rezvan Hosseini Rad[1], Volker Brüser[1], and Ronny Brandenburg[1,2] — [1]Leibniz Institute for Plasma Science and Technology, Felix-HausdorffStraße 2, 17489 Greifswald, Germany — [2]University of Rostock, Institute of Physics, Albert-Einstein-Str. 23-24, 18059 Rostock, Germany

Packed Bed Dielectric Barrier Discharges (PB-DBDs) are gaining widespread attention due to direct interaction between plasma and catalyst, resulting in enhanced product selectivity in gas processing. In this contribution, a small scale coaxial DBD reactor, enabling the end-on view observation of the discharge gap, has been constructed. The primary objective is to correlate electrical measurements such as voltage-charge (V-Q) plots with the plasma morphology in PB-DBD for different pressures, gas compositions, packing materials and applied voltage amplitudes. Simultaneous imaging and V-Q plot analysis, with special attention to parasitic capacitances, result in the revision of equivalent circuit for PB-DBDs and a more accurate experimental determination of the key capacitance values, namely the cell capacity (Ccell), and effective dielectric capacity (ζdiel). Additionally, the analysis includes the role of parasitic discharges, which can lead to the overestimation of input power. We aim to enhance the understanding of PB- DBDs, to provide sound knowledge about the power input and penetration of the flowing gas by active plasma.

P 10.7 Tue 15:45 WW 1: HS

Novel methods for determination and manipulation of surface charges in an atmospheric DBD microplasma — •Robin Labenski[1], David Steuer[1], Henrik van Impel[1], Marc Böke[2], Volker Schulz-von der Gathen[2], and Judith Golda[1] — [1]Plasma Interface Physics, Ruhr-University Bochum — [2]Experimental Physics II, Ruhr-University Bochum

In photo- and electrocatalysis it is already well-established that surface charges can alter the chemical adsorption and reaction paths of the catalyst. However, the novel realm of plasma catalysis lacks experimental exploration regarding the impact of plasma-induced surface charges on catalysis. We pave that way by introducing a straightforward method for precisely charging the dielectric (catalyst) using a microplasma at atmospheric pressure, while also monitoring the level of deposited surface charge over time. Through pre-charging we examine its effect on re-ignition and forming of equilibria in the discharge. Additionally, a laser assisted technique is introduced to further fine-tune the amount of surface charge on the dielectric and assess the plasma's response to this subtle manipulation of surface charge.

P 11: Codes and Modeling I

Time: Tuesday 16:30–17:40 Location: ELP 6: HS 3

Invited Talk P 11.1 Tue 16:30 ELP 6: HS 3

Collaboration on RDM in low-temperature plasma physics — •Marina Prenzel[1], Kerstin Sgonina[2], and Markus Becker[3] — [1]Research Department Plasmas with Complex Interactions, Ruhr-University Bochum (RUB) — [2]Institute of Experimental and Applied Physics, Kiel University (CAU) — [3]Leibniz Institute for Plasma Science and Technology (INP)

The dynamic research environments in low-temperature plasma physics, including plasma sources and instrumentation often developed in the course of research, have historically lacked standardized research data management (RDM). The absence of established standards not only complicates the implementation of structured RDM, but also hinders data comparability and reusability, impeding the seamless transfer of research outcomes to new plasma applications. In response to these challenges, research groups at INP, RUB and CAU have started a collaborative initiative to develop common standards and tools for comprehensive data documentation.

This contribution provides an update on the current status of these collaborative efforts, focusing on the practical implementation of data management standards in laboratory settings and presenting real-world examples from different research groups.

The presentation aims to underscore the significance of structured RDM in low-temperature plasma physics and its concrete implications for advancing research outcomes in this field.

The work was supported by grants 16QK03A (BMBF) and 327886311 (DFG).

P 11.2 Tue 17:00 ELP 6: HS 3

Learning physics-based reduced models from data for the Hasegawa-Wakatani equations — •Constantin Gahr[1], Ionuț-Gabriel Farcaș[2], and Frank Jenko[1] — [1]Max-Planck-Institute for Plasma Physics, 85748 Garching, DE — [2]Oden Institute for Computational Engineering & Sciences, Austin, TX 78712, US

This presentation focuses on the construction of non-intrusive Scientific Machine-Learning (SciML) Reduced Order Models (ROMs) for nonlinear, chaotic plasma turbulence simulations. In particular, we propose using Operator Inference (OpInf) to build low-cost physics-based ROMs from data for such simulations. As a representative example, we focus on the Hasegawa-Wakatani (HW) equations used for modeling two-dimensional electrostatic drift-wave plasma turbulence. We first use the data obtained via a direct numerical simulation of the HW equations starting from a specific initial condition and train OpInf ROMs for predictions beyond the training time horizon. In the second, more challenging set of experiments, we train ROMs using the same data set as before but this time perform predictions for six other initial conditions. Our results show that the OpInf ROMs capture the important features of the turbulent dynamics and generalize to new and unseen initial conditions while reducing the evaluation time of the high-fidelity model by up to six orders of magnitude in single-core performance. In the broader context of fusion research, this shows that non-intrusive SciML ROMs have the potential to drastically accelerate numerical studies, which can ultimately enable tasks such as the design and real-time control of optimized fusion devices.

P 11.3 Tue 17:25 ELP 6: HS 3

Solving the Parametric Boltzmann Equation for Electrons Using Physics-Informed Neural Networks — •Ihda Chaerony Siffa[1], Detlef Loffhagen[1], Markus M. Becker[1], and Jan Trieschmann[2] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Kiel University, Kiel, Germany

The coupling of fluid-Poisson models for low-temperature plasma simulations with the Boltzmann equation of electrons is often needed to ensure the reliability of such models. A direct coupling is, however, often too expensive with respect to calculation time. The pre-calculation of look-up tables for the electron transport and rate coefficients as a function of the reduced electric field strength or mean electron energy is therefore a common practice. In this work, we present a way to parametrically solve the electron Boltzmann equation in two-term approximation using the so-called Physics-Informed Neural Networks (PINNs). PINNs are a mesh-free method and provide differentiable solutions with the potential to ultimately predict electron properties more efficiently than traditional Boltzmann solvers. Presently, the artificial neural network surrogate model takes into account two inputs, the kinetic energy of electrons and an additional input parameter, which represents either the reduced electric field or the mean electron energy, and outputs the isotropic component of the electron velocity distribution function. This contribution discusses the advantages and limitations of the present approach, and gives an outlook for future work.

P 12: Poster II

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

P 12.1 Tue 16:30 ELP 6: Foyer

Inference of transport coefficients in helium puff modulation studies at W7-X — •Thilo Romba[1], Felix Reimold[1], Oliver Ford[1], Peter Zsolt Poloskei[1], Sebastian Bannmann[1], Tabea Gleiter[2], Erik Flom[3], and Thomas Klinger[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald 17491, Germany — [2]Max-Planck-Institute for Plasma Physics, Garching 85748, Germany — [3]University of Wisconsin-Madison, Madison, WI 53706, USA

The precise monitoring of the impurity content and the understanding of the transport mechanisms is crucial for future fusion reactor operation due to the associated restrictions to the operational parameter space via dilution and increased radiative losses.

This work aims to analyze the transport properties of the fusion ash helium in the confined region of the optimized stellarator Wendelstein 7-X (W7-X) [1]. Spatially and temporally densities of He2+ are measured using charge exchange recombination spectroscopy (CXRS) [2]. To introduce a time variation in the local density response, periodic helium puffs outside the confined region are imposed as the helium source.

Based on the local helium density response measured, local diffusion and convection coefficients of the helium particle transport are inferred with the 1.5D transport code aurora [3]. Experiments over varying magnetic configurations show dominant anomalous transport in all cases, consistent with previous results for higher Z impurities [4].

[1] Erckmann 1997, [2] Fonck RSI 1985, [3] Sciortino PPCF 2021, [4] T Romba PPCF 2023

P 12.2 Tue 16:30 ELP 6: Foyer

Influence of density-potential cross-phase on particle and momentum transport in TJ-K — •Ralph Sarkis, Mirko Ramisch, and Günter Tovar — IGVP, University of Stuttgart, Germany

Transport formation in magnetically confined plasmas is heavily dependent on the coupling between density and potential. Drift-waves can be destabilized when the electron response to a density perturbation is hindered and the positive potential perturbation that arises has a non-zero phase shift with respect to the density perturbation. The momentum transport, also called Reynolds stress, and particle transport have opposite promoting conditions with respect to the density-potential coupling, that is highly coupled and decoupled, respectively. To understand the conflicting occurrence of both transport phenomena peaking at comparable poloidal positions, as observed at the stellarator experiment TJ-K, a spatio-temporal analysis is performed by means of a poloidal Langmuir probe array, which allows for the spectral decomposition in order to determine the transports' interplay on the basis of the coupling/decoupling influence. Conditional sampling reveals a separation of particle and momentum transport peaks in time. Both transports dynamics are related to the evolution of the density-potential cross-phase in time, and differentiated from the amplitude modulation, to establish a time-based relation between the spectral components and the transport events. Scale separation of the components and of the transport phenomena in the time-based analyses provides a deeper insight of the weighted contribution of each scale investigated.

P 12.3 Tue 16:30 ELP 6: Foyer

Hybrid kinetic-MHD simulations of the fishbone instability with JOREK — •Felix Antlitz[1], Xin Wang[1], Matthias Hoelzl[1], and Guido Huijsmans[2,3] — [1]Max Planck Institute for Plasma Physics, Garching b. M., Germany — [2]CEA, Saint-Paul-Lez-durance, France — [3]Eindhoven University of Technology, Eindhoven, Netherlands

Energetic particles (EPs) will play a central role in future burning plasma experiments, as they can strongly interact with the bulk plasma and drive magnetohydrodynamic (MHD) instabilities. For instance the fishbone instability is the result of an internal kink mode destabilized by EPs in tokamaks. This contribution describes applications and developments of the nonlinear extended MHD code JOREK, whose kinetic module is used to investigate the interaction between EPs and core MHD instabilities both in the linear and the nonlinear regime. The kinetic module uses a particle-in-cell technique and describes the EP distribution function with a full-f formulation. The results will also be compared to gyrokinetic simulations performed with the ORB5 code. Furthermore, the current work on implementing a model in JOREK that describes also the thermal ions kinetically is presented.

P 12.4 Tue 16:30 ELP 6: Foyer

Dynamics of a pellet produced plasmoid in a stellara-

tor — •Carl Wilhelm Rogge[1,3], Ksenia Aleynikova[1], Pavel Aleynikov[1], Rohan Ramasamy[2], Matthias Hoelzl[2], and Per Helander[1,3] — [1]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany — [2]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [3]University of Greifswald

Pellet injection will play a critical role in refueling future tokamak and stellarator reactors. Although pellet plasmoid physics has been extensively studied in tokamak magnetic geometries, understanding in stellarator geometries remains less comprehensive. This gap partially arises due to the lack of numerical tools capable of accurately describing the 3D physics effects with sufficient spatial and temporal resolutions, covering extensive time spans that encompass the various timescales of key physical effects. The non-axisymmetry of the equilibrium field in stellarators increases the complexity of numerical analysis.

However, recent advancements in the stellarator extension of the JOREK non-linear 3D MHD code, which employs a reduced MHD model for stellarator geometry, show significant promise in addressing this challenge. Consequently, this project aims to leverage JOREK to gain a deeper understanding of pellet plasmoid dynamics in stellarator geometries. This poster offers an overview of pellet physics, employed physics and numerical models, and outlines future research inquiries.

P 12.5 Tue 16:30 ELP 6: Foyer

Investigating density build-up in the W7-X island divertor — •Nassim Maaziz, Felix Reimold, Victoria Winters, David Bold, Frederik Henke, and Yuhe Feng — Max-Planck-Institute for Plasma Physics, Greifswald 17491, Germany

The island divertor has been proposed for power and particle exhaust in stellarators and is investigated as a viable solution for a reactor in the Wendelstein 7-X (W7-X) experiment. The divertor capabilities increase with higher divertor densities. However, significantly lower densities have been measured in the W7-X divertor in comparison to tokamaks. We assess the impact of the island field line pitch on the density build-up with EMC3-EIRENE modeling and comparing to experimental measurements. The modeling shows an increase of field line pitch leads to higher achievable divertor densities. A more fundamental understanding of the density build-up motivated the development of a simplified geometry model for the island divertor, which we study with EMC3-EIRENE. We look at both, the impact of the field line pitch as well as the effect of the divertor geometry. The beneficial effect on the density build-up of increasing the field line pitch has been observed in this simplified case. A close divertor geometry appears to provide significantly higher achievable densities.

P 12.6 Tue 16:30 ELP 6: Foyer

Towards a 3D Full MHD plasma model comprehensive of electromagnetic and halo current coupling with 3D conductive structures — •Raffaele Sparago[1], Javier Artola[2], and Matthias Hoelzl[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]ITER Organization, St. Paul Lez Durance Cedes, France

An adequate modelling of the electromagnetic interaction of the plasma with the surrounding conductors is paramount for the correct reproduction of 3D plasma dynamics. Simulations of the latter provide in turn useful predictions regarding the plasma evolution, the related MHD modes leading to disruptions and the electromagnetic forces acting on the vacuum vessel's components when said disruptions occur. The latest modelling efforts with the 3D FEM non-linear JOREK code have been directed towards the eddy current coupling of a reduced MHD plasma model with thin and volumetric wall codes. In the context of this work, an eddy current coupling between the full MHD model of JOREK and the STARWALL code has been performed; this new coupling scheme relaxes all the degrees of freedom in JOREK's magnetic boundary conditions, allowing for three-dimensional interactions between the magnetic vector potential A and the magnetic field B. Preliminary benchmarks prove the consistency of the Full MHD coupling. Furthermore, this contribution features the recent theoretical development in view of the coupling of halo currents, which flow from the plasma to the wall and viceversa, thus originating additional electromagnetic loads on the vessel that require proper modelling.

P 12.7 Tue 16:30 ELP 6: Foyer

Characterization of electromagnetic instabilities in high-beta plasmas at Wendelstein 7-X — •Charlotte Büschel, Christian Brandt, Henning Thomsen, Kian Rahbarnia, Sara Vaz Mendes, Adrian von Stechow, and Jan-Peter Bähner — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

In the last campaigns of Wendelstein 7-X, comparable high plasma beta core values around $\beta_0 \sim 2.5\,\%$ have been reached in different scenarios, e.g. after the injection of frozen hydrogen pellets or with heating scenarios combining electron cyclotron resonance heating and neutral beam injection. However maintaining the plasma in this state with plasma energies up to 1.2 MJ and densities around $1.4 \times 10^{20}\,\mathrm{m}^{-3}$ has up to date been challenging. With increasing density, strong mode activity in the range of 20-50 kHz has been observed, which might contribute to the decrease of the plasma energy and density after a transient peak. To determine the driving instability, these modes are characterized by analyzing data from Mirnov coils, the phase contrast imaging diagnostic and the soft X-ray tomography system. Furthermore the dependency on local and global plasma parameters is investigated.

P 12.8 Tue 16:30 ELP 6: Foyer

Tomographic localization of turbulent density fluctuations in the Wendelstein 7-X stellarator — •Christian Brandt, Thomas Wegner, Charlotte Büschel, Sara Vaz Mendes, Kian Rahbarnia, Henning Thomsen, and and the W7-X Team — Max-Planck-Institute for Plasma Physics, Greifswald, Germany

The soft X-ray tomography system in the Wendelstein 7-X stellarator is suited to spatially localize turbulence activity by elaborating X-ray radiation fluctuations, which are the results of turbulent density fluctuations. The amplitude of fluctuations investigated in poloidal-radial mappings of temporal evolving tomographic inversions suggests a connection to the flux surface geometry, especially to the flux surface compression. This effect is investigated for different plasma scenarios in terms of heating and density, which enable a variation of turbulent fluctuation levels as generally known from other measurements. The presented diagnostic approach as well as the link to the driving mechanism of turbulence are discussed.

P 12.9 Tue 16:30 ELP 6: Foyer

Modulational instability in isolated dynamics of Geodesic-Acoustic-Mode packets — •David Korger[1,2], Emanuele Poli[1], Alessandro Biancalani[3], Alberto Bottino[1], Omar Maj[1], and Juvert Njeck Sama[4] — [1]Max-Planck-Institut für Plasmaphysik, Garching, 85748, Germany — [2]Ulm University, Ulm, 89081, Germany — [3]École supérieure d'ingenieurs Léonard-de-Vinci (ESILV), Paris La Défense, F-92916, France — [4]Institut Jean Lamour, Université de Lorraine, Nancy, 54011, France

The geodesic-acoustic-mode (GAM) is a plasma oscillation observed in fusion reactors with toroidal geometry and is recognized to be the nonstationary branch of the zonal flows (ZFs). It was recently shown that the dynamics of the isolated, undamped GAM is well described by a (cubic) nonlinear Schrödinger equation (NLSE). This model equation predicts the susceptibility of GAM packets to the modulational instability (MI).

The necessary conditions for this instability are analyzed analytically and numerically using the NLSE model. The predictions of the NLSE are compared to gyrokinetic simulations performed with the global particle-in-cell code ORB5, where the GAM packets are created from initial perturbations of the axisymmetric radial electric field E_r. An instability of the GAM packets with respect to modulations is observed, in both cases in which an initial perturbation is imposed and when the instability develops spontaneously. However, significant differences in the dynamics of the small scales are discerned between the NLSE and gyrokinetic simulations.

P 12.10 Tue 16:30 ELP 6: Foyer

Real-time vibration monitoring system for the pellet centrifuge at ASDEX Upgrade with empirically derived limit values — •Fin Schmidt[1], Bernhard Ploeckl[2], Martin Prechtl[1], P. T. Lang[2], and ASDEX Upgrade team[3] — [1]Hochschule Coburg — [2]Max-Planck-Institut für Plasmaphysik — [3]see author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

The ASDEX Upgrade centrifuge pellet launcher, utilized to reliably control the particle flux and ELM frequency, is now in operation for more than 30 years. The units age as well as its unique design necessitate a real-time vibration monitoring system, to reliably detect, warn and prevent damage or malfunctions. Due to space restrictions, two sensors were affixed close to the lower ball bearing. This configuration allows for an efficient monitoring of both the overall structure and at least one of the two bearings, providing some insight into the stability of the rotor. In the absence of literature and established standards for vibration control specific to this structure and application, the key to find vibrational limits is to derive them empirically. Setting a baseline for limit values considers the current operational values as optimal and establishes more precise limits based on the observed behavior of the unit during different operational states. Advanced tools, such as envelope analysis, are employed to monitor specific machine components, especially the ball bearings. Beyond enhancing the safety of pellet injection at ASDEX Upgrade, the current state of the system includes a scheme to safely shutting down the centrifuge before reaching threatening vibration magnitudes.

P 12.11 Tue 16:30 ELP 6: Foyer

Parametrisation of target heat flux in W7-X — •Johannes Droste[2], Felix Reimold[1], David Bold[1], and Ralf Schneider[2] — [1]Max-Planck Institute for Plasma Physics, Greifswald, Germany — [2]Universität Greifswald

This poster presents an approach to address the complex behaviour of the W7-X strike line. It introduces a tool for parameterising the heat flux on to the W7-X island divertor. Particularly distinctive at high densities, the strike line profile exhibits multiple, sometimes overlapping features. The developed tool allows for the separation and characterisation of these features. Through a comparative analysis of feature positions and corresponding connection lengths, a link is established to different transport channels within the island. In addition, the methodology allows the localisation of errors in heat flux calculations due to material deposition and damage to the target surface of the divertor. The width and amplitude of the strike line are key parameters, providing valuable insight into transport and diffusion within the scrape-off layer. Accurate measurement of these parameters is essential for improving and validating scrape-off layer modeling. The influence of time dependent parameters like toroidal plasma current and its influence on strike line position is also investigated.

P 12.12 Tue 16:30 ELP 6: Foyer

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P 12.13 Tue 16:30 ELP 6: Foyer

Modelling of shattered pellet injection in ASDEX Upgrade — •Peter Halldestam[1], Paul Heinrich[1], Gergely Papp[1], Mathias Hoppe[2], Oskar Vallhagen[3], Matthias Hoelzl[1], and Frank Jenko[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Royal Institute of Technology, Stockholm, Sweden — [3]Chalmers University of Technology, Göteborg, Sweden

One of the main issues threatening the success of future reactor-scale tokamaks is disruptions. It is the sudden loss of confinement where the plasma rapidly dissipates its energy onto the surrounding structures, exposing the device to excessive mechanical stress and heat loads. In addition, an electric field is induced that can accelerate a significant fraction of the electrons to relativistic energies, giving rise to runaway electrons (REs). Unmitigated disruptions could potentially cause severe damage to the device and thus, modeling such events is crucial for being able to assess the effectiveness of various mitigation techniques.

With the modeling framework DREAM [Hoppe CPC 2021], we self-consistently evolve in time the poloidal flux and parallel current density, ion charge state densities and temperatures, thermal electron temperature (their density follows from quasi-neutrality) as well as the RE density – all in a flux surface-averaged fluid description of the plasma. In this contribution we study the effects shattered pellet injection (SPI) of deuterium and neon has on disrupting plasmas for ASDEX Upgrade. Initial simulations show good agreement with experimentally observed current quench rates and radiated energy fractions.

P 12.14 Tue 16:30 ELP 6: Foyer

An engineering tool for the minimization of leading edges in a tungsten-based divertor for W7-X — •Antara Menzel Barbara[1,2], Joris Fellinger[1], Rudolf Neu[1,2], and Dirk Naujoks[1] — [1]Max Planck Institute for Plasma Physics, Greifswald/Garching, Germany — [2]Technical University of Munich, Munich, Germany

An innovative engineering tool is developed specifically for minimizing leading edges in the design of a future tungsten divertor for the Wendelstein 7-X fusion device. Traditionally, mitigating leading edges involves shadowing techniques such as tilting the divertor target or chamfering the problematic edges. However, as W7-X is capable of operating various magnetic configurations, this can lead to particle fluxes impinging from opposing directions on the same target surface, potentially exposing new leading edges when mitigating one. The tool harnesses an extensive ANSYS dataset to correlate heat flux and incidence angles from EMC3-Lite simulations with maximum temperatures at potential leading edges. It comprehensively evaluates major magnetic configurations across varied plasma pressures and toroidal currents, while considering manufacturing and assembly tolerances. In instances where chamfering is necessary, the tool analyzes possible chamfer geometries and assesses the resulting exposed leading edges on neighboring components under different magnetic configurations. Its computational efficiency, enabling analysis within minutes on a single core, allows seamless integration into broader optimization frameworks.

P 12.15 Tue 16:30 ELP 6: Foyer

In-situ Uptake Measurement of Deuterium Atoms in Self Damaged Tungsten at Different Temperatures — •Abdulrahman Albarodi[1,2], Thomas Schwarz-Selinger[2], and Klaus Schmid[2] — [1]Tech. Univ. München, 85748 Garching, Germany — [2]Max-Planck Institut für Plasmaphysik, 85748 Garching, Germany

Self-damaged tungsten samples (damage dose 0.23 dpa) were exposed to low energy deuterium (D) atoms (< 5 eV) from a microwave plasma source at 400, 500 and 600 K to investigate D uptake and D retention at different temperatures. The time evolution of the D depth profile was observed in-situ with $_3$He nuclear reaction analysis after each uptake increment. Thermal desorption spectroscopy was performed ex-situ to determine the de-trapping energies and the surface adsorption energies in the tungsten samples. The deuterium flux was measured by an independent erosion measurement to be 2.1 x 10^{21} D/m^2/s. The macroscopic rate equation code TESSIM will be used to model the uptake using the measured de-trapping energies, D flux, the surface binding energy and the surface barrier energy in order to determine the incident particle energy. The results are expected to show an increase in the total retention and uptake of deuterium at higher exposure temperatures.

P 12.16 Tue 16:30 ELP 6: Foyer

Build quality benchmark of tungsten powder bed fusion additive manufacturing processes — •Robert Lürbke[1,2], Alexander von Müller[2], Georg Schlick[3], and Rudolf Neu[1,2] — [1]Technical University Munich, 85748 Garching, Germany — [2]Max Planck Institute for Plasma Physics, 85748 Garching — [3]Fraunhofer Institue for Casting, Composite and Processing Technology, 86159 Augsburg, Germany

Plasma-facing components (PFCs) in future magnetic confinement fusion reactors must sustain high heat fluxes and intense neutron irradiation. These extreme conditions might create the need for specially engineered materials. Tungsten (W) is currently considered the preferred plasma-facing material in fusion devices. To create a wall component, it has to be joined to an actively cooled heat sink. Additive manufacturing (AM) of W is a potentially helpful tool to create tailored structures to reinforce a high-conductivity copper matrix, forming a composite heat sink with optimized thermomechanical behavior. AM of W is a rapidly developing field, and various processes have been elaborated recently by research institutions and industry. The contribution will give an overview of AM powder bed fusion processes for W and highlight the development of a benchmark part based on which the processes shall be evaluated in view of their capabilities related to PFC production.

P 12.17 Tue 16:30 ELP 6: Foyer

Validation of the GENE - KNOSOS - Tango Framework Using W7-X Discharges — •Don Lawrence Carl Fernando[1], Alejandro Bañon Navarro[1], Daniel Carralero[2], Jose Luis Velasco[2], J. Arturo Alonso[2], Alessandro Di Siena[1], Felix Wilms[1], Frank Jenko[1], and W7-X Team[3] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Laboratorio Nacional de Fusión, CIEMAT, 28040 Madrid, Spain — [3]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

A pre-requisite to carrying out plasma profile predictions using simulation codes are validation studies. Validation ensures the accuracy of the simulated quantities with respect to experimental results. For this reason, a validation study was carried out using four OP1.2b W7-X scenarios that exhibit different turbulence characteristics. The framework of GENE-KNOSOS-Tango, a coupling of gyrokinetic, neoclassical, and transport codes respectively, is used to predict plasma profiles.

The results of this study show the successful validation of this framework for the four scenarios. Additionally, different key effects are also touched upon, such as electron-scale turbulence and the neoclassical radial electric field and its shear. Finally, we looked into simulated turbulence characteristics, such as density fluctuations and heat diffusivity, and compared these with experimental values. Good qualitative agreement is observed as well. This is the first time that such a study has been done for stellarators. The validation of the GENE-KNOSOS-Tango framework enables us to make credible predictions of physical phenomena in stellarators and reactor performance.

P 12.18 Tue 16:30 ELP 6: Foyer

GRILLIX: Turbulence validation efforts and simulations of advanced divertor concepts — •Jan Pfennig, Wladimir Zholobenko, Andreas Stegmeir, Konrad Eder, Christoph Pitzal, Kaiyu Zhang, Garrad Conway, Gustavo Grenfell, Dominik Brida, and Frank Jenko — Max Planck Institute for Plasma Physics, 85748 Garching b. Muenchen, Germany

Predictive turbulence simulations represent a key tool to describing and understanding the anomalous transport of particles and energy across magnetic flux surfaces of tokamak fusion devices, which is commonly believed to be the main factor determining their confinement properties [1], and thus economic viability. In order to test and verify the physics quality of the locally field-aligned but flux coordinate independent edge turbulence code GRILLIX, extensive validation efforts against ASDEX Upgrade (AUG) L-mode have been performed. As a successive step, GRILLIX simulations of future machine advanced divertor concepts (ADCs), such as downscaled DEMO ADCs [2] as well as magnetic configurations of the new upper divertor in AUG [3], are performed and evaluated.

[1] - A. Dimits et al., Physics of Plasmas, Vol. 7, 2000, DOI 10.1063/1.873896

[2] - F. Militello et al., Nuclear Materials and Energy, Vol. 26, 2021, DOI 10.1016/j.nme.2021.100908

[3] - T. Lunt et al., Nuclear Materials and Energy, Vol. 12, 2017, DOI 10.1016/j.nme.2016.12.035

P 12.19 Tue 16:30 ELP 6: Foyer

GRILLIX: Turbulence validation efforts and simulations of advanced divertor concepts — •Jan Pfennig, Wladimir Zholobenko, Andreas Stegmeir, Konrad Eder, Christoph Pitzal, Kaiyu Zhang, Garrad Conway, Gustavo Grenfell, Dominik Brida, and Frank Jenko — Max Planck Institute for Plasma Physics, 85748 Garching b. Muenchen, Germany

Predictive turbulence simulations represent a key tool to describing and understanding the anomalous transport of particles and energy across magnetic flux surfaces of tokamak fusion devices, which is one of the main factors determining their confinement properties [1], and thus economic viability. In order to test and verify the physics description of the locally field-aligned but flux coordinate independent edge turbulence code GRILLIX, extensive validation efforts against ASDEX Upgrade (AUG) L-mode have been performed. As a successive step, GRILLIX simulations of future machine's advanced divertor concepts (ADCs), such as downscaled DEMO ADCs [2] as well as magnetic configurations of the new upper divertor in AUG [3], are performed and evaluated.

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P 12.20 Tue 16:30 ELP 6: Foyer

Hybrid gyrokinetics: Electromagnetic effects in weakly magnetized plasmas — •Sreenivasa chary Thatikonda[1], Felipe nathan De Oliveira lopes[1], Aleks Mustonen[2], Rainer Grauer[2], Daniel Told[1], and Frank Jenko[1] — [1]Max planck institute for plasma physics, Garching, Germany — [2]Ruhr-Universität Bochum

We aim to study instabilities, turbulence and reconnection phenomena in weakly magnetized plasmas. Such conditions may be found in natural plasmas such as the solar wind, but also in laboratory applications, e.g. in the edge of fusion plasmas. Due to steep gradients in the edge of fusion plasmas and high frequencies in space plasmas, the ordering assumptions of gyrokinetic theory (like low frequency or moderate gradients) may be challenged, particularly for ions. To overcome these limitations, we derived equations for a hybrid model that includes fully kinetic physics for the ions, but gyrokinetic physics for the electrons. The hybrid model's electrostatic version has been numerically implemented into the existing simulation code, ssV. Semi-Lagrangian schemes (e.g., the PFC scheme [Filbet et al., JCP 2001])are employed in ssV.When implementing EM effects, we have to overcome some numerical problems such as the Ampere cancellation problem. To solve this problem, we need to have sufficient velocity space and evaluate the integrals with utmost care. Ongoing work on ssV includes it's applications to space and astrophysical plasmas: For example, magnetic reconnection at the ion scales.

P 12.21 Tue 16:30 ELP 6: Foyer

Plasma-neutrals fluid turbulence modeling in the tokamak edge — •Konrad Eder, Wladimir Zholobenko, Andreas Stegmeir, and Frank Jenko — MPG-IPP, Garching, Germany

Predictive studies of the plasma edge in prospective fusion reactors require self-consistent modeling of the turbulent transport involving an interplay of plasma, neutral gas, and impurity dynamics.

We present extensions to the edge turbulence code GRILLIX, which implements a drift-fluid plasma model and a diffusive neutral gas model. The latter has been upgraded to a 3-moment fluid, i.e. neutral gas density, momentum, and pressure. Furthermore, we show a scheme to implement neutrals recycling for the Flux-Coordinate-Independent (FCI) approach, on which GRILLIX is based and which enables it to handle complex diverted geometries.

The updated model is validated against ASDEX-Upgrade L-mode discharge #36190, demonstrating improved agreement in the divertor profiles of density and electron temperature. We note that: first, the recycling boundary conditions allow for a more realistic in-homogeneous neutrals distribution at the divertor. Second, the evolution of neutrals temperature allows it to decouple from the ion temperature, causing significant change in the poloidal morphology.

Simulations of a density ramp in AUG are carried out, which aim to reproduce detached divertor regimes observed in experiments. Finally, in fully detached conditions, we perform simulations with an X-point radiator to study its impact on turbulent transport, paving the way for predictive reactor simulations of ELM-free regimes.

P 12.22 Tue 16:30 ELP 6: Foyer

Electromagnetic turbulence simulations of the tokamak edge plasma in the quasi-continuous exhaust regime — •Kaiyu Zhang, Wladimir Zholobenko, Andreas Stegmeir, and Frank Jenko — Max Planck Institute for Plasma Physics, Garching, Germany

The global fluid turbulence code GRILLIX has undergone recent advancements to include electromagnetics. This extension has revealed that the electromagnetic flutter effectively reduces ExB transport by intervening in the dynamics of drift-wave turbulence on the tokamak edge [1]. As a result, it imparts stabilizing factors of 2 in L-mode and a remarkable 100 in H-mode.

With the improved capability to resolve electromagnetic turbulence, GRILLIX is now simulating the quasi-continuous exhaust (QCE) regime. QCE is acknowledged as a promising H-mode regime for reactors due to its suppressed type-I ELMs and broadened heat fall-off length [2]. Previous research suggested that these QCE advantages stem from enhanced transport near the separatrix. Our simulations establish self-consistent turbulence transport in QCE, and the turbulence mode structures will be diagnosed to unveil the underlying mechanisms for this enhanced transport.

[1] K. Zhang , et al. arXiv:2309.07763, 2023.
[2] M. Faitsch , et al. Nuclear Fusion, 2023, 63(7): 076013.

P 12.23 Tue 16:30 ELP 6: Foyer

Validation of theoretical upper bounds on local gyrokinetic instabilities — •Linda Podavini, Per Helander, Gabriel Plunk, and Alessandro Zocco — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald, Germany

Turbulence in magnetic confinement fusion devices is driven by the presence of microinstabilities. In the last decades these instabilities have been studied considering various assumptions about plasma parameters and magnetic geometry, thus hampering a desirable unified theory.

The theory of upper bounds on the growth rates of local gyrokinetic instabilities [1,2,3] aims at filling this gap by introducing results which are valid for all microinstabilities. Moreover, they are independent of magnetic geometry and many plasma parameters, such as the number of particle species, beta and collisions.

We compare the upper bounds to solutions of the linear gyrokinetic equation. The latter are obtained through flux-tube simulations performed with the gyrokinetic code stella. The validation focuses on fusion-relevant instabilities and it is carried out for different magnetic field geometries and plasma parameters, to highlight the universality of the theory. The validation also includes a comparison with analytical results obtained in simple magnetic field geometries.

[1] P. Helander, and G. G. Plunk, PRL (2021)
[2] P. Helander, and G. G. Plunk, JPP (2022)
[3] G. G. Plunk and P. Helander, JPP (2022)

P 12.24 Tue 16:30 ELP 6: Foyer

Adding global parallel magnetic fluctuations to the GENE code — •Facundo Sheffield[1], Tobias Goerler[1], Felix Wilms[1], Gabriele Merlo[2], and Frank Jenko[1] — [1]Max-Planck-Institut für Plasmaphysik — [2]The University of Texas at Austin, USA

One of the main challenges of controlled nuclear fusion is the turbulent nature of the plasma itself, which causes increased transport of energy and particles. While great progress has been made, there are still many areas of active research. Among these, the inclusion of parallel magnetic fluctuations ($B_{1||}$) in turbulence simulations has become more and more relevant due to their impact on high beta and reactor relevant scenarios, potentially affecting the constraint of the edge/pedestal profiles in KBM driven scenarios.

Therefore, a long wavelength ($k_\perp \rho_s \ll 1$) approximation for parallel magnetic fluctuations was implemented on the global version of the gyrokinetic delta-f code GENE in order to improve its predictive power and asses its importance for global physics.

The approximation has been successfully tested with convergence tests and comparisons with the local version of GENE. The latter were done by porting the approximation to local GENE, which possesses an arbitrary wavelength solver, and verifying how well it agrees with the full local model. The LW approximation performs much better than previously established treatments for $B_{1||}$ and surprisingly good agreement with the full model is found even at smaller wavelengths. These results are encouraging to all global GK codes implementing or employing a LW approximation for $B_{1||}$. Further studies are ongoing.

P 12.25 Tue 16:30 ELP 6: Foyer

Analysis of Nonlinear Dynamics of Shear Alfvén Waves Driven by Energetic Trapped Particles — •Farah Atour — IPP Garching

In controlled fusion devices, shear-Alfven waves can be driven unstable by resonant interactions with energetic alpha particles. This results in many issues regarding the confinement of the particles and therefore can prevent thermalization of the plasma core or increase the thermal load on the material wall. The source of these particles is either from the nuclear fusion reaction produced by the background plasma and/or external heating systems. Due to the importance of these issues, there exists an extensive literature on this topic. These studies mostly focus on the nonlinear dynamics of passing particles since they have more significant impacts. However, the nonlinear dynamics of shear-Alfven waves driven by energetic trapped and anomalous particles deserves also depth analysis and will be the focus of this study. The overall goal of this work is to investigate on a deeper level the fundamental physical processes regarding both the linear stability properties and the nonlinear saturation. For this reason, to keep the context of the dynamical study simplified, these phenomena are investigated by HMGC code, which has a simple circular geometry and is based on the hybrid reduced MHD gyrokinetic model.

P 12.26 Tue 16:30 ELP 6: Foyer

Research plan for investigating differences and similarities between hydrogen and deuterium operation in negative ions sources for fusion applications — •Joey Rubin, Nicolaas den Harder, Dirk Wuenderlich, Christian Wimmer, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik (IPP), Boltzmannstr. 2, 85748 Garching

Negative ion sources for fusion applications face demanding requirements. The ITER NBI system requires extracted negative ion current densities of 329 A/m^2 in hydrogen for 1000s and 286 A/m^2 in deuterium for 3600s, with co-extracted electron fraction below 1 for both isotopes. Testbeds BATMAN Upgrade and ELISE in operation at IPP Garching, have successfully demonstrated the feasibility of meeting these requirements in hydrogen. However, deuterium operation presents a challenge due to a higher and more unstable co-extracted electron current density. The increase in co-extracted electron current density limits the pulse length as the heat load on the extraction reaches the limit. The focus of this thesis is to delve into the physics underlying the different performance of negative ion sources for fusion in hydrogen and deuterium. The present poster outlines the research plan designed to reach this objective.

P 12.27 Tue 16:30 ELP 6: Foyer

Influence of the presence of hydrogen isotopes on damage evolution in tungsten — •Zeqing Shen, Thomas Schwarz-Selinger, Mikhail Zibrov, and Armin Manhard — Max-Planck-Institut für Plasmaphysik, Boltzmannstrasse 2, Garching D-85748, Germany

The influence of the presence of deuterium (D) on damage evolution at elevated temperatures was studied for self-ion irradiated tungsten (W). W samples were irradiated by 20 MeV W ions at room temperature to the peak damage dose of 0.23 dpa and loaded with a low-temperature D plasma at 370 K to decorate the created defects. To study the evolution of the defects with D being present, samples were heated during plasma loading to 4 different temperatures, ranging from 470 K to 770 K. The annealing time was calculated by the rate equation modelling code TESSIM-X. For comparison, annealing experiments at each temperature were carried out also in vacuum. After annealing, all samples were re-exposed to the same D plasma as before to decorate the surviving defects. The duration was calculated again by TESSIM-X. At various steps of the experiment, nuclear reaction analysis (NRA) was used to determine the deuterium depth profile. After the last re-exposure thermal desorption spectroscopy (TDS) was used to measure the total amount of deuterium and de-trapping energy of D. The final results will give a quantitative understanding of the influence of the presence of hydrogen isotopes on defect evolution at elevated temperature.

P 12.28 Tue 16:30 ELP 6: Foyer

Atomic cascade computations for astro and plasma physics — •Stephan Fritzsche — Helmholtz-Institut Jena, Germany — Friedrich-Schiller University Jena, Germany

Electronic structure calculations of atoms and ions have a long tradition in physics with many applications in astro and plasma physics. With the Jena Atomic Calculator (JAC), I here present a modern implementation of a (relativistic) electronic structure code for the computation of atomic amplitudes, properties and cascades. JAC [1,2] is based on Julia, a new programming language for scientific computing, and provides an easy-to-use but powerful platform to model excitation and decay processes of open-shell atoms and ions across the periodic table. This toolbox also provides useful features to predict plasma rate coefficients for different capture and ionization processes.

[1] S. Fritzsche. A fresh computational approach to atomic structures, processes and cascades. Comp.Phys.Commun., 240, 1 (2019), DOI:10.1016/j.cpc.2019.01.012.

[2] S. Fritzsche. JAC: User Guide, Compendium & Theoretical Background. https://github.com/OpenJAC/JAC.jl, unpublished (02.11.2023).

P 12.29 Tue 16:30 ELP 6: Foyer

Influence of Plasma Instability for the Energy-loss of Relativistic Pair Beams from TeV Blazars — •Suman Dey and Günter Sigl — II. Institut für Theoretische Physik, Universität Hamburg, 22761 Hamburg

The interaction of TeV photons from blazars with the extragalactic background produces a relativistic beam of e^-e^+ pairs streaming through the intergalactic medium, producing a cascade through upscattering low-energy photons. Plasma instability is considered one of the underlying energy-loss processes of the beams. This study aims to investigate the energy loss of beams due to plasma instability using a particle-in-cell (PIC) simulation. We extrapolated the instability growth trend observed in laboratory settings to the astrophysical scale, assuming no other important mechanisms. For relativistic jets, the beam undergoes a continuous influx of new particles by pair production, which persists in driving the instability. We estimated the saturated value of the energy-loss term and diffusion coefficient when equilibrium is achieved. Moreover, in extrapolating to astrophysical scales, we noted that the system started to develop secondary instability and emerged from a reactive to kinetic regime. Momentum broadening suppresses the secondary instability and saturates. We compared the energy-loss time scale (τ_{loss}) and diffusion time scale (τ_{diff}) with inverse Compton (IC) cooling time (τ_{IC}). We observed that the τ_{loss} is almost comparable to τ_{IC}, whereas τ_{diff} exceeds both. This opens a future scope to explore the effect of intergalactic magnetic field (IGMF) on instability using the modular structure of CRPropa code.

P 12.30 Tue 16:30 ELP 6: Foyer

Turbulence in Molecular Clouds — •Christian Heppe[1], Alexei Ivlev[2], and Frank Jenko[1] — [1]Max-Planck-Institut für Plasmaphysik — [2]Max-Planck-Institut für extraterrestrische Physik

In the Interstellar Medium a vast array of different plasma can be observed. Ranging from the almost fully ionized low density plasma in between stars to the cold, dense gas in Molecular clouds where ionization is solely governed by the presence of high energy cosmic rays. Where either magnetic or thermal pressure can dominate. In these environments the dynamics of the medium are governed by turbulence.

As the coupling between neutral and ionized gas can strongly vary in such inhomogeneous environments two fluid effects become necessary to account for. The coupling of the neutral and ionized gas is mediated by collisions and current theory suggests that one can identify three coupling regimes. At large scales, in the strongly coupled regime, the ionized and neutral gas move together as one fluid. Beyond this, in the weakly coupled regime, the dynamics of both species begin to decouple. Finally, in the decoupled regime at even smaller scales, both gases move independent of each other. Despite this, the current models lack physical insight and yield qualitative results that do not match relevant simulations.

By systematically probing different turbulent environments with two fluid MHD simulations we hope to find a phenomenological explanation as to how the turbulent cascade manages to bridge the decoupling regime and transport energy to smaller scales, possibly identifying an elementary turbulent interaction.

P 12.31 Tue 16:30 ELP 6: Foyer

Study of structure and electron acceleration processes at planetary and astrophysical shocks using Particle-In-Cell simulations. — •Valentine Devos, Artem Bohdan, and Frank Jenko — Max Planck Institut for Plasma Physics, Germany

The first aim of the project is to study the structure of shocks, at planetary and astrophysical scales, for intermediate Mach numbers using Particle-In-Cell simulations. More precisely, the transition between low Mach numbers instabilities (as shock whistler precursor, modified 2-stream instabilities, etc.) to high Mach numbers instabilities (Weibel instabilities, Buneman instabilities, etc.). The different processes of electron acceleration within these shocks will be also discussed. Those processes are notably the Diffusive Shock Acceleration, the Shock Surfing Acceleration or the Shock Drifting Acceleration

P 13: Magnetic Confinement IV/HEPP IV

Time: Wednesday 11:00–12:20 Location: ELP 6: HS 3

P 13.1 Wed 11:00 ELP 6: HS 3

Non-linear free boundary simulations of resonant magnetic perturbations in ASDEX Upgrade — •Verena Mitterauer[1], Matthias Hoelzl[1], Matthias Willensdorfer[1], and ASDEX Upgrade Team[2] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]See author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

The suppression of ELMs by resonant magnetic perturbations RMPs in an ASDEX Upgrade plasma is modeled using the free boundary MHD code JOREK-STARWALL. The simulations are performed with fully realistic plasma parameters and plasma flows, which allows qualitative and quantitative comparisons with experimental observations, reveals important mechanisms, and forms a basis for more accurate predictive studies than previously possible. Simulations of the ELM suppressed state show a local structure in the radial displacement of the plasma around resonant surfaces that can be linked to the presence of magnetic islands. Together with recent experimental findings, this provides strong indications for the presence of a magnetic island chain at the pedestal top during ELM suppression in an ASDEX Upgrade discharge, contributing to resolving a long-standing open question. Furthermore, the transition out of the ELM-suppressed phase into an ELM-unstable state is modeled through an increase of the pedestal density values. The simulations allow to disentangle the role for suppressing ELM instabilities of the edge pressure profile evolution on one hand and non-linear coupling between peeling-ballooning instabilities with the RMP-driven perturbations on the other hand.

P 13.2 Wed 11:25 ELP 6: HS 3

Alfvenicity to Damping: Computational Insights from IMAS FALCON Integration and beyond — •Virgil - Alin Popa, Philipp Lauber, and Thomas Hayward-Schneider — Max Planck Institute for Plasma Physics, Garching, Germany

Building upon the robust infrastructure given by the Energetic Particle Workflow, we have integrated a new actor into the IMAS (Integrated Modeling and Analysis Suite) compliant workflow. The name of the new computational tool is FALCON (Floquet ALfven CONtinuum code). The model focuses on the continuous spectrum of SAWs in the ideal magnetohydrodynamic (MHD) limit. A formula for mapping Alfvenicity (given by FALCON) and kinetic damping (given by LIGKA) was developed. For this, various ITER scenarios were used for obtaining and validating the mapping formula. Furthermore, the workflow has been able to achieve significant speed-up in calculating the global linear properties of modes by exploiting analytical features and equilibrium profile information. This is of great importance when integrating the workflow into a transport code, where computational time is important.

P 13.3 Wed 11:50 ELP 6: HS 3

The change of Jacobian of Poincaré map of magnetic island X/O-cycles under three-dimensional perturbation field — •Wenyin Wei[1,2,3] and Yunfeng Liang[1,2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, Jülich 52425, Germany — [2]Institute of Plasma Physics, Hefei Institutes of Physical Science, Chinese Academy of Sciences, Hefei 230031, People's Republic of China — [3]University of Science and Technology of China, Hefei 230026, People's Republic of China

Based on the first-order shift formula of X/O-cycles under perturbation, the change of Jacobian (denoted as DP^m) of Poincaré map of X/O-cycles (of m toroidal turns) under perturbation is further investigated and formulated. Notably, neither the perturbation field nor the field to be perturbed is required to be axisymmetric or divergence-free for the formulae to apply.

In divertor configurations, the connection lengths of magnetic field lines in the scrape-off layer (SOL) are significantly affected by the DP^m eigenvalues of the outmost X-cycle(s). The number of the outmost X-cycle(s) depends on the experiment setup. Tuning the eigenvalues of DP^m of the X-cycle(s) closer to unity can markedly increase the connection lengths in the SOL, as the neighboring field lines will be more parallel to the X-cycles(s). Additionally, the width of a magnetic island is largely determined by the included angle of the two eigenvectors of DP^m of the adjacent X-cycle(s).

P 13.4 Wed 12:05 ELP 6: HS 3

Pedestal destabilization by 3D magnetic perturbation fields in tokamaks — •Jonas Puchmayr[1], Mike Dunne[1], Erika Strumberger[1], Matthias Willensdorfer[1], Hartmut Zohm[1], Florian Hindenlang[1], and ASDEX Upgrade Team[2] — [1]Max

Planck Institute for Plasma Physics, Garching, Germany — [2]See U. Stroth et al 2022 Nucl. Fusion 62 042006

In H-mode tokamak plasmas, edge localized modes (ELMs) limit the achievable pressure gradient in the edge region and might cause severe damage in future fusion devices. Consequently, it is crucial to understand the onset of ELMs and methods to mitigate or suppress them. The onset of an ELM is typically well-described by the growth of magnetohydrodynamic instabilities at the plasma edge.

One method to mitigate or suppress ELMs is the application of magnetic perturbation (MP) fields. In this work, we use the linear extended MHD stability code CASTOR3D to show for the first time that symmetry-breaking by MP fields can significantly reduce the achievable stable pedestal pressure by up to 30%, resulting in mitigated ELMs. The destabilizing effect on the achievable stable pedestal pressure due to MP fields remains if ion diamagnetic drift effects, which strongly stabilize high-n ballooning modes, are included. The lowest pedestal top pressure resulting in the onset of MHD modes in 3D AUG plasmas has been found by interpolating between two equilibria featuring ELM mitigation and suppression, corresponding to the empirically observed pedestal pressure limit for complete ELM suppression.

P 14: Low Pressure Plasmas and their Application I

Time: Wednesday 11:00–12:30 Location: WW 1: HS

Invited Talk P 14.1 Wed 11:00 WW 1: HS

Insights into the Non-Thermal Character of Molecular Plasmas from Optical Frequency Comb Spectroscopy — •Ibrahim Sadiek, Norbert Lang, and Jean-Pierre H. van Helden — Leibniz Institute for Plasma Science and Technology (INP)

Our ability to model, optimize and control plasma-activated chemical processes depends strongly on the knowledge of the absolute concentrations and temperatures of reactive species in the plasma, and their reaction kinetics. This knowledge can be acquired through absorption spectroscopy using continuous wave (CW) lasers. However, the narrow spectral tuning range of these CW lasers limits the number of detectable molecules and cannot provide precise information about the non-thermal nature of plasma-generated species, particularly the distribution of energy among different molecular degrees of freedom. We overcome this hurdle by using state-of-the-art optical frequency combs as diagnostic light sources. We develop and apply frequency comb-based detection techniques, offering a unique combination of broad bandwidth and high spectral resolution. This enables the simultaneous detection of multiple species in the plasma.

In this paper, we will present insights into the non-thermal nature of low-pressure molecular plasmas containing nitrogen, hydrogen, and methane through frequency comb-based Fourier transform spectroscopy measurements. This technique enables us to provide quantum-state-resolved knowledge of plasma-generated molecular species, thereby paving the way for precise modelling of plasma chemical processes.

P 14.2 Wed 11:30 WW 1: HS

Ro-vibrationally resolved corona modelling for the Fulcher-α band of H_2 plasmas: a powerful tool for spectra analysis — •Richard C. Bergmayr[1], Dirk Wünderlich[1], Liam H. Scarlett[2], Mark C. Zammit[3], Igor Bray[2], Dmitry V. Fursa[2], and Ursel Fantz[1] — [1]IPP Garching, Germany — [2]Curtin University, Australia — [3]Los Alamos National Laboratory, USA

Collisional radiative (CR) modelling combined with emission spectroscopy enables the derivation of the plasma parameters (e.g. n_e and T_e) from the naturally emitted radiation of molecular hydrogen (H_2) plasmas. Under certain conditions discussed in this contribution the simplified approach of corona modelling is valid, wherein collisional excitation from the ground state is balanced with spontaneous emission in the form of rate equations depending on reaction probabilities (e.g. cross sections) as input. The flexible Yacora code can solve the underlying system of equations coupling the manifold of ro-vibrational levels in H_2. An electronically resolved CR model can determine for which plasma regimes the corona approximation must be extended by further process channels (e.g. cascades). This contribution discusses a corona model for the Fulcher-α band of H_2 applying fully ro-vibrationally resolved MCCC cross sections. The MCCC (molecular convergent close-coupling) method in the adiabatic-nuclei formulation is an ab initio approach for electron scattering problems able to provide accurate ro-vibrationally resolved cross sections. The model derived spectra are compared with various benchmark cases demonstrating the model's suitability as part of a non-invasive diagnostic.

P 14.3 Wed 11:45 WW 1: HS

Plasma sheath tailoring by a magnetic field for three-dimensional plasma etching — •Elia Jüngling[1], Sebastian Wilczek[2], Thomas Mussenbrock[2], Marc Böke[1], and Achim von Keudell[1] — [1]Chair Experimental Physics II, Ruhr University Bochum, Bochum, Germany — [2]Chair of Applied Electrodynamics and Plasma Technology, Ruhr University Bochum, Bochum, Germany

Three-dimensional (3D) etching of materials by plasmas is an ultimate challenge in microstructuring applications. A method is proposed to reach a controllable 3D structure by using masks in front of the surface in a plasma etch reactor in combination with local magnetic fields to steer the incident ions in the plasma sheath region towards the surface to reach 3D directionality during etching and deposition. This effect can be controlled by modifying the magnetic field and/or plasma properties to adjust the relationship between sheath thickness and mask feature size. Since the guiding length scale is the plasma sheath thickness, which for typical plasma densities is at least tens of microns or larger, controlled directional etching and deposition target the field of microstructuring, e.g. of solids for sensors, optics, or microfluidics. In this proof-of-concept study, it is shown that $\vec{E} \times \vec{B}$ drifts tailor the local sheath expansion, thereby controlling the plasma density distribution and the transport when the plasma penetrates the mask during an RF cycle. This modified local plasma creates a 3D etch profile. This is shown experimentally as well as using 2d3v Particle-In-Cell/Monte Carlo collisions simulation.

P 14.4 Wed 12:00 WW 1: HS

Simulation and Modeling of DC Glow Discharges — •Tim Bolles[1], Maximilian Klich[1], Katharina Nösges[1], Máté Vass[1,2], and Thomas Mussenbrock[1] — [1]Ruhr University Bochum, 44780 Bochum, Germany — [2]Wigner Research Centre for Physics, 1121 Budapest, Hungary

DC (Direct Current) discharges are well established systems with extensive applications, particularly in the high gas pressure regime. Their physics is more complex than initially assumed. The reason for this is that they are very sensitive to external conditions and internal fluctuations such as the plasma density or the electron temperature. The simulation of DC discharges, especially if kinetic effects need to be considered, can be rather complex, as it needs to accurately capture the variable and often unstable properties of the discharge. Kinetic models, which consider the movements and interactions of individual particles within the plasma, must be able to handle these instabilities and fluctuations, presenting a significant challenge. This contribution focuses on addressing the complexities in the kinetic simulation of DC discharges, outlining the challenges and proposing solutions. Specifically, it will illustrate the indispensable elements of a kinetic simulation model for DC discharges, as demonstrated through a case study. Valuable discussions with Zoltan Donko (Wigner Research Center for Physics) are gratefully acknowledged.

P 14.5 Wed 12:15 WW 1: HS

Deposition system for graphene nanostructures — •Simeon Marinov, Ivan Ivanov, and Zhivko Kissovski — Faculty of Physics, Sofia University, St. Kl. Ohridski, Sofia, Bulgaria

A microwave plasma system has been developed for the deposition of carbon nanostructures on metal and ceramic substrates at low and atmospheric pressure. The microwave surface wave discharge at frequency of 2.45 GHz is applied for PECVD (Plasma Enhanced Chemical Vapor Deposition), because it produces a dense plasma providing efficient decomposition of the carbon precursor (methane CH_4 or ethanol C_2H_5OH). At atmospheric pressure a plasma jet is used while at low pressure (0.4-8 Torr) a planar microwave plasma source as both discharges create a large number of reactive particles which results in lower substrate temperature for graphene deposition compared to

CVD method. Optimization of the gas mixture of H_2, Ar and the precursor, and the gas pressure in the chamber for the second setup results in a homogeneous graphene structures deposition on the substrates of Ni-foil, Ni-foam and ceramic substrates (SiC) at substrate temperatures in the range 600-750 °C. The plasma parameters such as gas temperature, electron temperature and density are obtained by measuring OH and CN-bands, H_β broadening and Ar-lines using optical emission spectroscopy. The morphology of the carbon structures is obtained using SEM analysis and the characteristics of the graphene layers are determined by Raman spectroscopy. A self-consistent model of the atmospheric plasma jet is developed in COMSOL Multiphysics and plasma parameters in argon gas are obtained.

P 15: HEPP V

Time: Wednesday 14:00–16:10 Location: ELP 6: HS 3

Invited Talk P 15.1 Wed 14:00 ELP 6: HS 3

Particle fueling, profiles and transport in neutral beam heated plasmas at Wendelstein 7-X — •Sebastian Bannmann, Oliver Ford, Peter Poloskei, Jakob Svensson, Samuel Lazerson, Hakan Smith, and Robert Wolf — Max-Planck-Institut für Plasmaphysik, Greifswald, DE

A spontaneous reduction in anomalous particle transport in the plasma core is seen experimentally in reproducible, purely neutral beam (NBI) heated plasma phases at Wendelstein 7-X (W7-X). A significant acceleration of the density peaking occurs after a certain onset time and is examined with a detailed particle transport analysis in several discharges. By invoking the particle continuity equation, the total experimental radial electron flux is deduced from the time evolution of the electron density profile and the radially resolved particle sources. To calculate the neutral beam particle deposition a full collisional-radiative (CR) neutral beam injection model based on Gaussian pencil (Gausscil) beams and a diffusive CR neutral halo model is implemented and verified. All important parameters defining the neutral beams are inferred from Balmer-alpha (Halpha) emission data and compared to available reference values. By employing Bayesian inference techniques provided by the Minerva framework, the full electron density profile from the plasma core to the edge is inferred solely from neutral hydrogen beam and halo Halpha emission data. Exploiting the evolving plasma conditions, anomalous diffusion and convection coefficients are successfully computed from the flux variation with density and density gradients.

P 15.2 Wed 14:30 ELP 6: HS 3

Effect of the newly installed cryo-vacuum pump on neutral gas pressures and particle exhaust — •Victoria Haak, Chandra Prakash Dhard, Thierry Kremeyer, Dirk Naujoks, Georg Schlisio, and W7-X Team — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Gas exhaust is a key requirement for density control in a fusion device and, apart from the pumping speed and the subdivertor geometry, strongly dependent on the neutral gas pressure in the subdivertor and in front of the pumps. In each of the ten island divertor modules in Wendelstein 7-X, a cryo-vacuum pump (CVP) has been installed for the last campaign (OP2.1) to improve the particle exhaust capabilities. During dedicated gas injection tests, the pumping speed of the CVPs has been determined for hydrogen ($70\,\mathrm{m^3/s}$), nitrogen ($21\,\mathrm{m^3/s}$), neon ($22\,\mathrm{m^3/s}$) and argon ($9\,\mathrm{m^3/s}$). No significant differences in the neutral gas pressures in the subdivertor have been observed in discharges with and without CVPs in operation. Overall, neutral gas pressures on the order of few times 10^{-4} mbar were measured in the subdivertor region, which still corresponds to the molecular flow regime in which the effect of the cryo-vacuum pump on particle exhaust is limited.

P 15.3 Wed 14:55 ELP 6: HS 3

Heat Load Optimization for the Island Divertor of the Wendelstein 7-X Stellarator — •Amit Kharwandikar[1], Dirk Naujoks[1], Felix Reimold[1], Ralf Schneider[2], and The W7X-Team[1] — [1]Max Planck Institute for Plasma Physics, Greifswald — [2]Universität Greifswald, Greifswald

The Wendelstein 7-X (W7-X) stellarator implements the island divertor concept and has demonstrated the viability of using magnetic islands as a exhaust solution for low-shear stellarators. During the experiments, the divertor design revealed challenges in two aspects in particular: unexpected hotspots that limited operation and a poor neutral particle exhaust, motivating an investigation of new geometries to advance the W7-X island divertor. Early stages of such an exploratory challenge calls for fast and simple tools to scan the large 3D design space. In the same spirit, this contribution proposes a framework to analyse the heat flux compatibility of new divertor geometries.

The problem is approached in 2 steps - first, obtaining a simple picture of heat transport in an island scrape-off layer (SOL) to build fast predictive models of target heat flux distribution, followed by shape exploration of target geometries. In terms of tools, we utilize the Monte-Carlo code for 3D SOLs, EMC3-Lite, and compliment it with a newly developed empirical approach - Simple model for loads in island divertor (SMoLID) - based on estimating the SOL width and perpendicular transport length scales for a given magnetic topology and plasma conditions. Eventually, these tools are applied to investigate the heat load compatibility of certain "closed" divertor geometries.

P 15.4 Wed 15:20 ELP 6: HS 3

Investigations of impurity concentration in seeded divertor plasmas of W7-X via line ratio spectroscopy — •Frederik Henke, Maciej Krychowiak, Felix Reimold, Ralf König, Dorothea Gradic, Erik Flom, and Victoria Winters — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

In future fusion power plants, managing power exhaust in the divertor poses a significant challenge, requiring seeding of extrinsic impurities. Retaining these impurities at the plasma edge is crucial to avoid fuel dilution and radiative energy losses in the core, limiting the reactor's operational space.

Ongoing research explores power exhaust scaling with spectroscopically measured impurity concentration and machine parameters in tokamak plasmas. This study focuses on measuring multiple spectral lines of the same impurity ion using passive divertor spectroscopy, employing their ratios to reconstruct local plasma parameters.

W7-X's recent operational campaign featured experiments with various seeded impurity species, revealing challenges in the analysis. Notable variations in measured line ratios among different magnetic configurations indicate distinct local plasma parameters. Due to different plasma conditions in the divertor, line-ratio analysis methods require re-validation. This study presents initial results of impurity concentrations, discussing factors influencing the diverse behavior of line ratio measurements.

P 15.5 Wed 15:45 ELP 6: HS 3

Investigation of radiation distribution and scaling for power exhaust in W7-X — •Gabriele Partesotti[1], Felix Reimold[1], Glen Wurden[2], Daihong Zhang[1], and Byron Peterson[3] — [1]Max-Planck Institute for Plasma Physics, Greifswald, Germany — [2]Los Alamos National Lab, Los Alamos (NM), USA — [3]National Institute for Fusion Science, Toki, Japan

Radiation emission is one of the main heat loss channels for magnetically confined fusion plasmas. In terms of performance, its effect can be either beneficial - e.g. mitigation of power load on the plasma-facing components - or detrimental - e.g. core cooling, radiation collapse. Still, the toroidal distribution of radiated power in a stellarator machine and its behavior in the island divertor are not fully understood yet. In light of this, the present work aims to study the three-dimensional characteristics of radiation in the stellarator geometry of Wendelstein 7-X (W7-X), and its sensitivity to magnetic configuration and plasma parameters. The analysis begins with an introduction of the diagnostic systems, including both resistive and infrared imaging bolometers. It follows a description of the principal features of the W7-X edge radiation resulting from EMC3-EIRENE simulations. Based on these findings, a new concept of Compact Bolometer Camera (CBC) is designed and tested to improve diagnostic coverage and assess poloidal and toroidal radiation asymmetries. Finally, the toroidal variation of the radiated power distribution is investigated by comparing local measurements with projected tomographic reconstructions.

P 16: Atmospheric Pressure Plasmas and their Applications III

Time: Wednesday 14:00–16:00 Location: WW 1: HS

Invited Talk P 16.1 Wed 14:00 WW 1: HS

CO_2 dissociation by microwave plasmas: experimental studies on interfaces in view of industrial applications — •Rodrigo Antunes[1], Christian K. Kiefer[1], Ante Hecimovic[1], Katharina Wiegers[3], Arne Meindl[1], Andreas Schulz[3], and Ursel Fantz[1,2] — [1]Max Planck Institute for Plasma Physics, 85748 Garching b. München, Germany — [2]University of Augsburg, 86159 Augsburg, Germany — [3]University of Stuttgart, Stuttgart 70569, Germany

Microwave plasma (MW) torches are known to be an efficient technology for the conversion of CO_2 to CO up to atmospheric pressure. However, in order to evaluate its industrial applicability, the interfaces of the process in which the plasma torch will be integrated should be considered. For example, the CO_2 upstream might contain impurities such as that from carbon capture facilities, while the plasma-produced downstream mixture must have very low amounts of O_2 if to be used as feed gas in a Fischer-Tropsch reactor for fuel synthesis.

This talk provides an overview of the state-of-the-art for the dissociation of CO_2 by means of MW plasma torches. The influence of various relevant parameters on the conversion and energy efficiency is discussed. From the insights gained by the wall-plug efficiency, optimisation routes can be outlined. Using multiple membranes accommodated in the plasma effluent, the removal of O_2 from the outlet stream is demonstrated. Long-term performance stability and compatibility with intermittent power sources showcases that the plasma technology is a relevant addition to the portfolio of gas conversion techniques.

P 16.2 Wed 14:30 WW 1: HS

Development of a hybrid reactor for plasma-enhanced electrocatalysis for NH3 production — •Martin Leander Marxen[1], Luka Hansen[1], Gustav Sievers[2], Volker Brüser[2], and Holger Kersten[1] — [1]Plasmatechnology Group, IEAP, Kiel University, Kiel, Germany — [2]Plasma Process Technology, INP Greifswald, Greifswald, Germany

Plasma-catalytic approaches are promising for the conversion of mixtures of nitrogen (N_2) and hydrogen (H_2) into ammonia (NH_3) [1,2]. Activation of the reaction sluggish N_2 molecules is achieved by collisions with the highly energetic electrons present in the discharge.

In proton-exchange-membrane-electrolysis (PEM-electrolysis), water (H_2O) is split up into oxygen (1/2 O_2), protons (2 H^+) and electrons (2 e^-) at the anode. The protons permeate the membrane and are reduced at the cathode [3].

A hybrid reactor was developed, in which a surface dielectric barrier discharge (SDBD) is located right underneath the cathode of a PEM-cell. By operating the SDBD with N_2, excited, ionized and dissociated N_2 species will be present at the cathode of the PEM-cell, where they can react with the produced H / H^+ and, thus, be reduced to NH_3. The development and characterization of the reactor will be presented.

[1] K. H. R. Rouwenhorst, Green chem 22 (2020), 19

[2] A. Bogaerts et al., J Phys D: Appl Phys 53 (2020), 44

[3] S. S. Kumar und V. Himabindu, Mater Sci for Energy Technol 2 (2019), 3

P 16.3 Wed 14:45 WW 1: HS

CFD and Heat Transfer Modeling of a Microwave Atmospheric Plasma Torch for CO_2 Conversion — •Stefan Merli, Katharina Wiegers, Marc Bresser, Andreas Schulz, Matthias Walker, and Günter Tovar — IGVP, University of Stuttgart, Stuttgart, Germany

Microwave plasma torches at atmospheric pressure offer an interesting way to split CO_2 and convert it to O_2 and CO, the latter of which is an important base material for chemical synthesis. The investigated microwave plasma torch creates a CO_2 plasma inside a quartz tube via two resonators. To protect the quartz tube from the hot plasma of around 6000 K, tangential gas inlets generate a rotational cold gas flow around the tube surface. The hot gas from the plasma and the cold gas are then mixed in a nozzle to increase the amount of converted gas. The nozzle and the subsequent expansion zone also cause the gas to cool quickly, which quenches back reactions from CO and O_2 to CO_2. Since the gas flow conditions and the temperature distribution are of great importance for a high conversion efficiency, CFD and heat transfer simulations were carried out in Comsol Multiphysics. The aim is to improve the conversion efficiency by optimizing geometry of the torch and the nozzle with regard to hot/cold gas mixing and effective quenching. A comparison of simulations and experiment reveals different flow regimes of the effluent for different gas flows which are attributed to increasing turbulences in the expasion zone. Since the turbulences increase cooling and the contact with the wall, they are beneficial for quenching and therefore for a high conversion efficiency.

P 16.4 Wed 15:00 WW 1: HS

Ammonia synthesis in an atmospheric catalytic RF plasma — •Steijn Vervloedt and Achim von Keudell — Experimental Physics II, Ruhr University Bochum, Bochum, Germany

The synthesis of ammonia is a vital part of the production of nitrogen-based artificial fertilisers. Also, in the future, it might prove a worthy candidate for energy storage, by acting as a hydrogen carrier. In this contribution, the recent results of ammonia synthesis in an atmospheric RF-plasma are presented, as well as the impact of introducing various catalysts. The plasma physics and chemistry are simplified by using helium as a buffer gas. The nitrogen and hydrogen are admixed up to $\sim$1%, to minimise their impact on the plasma dynamics. The products of the plasma are measured with ex-situ infrared Fourier transform (FTIR) absorption spectroscopy. The plasma dynamics are probed by observing trends in the emission of the second positive and first negative systems of nitrogen. Furthermore, a kinetic model is able to explain the experimentally observed trends. The results indicate that the synthesis is very sensitive to the plasma properties, e.g. the electron energy distribution and differences of less than 0.1 eV are sufficient to explain the results. This likely originates from the sensitivity of the NH_3 production - which happens mostly at the surface - to the atomic nitrogen flux towards the surface where the rate-limiting step is the electron-induced dissociation of nitrogen molecules.

P 16.5 Wed 15:15 WW 1: HS

Enhancing CO_2 Conversion and Oxygen Separation Performance by Optimizing the Gas Flow of an Atmospheric Plasma Torch — •Katharina Wiegers, Stefan Merli, Marc Bresser, Andreas Schulz, Matthias Walker, and Günter Tovar — IGVP, University of Stuttgart, Stuttgart, Germany

The chemical industry needs to switch from processes that use fossil raw materials to renewable sources. Carbon dioxide (CO_2) is the base product for closing the carbon cycle. One possibility to convert CO_2 is through a plasma process at atmospheric pressure that splits CO_2 into carbon monoxide (CO) and oxygen (O_2). Since out of the two products, only CO is needed for industrial purposes, a gas separation step is required. By using oxygen-conducting ceramic hollow fiber membranes, oxygen can be removed from the product gas in situ. A promising candidate for the membrane material is $La_{0.6}Ca_{0.4}C_{0.5}Fe_{0.5}O_3$, which results in fibers with a high thermal stability of up to 1200°C inside CO_2 plasma. Moreover, the amount of produced CO can be further increased by improving the quenching of unwanted back reactions. This can be achieved by optimizing the gas management by introducing a restriction in the flow regime. Therefore, a nozzle has been designed with the aim to improve the quenching effect and, at the same time, increase the volume of the plasma interacting with the membranes and thus the amount of O_2 removed. The O_2 permeation in the fiber could thus be increased from 2.2 to 4.6 mL $\cdot$ min^{-1}.

P 16.6 Wed 15:30 WW 1: HS

Experimental observations on microsecond and nanosecond pulses applied to a surface dielectric barrier discharge — •Gerrit Hübner, Nils Schoeneweihs, Dominik Filla, Sebastian Wilczek, Thomas Mussenbrock, and Ihor Korolov — Ruhr-Universität Bochum

The conversion of volatile organic compounds (VOCs) has long been an area of interest in the plasma community. Surface dielectric barrier discharges (SDBD) have been used for such conversions, however the details behind the formation and behaviour of plasma streamers, typically observed in such discharges, are yet to be fully understood. This work focuses on investigation of a SDBD driven by microsecond and nanosecond pulses operated in mixtures of Helium and Nitrogen (or Oxygen). We use phase resolved optical emission spectroscopy (PROES) to study the spatio-temporal surface streamer dynamics on a nanosecond timescale. The quenching rates by He and N2 of the

Helium-I 706 nm emission line are also determined from the measured effective lifetime. We have calculated and compared the streamer propagation speed for different discharge conditions. The experimental findings are compared with fluid (nonPDPSIM) simulations and a very good qualitative agreement is found providing a deep understanding of the streamer behaviour on the ns time scale. **This work is supported by the DFG via SFB1316 (A5)

P 16.7 Wed 15:45 WW 1: HS

Influence of EHD Force on Gas Dynamics in Atmospheric Pressure Plasma Discharges: A Computational Analysis — •Sebastian Wilczek, Máté Vass, Alexander Böddecker, Ihor Korolov, and Thomas Mussenbrock — Chair of Applied Electrodynamics and Plasma Technology, Faculty of Electrical Engineering and Information Technology, Ruhr University Bochum

Recent advancements in plasma technology have led to the development of various atmospheric pressure plasma discharges for gas conversion. Most of these discharges, such as dielectric barrier discharges, ignite streamers that significantly impact the gas dynamics. The electrohydrodynamic (EHD) force plays a crucial role in this context, exerting a significant momentum transfer on the process gas and altering the overall gas dynamics. This work presents an analysis of results obtained from 2D plasma simulations, which are subsequently integrated into pure fluid simulations via OpenFOAM. The study highlights the formation of vortices in the gas dynamics, demonstrating significant consistency with experimental measurements, including particle image velocimetry (PIV) and Schlieren techniques. The findings offer valuable insights into the complex interactions between EHD forces and gas dynamics in plasma-based gas conversion processes, contributing to the broader understanding and optimization of these applications.

**This work is supported by the DFG via SFB1316

P 17: Magnetic Confinement V/HEPP VI

Time: Wednesday 16:30–18:35 Location: ELP 6: HS 3

Invited Talk P 17.1 Wed 16:30 ELP 6: HS 3

Finite Element Method to Describe Magnetic Measurements of Tearing Modes in ASDEX Upgrade — •Magdalena Bauer, Hartmut Zohm, Marc Maraschek, Anja Gude, Wolfgang Suttrop, Felix Klossek, Bernhard Sieglin, and Louis Giannone — MPI for Plasma Physics, Garching

In large tokamaks a disruption, i.e. a sudden loss of plasma current terminating the discharge, has to be avoided or at least mitigated. Tearing modes (TMs), resistive plasma instabilities, are common precursors to disruptions, particularly TMs with toroidal mode number n=1. Electromagnetic interaction with the vacuum vessel can slow down rotating TMs, which can eventually lock to the wall. Here, toroidal coupling, i.e. the coupling of modes with the same n but different poloidal mode numbers, m, plays an important role. Magnetic perturbations associated with TMs are detected by coils outside the plasma with different orientations and distances to conducting structures. To analyse TMs at all times, the frequency dependence of these measurements has to be described. For this purpose, a three-dimensional model using the finite element method is employed. A TM is introduced as a radially-localized helical current, while the plasma is modelled as vacuum. The vessel and additional conducting structures are integrated in a simplified form. The perturbed magnetic field measured by the coils is calculated taking into account induced currents in the conducting structures. In order to determine the mode composition in all stages of the locking process, agreement between model and measurement is required. The steps performed to achieve this are presented.

P 17.2 Wed 17:00 ELP 6: HS 3

Effect of magnetic islands on fast ion confinement in toroidal devices — •David Kulla[1,2], Samuel Lazerson[2], Athina Kappatou[1], Robert Wolf[2], and Hartmut Zohm[1] — [1]MPI für Plasmaphysik, Garching — [2]MPI für Plasmaphysik, Greifswald

We present applied modeling work with the newly validated BEAMS3D code for simulating neutral beam deposition and fast ion slowing down in tokamaks and stellarators. Fast alpha particles generated by fusion reactions have to heat the thermal plasma collisionally to reach self-sustaining conditions in a reactor and therefore be well confined in the magnetic field. Tokamaks are largely axisymmetric, but suffer from dynamic magnetic perturbations which can break this property and lead to increased fast ion transport and losses. Stellarators are intrinsically three-dimensional but are generally less prone to transient perturbations. In present experiments, neutral beam injection can be used to generate and study fast ions. Magnetic islands arise from helical perturbations of the background magnetic field, either internally from the plasma or externally from magnetic coils.

BEAMS3D has recently been verified against NUBEAM as well as validated against experimental data at the ASDEX Upgrade tokamak using fast-ion D-alpha light (FIDA). We present simulations studying the effect of internal magnetic islands in ASDEX-Upgrade (tokamak) and Wendelstein 7-X (stellarator), showing similarities and differences. The simulations are compared to experimental measurements where applicable.

P 17.3 Wed 17:15 ELP 6: HS 3

Neural Networks as ideal magnetohydrodynamic equilibrium solvers — •Timo Thun[1], Andrea Merlo[2], and Daniel Böckenhoff[1] — [1]Max-Planck- Institute for Plasma Physics, Wendelsteinstraße 1, 17491 Greifswald, Germany — [2]Proxima Fusion, Am Kartoffelgarten 14, 81671 Munich, Germany

Quick and accurate solvers for the ideal magnetohydrodynamic (MHD) equilibrium in non axisymmetric magnetic fields can accelerate stellarator optimisation, facilitate high-fidelity real-time control and enable other data-driven algorithms like symbolic regression. Unfortunately, current MHD equilibrium solvers either require high computational wall-time or suffer from a lack of accuracy. Neural Network (NN) based solvers enable very fast inference by transferring the bulk of computational load to model training and the creation of datasets, possibly overcoming this dilemma.

Recent work presented a fast NN based ideal MHD surrogate model in the magnetic configuration space defined by the stellarator research device Wendelstein 7-X. Training the model required a dataset calculated by conventional solvers, but results improved with the addition of the physics-based ideal MHD equilibrium force-residual as an additional training target. Training without a dataset removes implicit biases of its solution strategy and avoids computational costs associated with its creation.

We present a first step towards this physics-based NN training paradigm by training a NN model only on the force residual of a single non-axisymmetric ideal MHD equilibrium.

P 17.4 Wed 17:30 ELP 6: HS 3

Electron cyclotron resonance during plasma formation in nonuniform magnetic fields — •Albert Johansson and Pavel Aleynikov — Wendelsteinstraße 1, 17491 Greifswald

Electron cyclotron resonance is used to start up various fusion experiment devices. In Wendelstein 7-X (W7-X), the second harmonic extraordinary mode (X2) is used for breakdown. Third harmonic extraordinary mode (X3) breakdown is of particular interest, as some future experiments intend to investigate the effects of a lower magnetic field strength. Presently, no experiment at W7-X has successfully used X3 for breakdown. Because the resonance depends on the gyrofrequency, proportional to magnetic field strength over Lorentz factor B/γ, an energy increase is associated with an increase in γ and the resonance condition breaks, causing a finite resonance width. It has been shown that for a uniform magnetic field this resonance width is not enough to ensure a breakdown process [1].

However, the magnetic field of a stellarator is not homogeneous. This opens the possibility of field gradients along the electron trajectory. When the magnetic field strength is increasing in step with the electron energy, the “width” of the resonance is extended considerably. In addition, when several beams are used, a “resonance overlap” can be constructed such that electrons gain almost hundred times the ionization energy of 13.6 eV. We discuss the effect of magnetic field inhomogeneity on energy gain and show how the composition of multiple beams can be optimised.

[1] D Farina. *Nuclear Fusion* 2018, 58(6):066012

P 17.5 Wed 17:55 ELP 6: HS 3

Development of an ECRH plasma start-up scenario for X3 heating at $1.8\,T$ at Wendelstein 7-X — •Niklas Simon Polei, Torsten Stange, Frank Noke, Frank Hollmann, Heinrich Peter Laqua, and W7-X Team — Max-Planck-Institut für Plasmaphysik, 17491 Greifswald

One of the main goals of the Wendelstein 7-X stellarator is to show good confinement of fast particles in high beta scenarios. Beta is the ratio of kinetic pressure and magnetic pressure $\beta = \frac{2\bar{n}\bar{T}}{B^2/2\mu_0}$. The available power of the electron cyclotron resonance heating (ECRH) system is not sufficient to reach the necessary beta of 4-5% at $2.5\,T$, but higher beta values are expected at lower magnetic field. To still use the existing gyrotrons at $140\,GHz$, X3 heating has to be used at a field of $1.8\,T$, but a plasma start-up is not possible because $T_e > 0.5keV$ is needed for sufficient absorption. Therefore, the combination of ion cyclotron resonance heating and neutral beam injection has been considered as the start-up scenario so far. The usual ECRH X2 start-up is also possible, if one gyrotron is operated near its other operating point at $104\,GHz$.

However, operation at $101\,GHz$ is necessary and was succesfully demonstrated for $100\,ms$ with a power of $300\,kW$. Additionally, a multi-pass scenario with six passes through the plasma axis was developed to maximise the power density during the first $10-20\,ms$ of plasma initiation. For this purpose, two new tiles were designed and the beam positions of the different passes were verified in the plasma vessel in preperation for the next operation phase 2.2.

P 17.6 Wed 18:10 ELP 6: HS 3

The Disruptive H-Mode Density Limit and MARFE Behaviour — •Felix Klossek, Anja Gude, Marc Maraschek, Bernhard Sieglin, Matthias Bernert, Hartmut Zohm, and the ASDEX Upgrade Team — Max-Planck Insitute for Plasma Physics, Boltzmannstr. 2, 85748 Garching

The high confinement mode (H-mode) is an operational regime in tokamaks with suppressed turbulence near the edge, so that particles and energy are confined better. High densities, which are desirable in terms of fusion power, are prone to a density limit: a degradation of confinement and subsequent disruption.

When approaching a density limit disruption, a Multifaceted Asymmetric Radiation From the Edge (MARFE) forms as toroidal ring. It is strongly radiating and is therefore altering the power balance in the plasma and reducing the temperature in its vicinity. During the MARFE evolution, this effect becomes more pronounced. The MARFE starts near the X point, where it is also called X point radiator (XPR). It will subsequently move up on the high field side near the separatrix and stay some time at the top of the plasma, before approaching the low field side, entering the core and triggering MHD instabilities which finally lead to the disruption.

The MARFE position can be reconstructed using measurements from bolometer pinhole cameras. A robust and fast approach based on angular probability distributions for each camera is presented.

P 18: Atmospheric Pressure Plasmas and their Applications IV

Time: Wednesday 16:30–18:30 Location: WW 1: HS

Invited Talk P 18.1 Wed 16:30 WW 1: HS

Diffusion of reactive species in aqueous solutions treated by a humid atmospheric pressure plasma jet — •Steffen Schüttler, Emanuel Jess, and Judith Golda — Plasma Interface Physics, Ruhr-University Bochum, Universitätsstraße 150, 44801 Bochum, Germany

Plasma-treated liquids are used in various fields such as plasma medicine or plasma-assisted biocatalysis. Atmospheric pressure plasma jets are suitable for production of reactive species such as H2O2 and introducing them into liquids under very good control [1]. The use of reactive species in the liquid requires their solubility and transport through the liquid. In this work, the delivery of reactive species from a humid atmospheric pressure plasma jet into a liquid and the diffusion of OH and H2O2 in the plasma-treated liquid were investigated. The capillary plasma jet used is comparable to the COST reference jet and was operated in humid He. UV absorption was used to measure H2O2 in the liquid, the distribution of OH was visualised by the chemiluminescence of luminol and particle imaging velocimetry (PIV) was used to study convective transport. At low gas flow rates, diffusion of H2O2 through the liquid was measurable, whereas at high gas flow rates, convective transport dominates. In all treatments studied, OH was found to be present mainly at the liquid surface, even at high gas flow rates.

This work is supported by the DFG within CRC1316 (Subproject B11, project number 327886311).

[1] Schüttler et al., Plasma. Process Polym. 2023, e2300079

P 18.2 Wed 17:00 WW 1: HS

Hyperspektrale Untersuchungen von Reaktionen an Plasma-Flüssigkeit-Grenzflächen — •Daniel Tasche[1,2], Kai Bröking[1,2], Christoph Gerhard[1,3] und Wolfgang Viöl[1,2,4] — [1]HAWK Hochschule für angewandte Wissenschaft und Kunst, Fakultät Ingenieurwissenschaften und Gesundheit, Göttingen, Deutschland — [2]Technische Universität Clausthal, Fakultät für Natur- und Materialwissenschaften, Clausthal-Zellerfeld, Deutschland — [3]Politecnico di Milano, School of Industrial and Information Engineering, Mailand, Italien — [4]Fraunhofer-Institut für Schicht- und Oberflächentechnik IST - Anwendungszentrum für Plasma und Photonik, Göttingen, Deutschland

Mittels hyperspektraler Bildgebung können physikalische und chemische Vorgänge spektral, zeitlich und räumlich aufgelöst werden. Hierbei wird das Spektrum einer Szene mittels eines abbildenden Spektrographen aufgezeichnet. Die auf den Spektrographenspalt abgebildeten räumlichen Details bleiben über das gesamte optische System erhalten. Bei der plasmainduzierten Bildung von Silbernanopartikeln werden im violetten Spektralbereich lokale Informationen über Partikeleigenschaften und Bildungsraten zugänglich [1]. Durch Nutzung weiterer Wellenlängenbereiche erhält man Informationen über das Plasma und den optischen Einfluss des Mediums, in dem die Reaktion stattfindet. Damit wird die Möglichkeit gegeben, die Prozesse an der Grenzfläche genauer zu verstehen.

[1] Tasche et al., Nanomaterials 2020, 10, 555.

P 18.3 Wed 17:15 WW 1: HS

Impact of admixtures of H2O on the properties of a He jet plasma — •Tao Zhu[1], Margarita Baeva[1], Florian Sigeneger[1], Peter Bruggeman[2], and Shubham Dongawar[2] — [1]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany — [2]Department of Mechanical Engineering, University of Minnesota

Low temperature He plasma containing admixtures of H2O is currently investigated by modelling and experiments related to plasma catalysis in confined spaces in automotive exhaust. The RF plasma jet is operated in a capillary at atmospheric pressure at a power of a few watts. A global model describes the plasma chemistry and the gas heating. The model is extended to a plug flow model, which converts the temporal evolution of a volume element flowing with the gas into a spatial distribution. A power density profile is defined in the active region between the RF electrodes. This model provides the species densities, the electron mean energy and gas temperature. Experiments based on laser induced fluorescence deliver the density of OH radicals and the gas temperature. A fair agreement was found between modelling and experiments for two power values. The model delivered values of about 5e18 m-3 for the electron density and about 2.5 eV for the electron mean energy which are hardly influenced by the H2O admixture. The analysis of the dominant gain and loss processes of OH revealed pronounced changes of contributions from electron and heavy particle reactions depending on the power.

This work was supported by the DFG-NSF project 509169873.

P 18.4 Wed 17:30 WW 1: HS

Effect of PAW on Rice Seedling Growth and the Expression of Related Genes — Junwei Guo, Dan Zhang, Cheng Yang, and •Huang Feng — College of Science, China Agricultural University, Beijing 100083, China

In plasma agriculture, plasma activated water (PAW) has been shown to improve seed germination, plant growth and resistance to abiotic and biotic stress [1-2]. Due to the complex regulatory mechanism of PAW promoting plant growth, the molecular level hasn't been fully clarified. In this study, RNA-seq was used to analyze the expression levels of related genes after using PAW in rice seedling growth and real-time quantitative PCR was used to verify the expression levels. The key synthetic genes involved in the stress response of rice seedlings to PAW were identified. References [1] Judée, F., Simon, S., Bailly, C., & Dufour, T. (2018). Plasma-activation of tap water using DBD for agronomy applications: Identification and quantification of long lifetime chemical species and production/consumption mechanisms. Water Research, 133, 47-59. [2] Lukacova, Z., Svubova, R., Selvekova, P., & Hensel, K. (2021). The effect of plasma activated water on maize (Zea mays L.) under arsenic stress. Plants, 10(9), 1899.https://doi.org/10.3390/plants10091899

P 18.5 Wed 17:45 WW 1: HS

The ring-shaped spatial distribution of argon excimer, Ar_2^*, in the effluent of the kINPen-Sci — •Andy Nave, Jente Wubs, Philipp Mattern, and Jean-Pierre van Helden — Leibniz institute for Plasma Science and Technology (INP), Felix-Hausdorff-Str. 2, 17489 Greifswald, Germany

The argon excimer (Ar_2^*) species is considered to play an important role in the chemistry of cold atmospheric plasma jets (CAPJs), notably in the formation of reactive oxygen and nitrogen species (RONS). In the present work, we demonstrate that cavity ring-down spectroscopy (CRDS) can be used to detect and quantitatively measure Ar_2^* in the effluent of a cold atmospheric plasma jet, the so-called kINPen-Sci. The spectroscopic features of the $5p\pi^3\Pi_g \leftarrow a^3\Sigma_u^+$ $\Delta\nu = 0$ and $7p\sigma^3\Sigma_g^+ \leftarrow a^3\Sigma_u^+$ (ν' - ν'') systems were clearly identified allowing unambiguous assignment to the Ar_2^* species.

Moreover, spatially resolved measurements allowed to distinguish two distinct Ar_2^* populations in the effluent of the kINPen-Sci: a Gaussian and a toroidally shaped distribution. The production mechanisms of these populations seem to differ. On the one hand, a strong correlation was found between the Gaussian Ar_2^* population and the spatial distribution of the filaments produced in the effluent of the kINPen-Sci. On the other hand, the mechanism of formation of the toroid Ar_2^* population remains unclear. However, further measurements were performed while varying the experimental conditions under which the kINPen-Sci was operated. It was found that gas flow velocity must play a major role in the formation of the toroid Ar_2^* population.

P 18.6 Wed 18:00 WW 1: HS

Durability of metal-organic-frameworks (MOFs) in non-equilibrium atmospheric pressure plasmas — •Alexander Quack[1], Hauke Rohr[2], Kerstin Sgonina[1], Norbert Stock[2,3], and Jan Benedikt[1,3] — [1]Institute of Experimental and Applied Physics, Kiel University — [2]Institute of Inorganic Chemistry, Kiel University — [3]KINSIS, Kiel University

Metal-organic-frameworks (MOFs) have a high porosity and large surface area, which gives them potential catalytic properties. Nevertheless, MOFs mostly can not withstand high temperatures and pressures, which are needed in classical catalytic reactions. Non-equilibrium atmospheric pressure plasmas provide reactive and internally excited species and allow for plasma assisted catalysis at lower temperatures. For these processes MOFs can be used as a catalyst if they withstand the plasma conditions.

We have developed a DBD reactor (21 kHz, 16 kV_{pp}) to determine the stability and suitability of different MOFs for plasma assisted catalysis. Reactive plasmas using gas mixtures based on N_2, H_2 and CO_2 gases and in-plasma treatment under externally controlled temperature up to 200 °C have been applied to several MOFs including ZIF-8, ZIF-67 and MAF-6. The plasma exhaust is analyzed for chemical products like NH_3 or CH_4 using a quadrupole mass spectrometer. Additionally, the structural and chemical stability of the MOFs is examined with methods like XRD and FTIR. The results of both measurements are combined to judge the stability and suitability of the different MOFs and their chemical components for in-plasma catalysis applications.

P 18.7 Wed 18:15 WW 1: HS

Elucidating heat transfer occurring during the interaction of a helium jet with ambient air — •Bruno Honnorat[1], Fellype do Nascimento[2], Konstantin Georgiev Kostov[2], and Torsten Gerling[1,3] — [1]ZIK plasmatis, Leibniz Institute for Plasma Science and Technology (INP), 17489 Greifswald, Germany — [2]Faculty of Engineering in Guaratinguetá, São Paulo State University-UNESP, Guaratinguetá 12516-410, Brazil — [3]Diabetes Competence Centre Karlsburg (KDK), Leibniz Institute for Plasma Science and Technology (INP), 17495 Karlsburg, Germany

One of the simplest experimental setup imaginable, which consist of injecting helium at ambient temperature (Tamb) into air at Tamb, with a flow rate of a few SLM, leads to an extraordinary phenomenon. Without plasma discharge, the gas temperature rises by several degrees Kelvin. The underlying physics of this observation remained unclear. The Dufour effect is a thermodynamic phenomenon where a concentration gradient causes heat transfer. This study quantifies the contribution of the Dufour effect on helium jet temperatures. Order-of-magnitude calculations confirm the relevance of the Dufour effect. 2D-axisymmetrical laminar CFD simulations were done with OpenFOAM for different gas flows and gas composition. A fiber optic sensor was moved in the outstream of the jet to realize a 3D map of the temperature. Beside helium, argon and nitrogen jet temperatures were measured. The results show temperature increase in the center of up to 9.4 K and a radial cooling down by 8.4 K. The confrontation of simulations and experiments shows a good agreement.

P 19: Members' Assembly

Time: Wednesday 18:45–19:45 Location: ELP 6: HS 3

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

P 20: Magnetic Confinement VI

Time: Thursday 11:00–12:45 Location: ELP 6: HS 3

Invited Talk P 20.1 Thu 11:00 ELP 6: HS 3

Modelling of tungsten erosion and deposition in fusion devices — •Andreas Kirschner, Sebastijan Brezinsek, and Juri Romazanov — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany

In magnetically confined fusion devices plasma-wall interaction and resulting erosion and deposition at the wall components is a major concern due to lifetime limitations of the wall components, long-term tritium retention via co-deposition and plasma contamination by eroded impurities. Tungsten is currently the favoured wall material for future fusion devices due to comparably low sputtering and high melting point. However, as high-Z material, tungsten can lead to unacceptably high radiation in the core plasma resulting in plasma collapse. Therefore, detailed understanding of tungsten erosion, migration and redeposition is needed to minimise the net erosion of tungsten. The present contribution provides an overview of the main processes involved in tungsten erosion and migration. The role of the eroding species will be discussed in view of fuel ions (including isotope effects) and CX neutrals compared to plasma impurities and tungsten self-sputtering. Also, the contribution of intra- and inter-ELM phases to the tungsten erosion will be analysed. The importance and extent of tungsten prompt redeposition, which reduces the net erosion, will be examined. Besides more generic studies, ERO modelling in combination with experimental findings in particular from the divertor of JET will be shown.

Invited Talk P 20.2 Thu 11:30 ELP 6: HS 3

Drift flows in the island divertor of W7-X — •Carsten Killer[1], Sean Ballinger[2], Seung-Gyou Baek[2], Dario Cipciar[1], Olaf Grulke[1,3], Adrian von Stechow[1], and Jim Terry[2] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [2]MIT Plasma Science and Fusion Center, Cambridge, MA, USA — [3]Technical University of Denmark, Lyngby, Denmark

The plasma boundary in the W7-X stellarator is formed by a chain of intrinsic resonant magnetic islands that are partially intersected by the modular divertor targets. Transport of heat and particles in the island plasma is subject to the interplay of field-parallel gradients, drift flows and turbulent cross-field transport. Two new diagnostic tools, a gas-puff imaging system and a 2D array of Langmuir probes, provide insight into the role of poloidal and radial drift flows and the 3D equilibrium structure of plasma parameters. Stationary radial electric fields within the magnetic islands measured with probes are consistent with the direct imaging of poloidal drift flows with velocities of a few km/s. As parallel transport has to span several 100m of connection length to the divertor targets in W7-X, these drift flows on the island flux surfaces are a significant (and sometimes dominant) transport channel. We observe - sensitively depending on size and position of the magnetic island - multiple shear layers of opposing flows / electric fields with typical widths of just 1-2 cm. In addition, small poloidal electric fields and corresponding radial flows can be present in some scenarios. Turbulent radial transport levels are rather small, particularly when compared to the plasma edge in tokamaks.

P 20.3 Thu 12:00 ELP 6: HS 3

Edge impurity behavior and plasma distribution after boronization on W7-X — •Pei Ren[1,3], Yunfeng Liang[1,3], Yu Luo[1,3], Erhui Wang[1], Stepan Sereda[1,3], Ralph W.T. König[2], Maciej Krychowiak[2], Sebastijan Brezinsek[1], Dorothea Gradic[2], Marcin W. Jakubowski[2], Petra Kornejew[2], Olaf Neubauer[1], Arun Panaey[2], Shuai Xu[1], and The w7-x Team[1,2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany — [2]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [3]Faculty of Mathematics and Natural Science, Heinrich Heine University Düsseldorf, 40225 Düsseldorf, Germany

Controlling the impurity source and wall particle re-cycling is necessary to achieve long-pulse high-performance steady-state plasma operation on the W7-X stellarator. In the experimental campaign OP1.2b, the passively cooled test divertor unit made of graphite has been used. The low-Z impurities, oxygen and the carbon, were identified as mostly contributing to the radiated power in the initial phase of OP1.2b. With the help of boronized wall conditions, a significant reduction in impurity concentration was observed by a newly installed divertor spectroscopy endoscope on W7-X. These results demonstrate the potential of boronization for edge plasma parameter optimization and control in upcoming high-power steady-state plasma operations. In this paper, the changes in impurity content and distribution in the divertor area, as well as the related changes in the edge plasma profiles (Te, ne) before and after boronization will be discussed.

P 20.4 Thu 12:15 ELP 6: HS 3

Experimental investigation of the turbulent drive of the shear flow at the stellarator TJ-K — •Nicolas Dumérat and Mirko Ramisch — IGVP, University of Stuttgart, Germany

Drift wave turbulence has been found to be the dominant instability in the edge of the stellarator TJ-K. Naturally driven by the density gradient, drift waves play a key role in the turbulent transport of particles and energy at the edge of magnetically confined experiments. Inherently related to the coupling between density and potential fluctuations, the drift waves become unstable in case of a non-adiabatic response of the electrons to a density perturbation. Another key agent in such two- dimensional turbulence systems, the zonal flows (ZF) is tied to this cross-coupling. Its interplay with background turbulence is investigated in this work. To this end, convergent cross mapping, a method measuring the causal coupling between variables measured in the same dynamical system is used. By means of multi-dimensional Langmuir probe measurements, and conditional sampling, the plasma fluctuations can be resolved and studied from a new perspective: causality. The causal coupling between density and potential fluctuations during ZF occurrence indicates a clear causality of the density over potential while penetrating the ZF shear layer. Both fluctuations are shown to cause the growth of the ZF, following the drift wave character of the turbulence in the edge of TJ-K. Extending this analysis to wave-number space, the coupling between k_θ modes of plasma fluctuations, unveils the non-locality of the turbulence drive of the ZF as well as evidence of an inverse energy cascade.

P 20.5 Thu 12:30 ELP 6: HS 3

Estimation of turbulent diffusion by conditional variance — •Tobias Tork[1,2], Nicolas Bian[3], Felix Reimold[1], Carsten Killer[1], Wladimir Zholobenko[4], Peter Manz[2], Gustavo Grenfell[4], ASDEX Upgrade Team[4], and Wendelstein 7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, 17491 Greifswald, Germany — [2]Institue of Physics, University of Greifswald, 17489 Greifswald, Germany — [3]Department of Space Sciences and CSPAR, University of Alabama in Huntsville, USA — [4]Max-Planck-Institute for Plasma Physics, 85748 Garching, Germany

Particle and heat transport is of key importance for the optimization of magnetic confinement devices. Transport in magnetized plasmas is the result of interactions between different fields and therefore cannot be measured directly with just one observable. We conjecture estimating the turbulent diffusion coefficient by analyzing the growth of the variance conditioned on small perturbations. This transport estimate relies solely on a time series and the local spatial gradient of one measured variable in the relevant transport direction. We heuristically verify the conjecture with gyrofluid simulations and probe measurements from ASDEX Upgrade and Wendelstein 7-X. The vast majority of estimations demonstrate a considerable accuracy, typically within a factor of two of the actual transport.

P 21: Low Pressure Plasmas and their Application II

Time: Thursday 14:00–15:30 Location: ELP 6: HS 3

Invited Talk P 21.1 Thu 14:00 ELP 6: HS 3

The collisionally modified Bohm criterion: Insight or illusion? — •Ralf Peter Brinkmann — Ruhr-Universität Bochum

In low pressure plasmas, where the Debye length λ_D is much smaller than the mean free path λ, the transition from the quasineutral plasma to the electron-depleted sheath is governed by the Bohm criterion [1]: Ions exit the plasma into the sheath with a speed $v_\mathrm{B} = \sqrt{T_\mathrm{e}/m_\mathrm{i}}$. ($T_\mathrm{e}$ denotes the electron temperature and m_i the mass of the ions.) Long-standing debates surround the application of the Bohm criterion in plasmas where the $\lambda_\mathrm{D}/\lambda$ ratio is not small, prompting questions about the necessity of adjusting the critical velocity.

This contribution investigates a stationary model of a plasma-sheath transition where the electrons are in Boltzmann equilibrium and the ion motion is governed by the ambipolar field, the space-charge field, collisional friction, and inertia. Within the quasi-neutral presheath, the ambipolar field prevails over friction, while in the sheath, the space charge field balances the inertia. The mathematical description of this scenario results in a differential equation for the ion speed v_i as a function of a transformed spatial coordinate q. A removable singularity at a specific ion speed resembles a *collisionally modified Bohm criterion* [2]. The presentation will explore the physical significance of this feature, examining whether it truly reflects system characteristics (*insight*) or simply arises as a mathematical artifact (*illusion*).

[1] D. Bohm, in *The Characteristics of Electrical Discharges in Magnetic Fields*, A. Guthry and R.K. Wakerling (eds.) New York (1949)
[2] R.P. Brinkmann *J. Phys. D: Appl. Phys.* **44**, 042002 (2011)

P 21.2 Thu 14:30 ELP 6: HS 3

Optically trapped microparticles in a dual-frequency capacitively coupled rf discharge — •Jessica Schleitzer, Viktor Schneider, and Holger Kersten — Institute of Experimental and Applied Physics, Christian-Albrechts-University, Kiel, Germany

Many different diagnostics can be used to measure the spatial distribution and temporal evolution of plasma parameters. Over the past decade, the concept of utilizing externally injected small microparticles as non-invasive probes, influenced by various forces and energy fluxes in plasmas, has been implemented. Especially the manipulation of microparticles by an optical tweezer is of great interest, as it enables the microprobe to be positioned in areas of the plasma that are typically inaccessible by conventional diagnostic methods, such as the plasma sheath. In this study, optically trapped microparticles in an optical tweezer are used to investigate the sheath of a dual-frequency CCRF discharge. This discharge is known, in particular, for its ability to control the ion flux and the ion energy almost separately. It is generated by a superposition of two consecutive harmonics with variable phase angle between them. The crucial parameter to measure when employing optical tweezers is the external force acting on the microprobe. This force is determined by observing the displacement of the particle within the optical trap, while the confined microprobe is moved through the plasma and sheath. On the basis of the force profiles, the strength of the electric field force in the sheath as a function of the phase angle between the two harmonics, the extent of the sheath, as well as the particle charge evolution within the sheath are determined.

P 21.3 Thu 14:45 ELP 6: HS 3

Electron dynamics in partially magnetized low pressure plasma discharges — •Lukas Vogelhuber, Denis Eremin, Kevin Köhn, Dennis Krüger, and Ralf Peter Brinkmann — Department of Electrical Engineering and Information Science, Ruhr University Bochum, D-44780, Bochum, Germany

Partially magnetized plasma discharges in magnetron configurations are versatile and offer a wide range of applications in science and industry. These applications range from space propulsion systems that utilize Hall-effect thrusters to the deposition of thin films in the physical vapor deposition technology using "high power impulse magnetron sputtering" (HiPIMS). Their magnetic field configuration is described in cylindrical geometry (r, θ, z) with the magnetic field lines in the r-z plane. In such magnetron discharges, plasma non-uniformities are observable in the form of the rotating spokes phenomenon moving in the azimuthal (θ) direction. These structures exhibit a heightened ionization rate and increased potential, altering the electron dynamics in these regions and the overall plasma dynamics. The focus of this talk is the investigation of electron dynamics of partially magnetized electrons under the influence of a simplified but realistic axisymmetric magnetic field in the r-z plane. As a key diagnostic method serves the magnetic moment in higher-order approximations to understand the energization process of electrons under such conditions. Understanding the electron trajectories in these regions influenced by the spatially inhomogeneous magnetic field may contribute to future understanding of the adiabatic and non-adiabatic energy gain of electrons.

P 21.4 Thu 15:00 ELP 6: HS 3

Atomic oxygen measurements with THz absorption spectroscopy, ps-TALIF, and CRDS: A comparison — Jente R. Wubs[1], Uwe Macherius[1], Andy S. C. Nave[1], Laurent Invernizzi[2], Kristaq Gazeli[2], Guillaume Lombardi[2], Xiang Lü[3], Lutz Schrottke[3], Klaus-Dieter Weltmann[1], and •Jean-Pierre H. van Helden[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Laboratoire des Sciences des Procédés et des Matériaux (LSPM), CNRS, Université Sorbonne Paris Nord, Villetaneuse, France — [3]Paul-Drude-Institut für Festkörperelektronik, Leibniz-Institut im Forschungsverbund Berlin e.V., Berlin, Germany

Terahertz (THz) absorption spectroscopy with quantum cascade lasers (QCLs) has recently been developed and implemented as a new diagnostic technique for investigating ground state atomic oxygen densities in plasmas. It is based on the detection of the $^3P_1 \leftarrow {}^3P_2$ fine structure transition at approximately 4.75 THz (i.e., approximately 63 μm). In this contribution, we will compare the results obtained with this method with those obtained by picosecond two-photon absorption laser-induced fluorescence (ps-TALIF) at 226 nm, as this is currently the most established method for measuring atomic oxygen densities, and cavity ring-down spectroscopy (CRDS) using the forbidden $^1D_2 \leftarrow {}^3P_2$ transition at approximately 630 nm. All measurements were performed on the same low-pressure capacitively-coupled radio frequency plasma generated in pure oxygen, for a variation of the applied power and gas pressure.

P 21.5 Thu 15:15 ELP 6: HS 3

Investigation of geometric asymmetric electronegative capacitively coupled radio frequency discharges using a hybrid PIC/MCC simulation — •Katharina Noesges, Maximilian Klich, Sebastian Wilczek, and Thomas Mussenbrock — Ruhr University Bochum, Germany

Capacitively coupled radio frequency (CCRF) discharges are pivotal in numerous etching processes in the semiconductor industry. Operating at low pressures in the range of a few Pascals and requiring voltages of about hundreds of volts, these discharges facilitate anisotropic ion bombardment essential for precision etching. Carbon tetrafluoride (CF_4) discharges are significant in this context. These discharges are investigated using a one-dimensional hybrid particle-in-Cell/Monte Carlo collisions (PIC/MCC) simulation in the low-pressure regime (p = 6.67 Pa), assuming a spherical geometry. This approach considers the electrons kinetically and simultaneously utilizes the drift-diffusion approximation to solve a continuity equation; one each for the ion species. This work examines the influence of varying electrode gap sizes and applied voltages, demonstrating that the electronegativity strongly affects the electron dynamics. Because of the geometric asymmetry, a strong electric field reversal during the sheath collapsing phase accelerates many electrons toward the powered electrode. A spatially and temporally resolved analysis of the high-energy electron density reveals a sharp beam structure formed by electrons near the electrode. This beam structure is an accumulation of electrons accelerated by the expanding boundary sheath towards the grounded electrode.

P 22: Plasma Wall Interaction II/HEPP VII

Time: Thursday 14:00–15:50 Location: ELP 6: HS 4

Invited Talk P 22.1 Thu 14:00 ELP 6: HS 4

First Results of Laser-Induced Desorption - Quadrupole Mass Spectrometry (LID-QMS) at JET — •Miroslaw Zlobinski[1], Gennady Sergienko[1], Ionut Jepu[2,3], and et al[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]United Kingdom Atomic Energy Authority, Culham Centre for Fusion Energy, Culham Science Centre, OX14 3DB Abingdon, UK — [3]National Institute for Laser, Plasma and Radiation Physics, Magurele, Romania

Monitoring the tritium retention at the walls of fusion devices is important due to radiation safety, the fuel cycle and material degradation. In 2023 a new fuel retention diagnostic has been installed on JET and the first results are presented here. LID-QMS allows direct in situ measurements of the fuel inventory of plasma facing components. The diagnostic desorbs the retained gases by heating a 3 mm diameter spot on the wall using a 1 ms long laser pulse and detects them by Quadrupole Mass Spectrometry (QMS). The successful detection of tritium retention in the tritium campaign at JET has been demonstrated. Thus, this diagnostic is already foreseen as tritium monitor diagnostic for ITER.

Invited Talk P 22.2 Thu 14:30 ELP 6: HS 4

Deuterium retention analysis in pre-damaged tungsten using laser-induced breakdown spectroscopy — •Erik Wüst[1,2], Christoph Kawan[1,2], Sebastijan Brezinsek[1,2], and Thomas Schwarz-Selinger[3] — [1]Forschungszentrum Jülich GmbH, Institut für Energie und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]Faculty of Mathematics and Natural Sciences, Heinrich Heine University Düsseldorf, 40225 Düsseldorf, Gernany — [3]Max-Planck-Institut für Plasmaphysik, D-85748 Garching, Germany

Energetic neutrons are a product of the DT-fusion reaction and can induce material damage in Plasma-Facing Components (PFCs) in future nuclear fusion reactors. The damage increases with time and causes enhanced fuel, tritium (T) and deuterium (D), retention in tungsten (W) PFCs, which imposes issues for safety and closure of the T cycle in the fusion plant. Laser-Induced Breakdown Spectroscopy (LIBS) is a potential in-situ technique to monitor tritium inventory in W PFCs. LIBS on pre-damaged W (W-ions, 10.8 MeV, 0.23 dpa) with D contents of 0.1-1% owing to D plasma exposure in PlaQ and subsequent outgasing, was carried out to measure the depth-resolved fuel content in a laboratory set-up. LIBS was done using an Nd:YAG laser (35 ps, 355 nm, 20 mJ), ablating 15 nm per laser pulse. D was detected up to a depth of 1.3μm by observing Balmer α line from the laser-induced plasma plume. The depth profile and total amount was compared with nuclear reaction analysis (NRA) and showed good agreement. Deviations can only be observed for the first ablation cycle near the surface.

P 22.3 Thu 15:00 ELP 6: HS 4

Ion-driven deuterium permeation in tungsten-heavy-alloy-like multi-layer membranes — •Philipp Sand[1,2] and Armin Manhard[1] — [1]Max-Planck Institut für Plasmaphysik, 85748 Garching, Germany — [2]Techn. Univ. München, 85748 Garching, Germany

Tungsten heavy alloy (97W-2Ni-1Fe, %wt., THA) is a possible candidate as plasma-facing material in future nuclear fusion devices. It exhibits a similar heat conductance at high temperature and sputter yield as pure W, whilst showing an improved ductility [1]. Hydrogen isotope (HI) retention behaviour [2] was also shown to be favourable, which was attributed to the microstructure of this dual phase material: Upon plasma loading, the percolating matrix phase provides fast diffusion paths to vacuum [3], while W domains remain at low HI concentrations due to a low HI solubility. To predict HI uptake of THA under reactor relevant conditions, the parameters of HI transport across respective phase boundaries must be quantified. An ion-driven permeation experiment was benchmarked using pure W samples irradiated with of 170 eV/D at $5x10^{19}$ D/m^{2}s between 650 K and 900 K. D transport across the interface was studied at the same conditions in both directions using W substrates coated with matrix-like alloy on one side. The influence of surface oxides on permeation is investigated on both sides. It is confirmed that uptake from matrix into W is strongly suppressed while no significant barrier was observed for HI transport from W into matrix. [1] R. Neu, et al., Fusion Eng. Des. 124 (2017) 450-454, [2] H. Maier, et al., J. Nucl. Mater 18 (2019) 245-259, [3] A. Manhard, et al., Nucl. Mater 36 (2023) 101498

P 22.4 Thu 15:25 ELP 6: HS 4

Characterization of ionization pressure gauges for magnetic confinement fusion devices — •Bartholomäus Jagielski — Max Planck Institut für Plasmaphysik, Greifswald, Germany

This work describes advanced gas pressure gauges designed for use in strong magnetic fields during plasma operation in fusion devices. The performance of novel cathode designs and emitter materials, including LaB_6, ZrC, HfC, and TW, were systematically studied in terms of sensitivity and reliability in different gases. The study presents the setup of a unique laboratory featuring a high field magnet, enabling experiments with adjustable pressures and magnetic fields up to 6 T. Conditioning and stability of the emitters were explored in a magnetic field up to 6 T, revealing fluctuations in the electron and ion current, which have been studied in more detail using simulations, suggesting the existence of virtual cathodes within the potential well, affecting the potential distribution. Thermal studies using pyrometers and an infrared camera, alongside heat transfer analysis with Ansys, identified optimal LaB_6 emitter conditions. Additionally, Energy-Dispersive X-ray Surface Spectroscopy provided evidence of surface oxidation and emitter material emission under non-optimal conditions.
The optimized potential distribution and operating ranges for various cathodes were determined, achieving record values for a stable operation in a strong magnetic field. The results showcase the suitability of LaB_6 emitters in Wendelstein 7-X and for advancing fusion research, particularly in the context of large-scale projects like ITER and DEMO.

P 23: Complex Plasmas and Dusty Plasmas II

Time: Thursday 16:30–18:00 Location: ELP 6: HS 3

Invited Talk P 23.1 Thu 16:30 ELP 6: HS 3

Characterizing electron depleted, nanodusty plasmas recent developments and future outlooks — •Andreas Petersen and Franko Greiner — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

Although astrophysical issues and research on fundamental questions in the field of dusty plasmas remain topical, the synthesis of nanoparticles with selectable properties has become increasingly popular in recent years. Nanodusty plasmas can be characterized in various ways, but determining multiple parameters simultaneously can be problematic. The analysis of dust density waves enables a comprehensive characterization of all components of complex plasmas by modelling the two-stream instability that occurs in dusty plasmas. The dust density wave diagnostic (DDW-D) is presented and its results are considered in the context of other characterization methods. Additionally, new perspectives are discussed.

P 23.2 Thu 17:00 ELP 6: HS 3

The asynchronous melting process of binary mixtures — •Yang Liu and Dietmar Block — IEAP, Christian-Albrechts-Universität, D-24098 Kiel, Germany

Melting processes in binary mixtures are compared to their single-component counterparts a sophisticated task. Already the collective crystalline behavior within the mixture is poorly understood [1]. The glass-like formation of irregular and stable structures in the mixing region of binary mixtures does not allow to employ methods based on empirical rules derived from topological structures to describe lattice melting issues. This contribution utilizes the local relative interparticle fluctuation (IDF) method to investigate the melting process of finite binary monolayers and its dependence on component concentrations and size differences [2]. Our results indicate that, unlike monodisperse systems, the two components of binary mixtures exhibit asynchronous melting. The individual melting points strongly depend on particle size. Especially the hopping motion of particles, i.e. the fast transition of a particle from a local potential minimum to a neighboring lattice point, is studied in detail. Based on six fundamental particle arrangements and related escape models, i.e. calculations of the energy barriers, the melting process in binary mixtures is discussed.

References

[1] G. Gompper and M. Schick, in Soft Matter, Complex Colloidal Suspensions Vol. 2 (Wiley, Weinheim, 2006).

[2] V. S. Nikolaev and A. V. Timofeev, Physics of Plasmas, 2021, 28(3): 033704.

P 23.3 Thu 17:15 ELP 6: HS 3

Mach cones in Dusty Plasmas under Weigthlessness — •Daniel Maier, Christina Knapek, André Melzer, Daniel Mohr, and Stefan Schütt — Institute of Physics, University of Greifswald, Germany

The concept of the Mach cone is well known from objects moving through air when the velocity of the moving object is higher than the speed of sound. But theoretically a Mach cone can appear in every environment if the velocity of a moving object is higher than the characteristic wave velocity of the surrounding medium.

Accordingly this phenomenon has also be seen in dusty plasmas where micrometer sized particles are added into a low temperature plasma creating a complex system. If now a single particle or a bigger agglomerate of many particles moves through the plasma at a sufficient speed a Mach cone like structure can be observed.

During our last experimental campaign with dusty plasma under weightlessness using a capacitive coupled RF - discharge Mach cone structures caused by particle agglomerates travelling through the plasma were visible. In this contribution first results on the investigations of these Mach cone structures observed with a stereoscopic camera system will be shown.

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

P 23.4 Thu 17:30 ELP 6: HS 3

Agglomeration, structure and dynamics of binary dust systems — Baoxia Li[1], Yang Liu[2], Hanyu Tang[2], Xiaojiang Tang[1], Eric Guo[2], and •Feng Huang[2] — [1]College of Information and Electrical Engineering, China Agricultural University, Beijing 100083, China — [2]College of Science, China Agricultural University, Beijing 100083, China

Agglomeration and spatial distribution of a binary dusty system formed by dust particles with different sizes were experimentally studied. The agglomeration process of dust particles was characterized by direct micrograph image and the evolution of scattered light as time. The fractal dimension and average particle area in the steady state changing in space were used to show the spatial distribution of the binary dusty system. The effects of temperature and dust particle number on the structure and dynamics of a binary complex plasma system are investigated through two-dimensional (2D) Langevin dynamics simulation. Two kinds of dust particles with different masses are considered in the binary complex system. The particle distribution, Voronoi structure diagram and pair correlation function are used to characterize the system structure. The evolution process of kinetic energy, speed and trajectories of binary particles as time are used to study the dynamical characteristics of the system. The investigations indicate that the structures and dynamics of the binary complex plasma can be obviously affected by system temperature and particle number. This study is helpful for the application of phase separation in practical plasma environment related to different particle species.

P 23.5 Thu 17:45 ELP 6: HS 3

The low-energy electron sticking coefficient of dielectric materials — •Armin Mengel and Franko Greiner — Institute of Experimental and Applied Physics, Kiel University

An important property of surfaces is their interaction with electrons, which often depends on the electron energy. In particular, the electron sticking coefficient affects the plasma-surface interaction, amongst others, and has an impact on dust charging in a plasma. While it can be measured well using electron beams for conducting surfaces or at high energies, this conventional approach fails for dielectric materials at low energies ($< 10\,\mathrm{eV}$). By introducing a micrometer-sized grain of dielectric material into a low-pressure discharge, we can investigate the interaction of the dielectric surface with the ambient electrons of the plasma ($T_e \approx 2...5\,\mathrm{eV}$). Using a relative measurement scheme employing electric particle excitation methods like PRRM or PEOM as well as long-distance microscopy, the sticking coefficient of the dielectric material can then be determined in relation to particles with a conducting surface.

P 24: Codes and Modeling II

Time: Thursday 16:30–17:45 Location: ELP 6: HS 4

Invited Talk P 24.1 Thu 16:30 ELP 6: HS 4

Electron surface scattering kernel for plasma simulations — •Franz Xaver Bronold and Felix Willert — Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany

Applying the invariant embedding principle, originally developed for the calculation of the albedo of planetary and stellar atmospheres, to secondary electron emission from surfaces, we construct an electron surface scattering kernel to be used in the boundary condition for the electron Boltzmann equation of a simulation of a plasma confined by a solid. In principle, the kernel takes the microphysics responsible for electron emission and backscattering from the plasma-solid interface fully into account. To demonstrate the potential of the approach, we apply it to a polycrystalline silicon surface using a semiempirical jellium-randium model for the solid. It contains the Schottky barrier, impact ionization across the band gap as well as scattering on phonons, defects, and ion cores. The emission yields we deduce from the kernel, which in turn is obtained by solving the nonlinear embedding equation for the electron backscattering function without approximate decoupling of the angle and energy variables, agree well enough with measured data to support using the kernel in the boundary condition of the electron Boltzmann equation of a simulation describing a plasma in contact with a polycrystalline silicon surface. [1] F. X. Bronold and F. Willert, arXiv:2309.00534.

P 24.2 Thu 17:00 ELP 6: HS 4

Unveiling the non-linear Zeeman effect in isotopes of krypton and xenon at the linear plasma device PSI-2 — •Marc Sackers[1], Oleksandr Marchuk[1], D Dipti[2], Stephan Ertmer[1], Yuri Ralchenko[3], and Arkadi Kreter[1] — [1]Forschungszentrum Jülich GmbH - Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]International Atomic Energy Agency, Vienna, Austria — [3]National Institute of Standards and Technology - Atomic Spectroscopy Group, 20899 Gaithersburg, USA

Isotopic broadening alters the line shape of atomic transitions and contributes noticeably to the laser absorption spectra of neutral Kr and Xe investigated at the linear plasma device PSI-2. Of high interest are the odd-numbered isotopes having a nonzero nuclear spin resulting in the hyperfine interaction. The main challenge in analyzing such isotopes is that the hyperfine and Zeeman terms can be of the same order of magnitudes, rendering conventional weak field and strong approximation formulas inadequate for analysis.

The magnetic field at PSI-2 of < 90 mT creates such conditions for the Kr I 760.4 nm, Kr I 785.7 nm, and Xe I 764.4 nm lines. This contribution shows how to correctly account for the Zeeman effect by using a Hamiltonian containing both hyperfine and Zeeman interaction terms as the perturber. Standard atomic physics procedures allow us to derive the energy eigenvalues and relative intensities. Crucially, the theoretical analysis is backed by experimental data, confirming the validity of the methodology in modeling observed spectral features.

P 24.3 Thu 17:15 ELP 6: HS 4

Modelling study of the effects of gas temperature on self-pulsing spark discharges in atmospheric-pressure argon — •Aleksandar P. Jovanović[1], Hans Höft[1], Detlef Loffhagen[1], Markus M. Becker[1], and Torsten Gerling[1,2,3] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Kompetenzzentrum Diabetes Karlsburg (KDK), Karlsburg, Germany — [3]ZIK plasmatis, Greifswald, Germany

Self-pulsing discharges, such as transient sparks, are commonly used to generate non-thermal atmospheric pressure plasmas. Although the self-pulsing prevents excessive gas heating and thermalisation of the discharge, gas might still heat to some extent. The increase in gas temperature could alter the discharge stability and the characteristics of the plasma, such as mode transitions and the excitation of ion acoustic waves. In the present contribution, the self-pulsing discharges in argon at atmospheric pressure are analysed by means of a fluid-Poisson model coupled with a circuit equation. The effects of gas heating on the discharges and self-pulsing modes are investigated by treating the gas temperature as a parameter in the model and by coupling a heat equation for the background gas to the fluid-Poisson model. The modelling results show that higher gas temperatures affect both the frequency and the periodicity of the discharges, noting that the change in gas density has the most significant influence, while temperature-dependent collisional processes play a minor role.

Funded by the Deutsche Forschungsgemeinschaft (DFG) – project number 466331904.

P 24.4 Thu 17:30 ELP 6: HS 4

The Poisson-Boltzmann equation and quasi-neutrality assumption in the presence of electron number perturbations — •Kevin Köhn[1], Lukas Vogelhuber[1], Dennis Krüger[1], Denis Eremin[1], Liang Xu[2], and Ralf Peter Brinkmann[1] — [1]Ruhr University Bochum, Germany — [2]Soochow University, China

The Poisson-Boltzmann (PB) equation is a 3D elliptical partial differential equation used to determine the electric potential in a plasma chamber with appropriate boundary conditions. Solutions of the PB equation usually exhibit a typical bulk-sheath structure, with strong gradients in the sheath and approximately constant potential in the quasi-neutral bulk. In recent years, much research in the field of partially magnetized discharges, e.g. high power impulse magnetron sputtering, was dedicated to the so-called spoke phenomenon. These spokes can be characterized as self-emerging rotating structures of increased ionization, density and potential that rotate in the ExB direction. As these structures clearly break the discharge symmetry, researchers suggested that in order to fully capture the plasma potential dynamics of such a discharge the quasi-neutrality assumption in the bulk must be dropped and the full 3D PB equation would be required. In this talk, we present investigations of the PB equation in simple geometry with small and large scale periodic electron number perturbations to find a criterion if the quasi-neutrality assumption holds based on pertubation scale, bulk length and Debye length.

P 25: Poster III

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

P 25.1 Thu 16:30 ELP 6: Foyer

Optical damage threshold of plasma density gratings — •Sophie Opara and Götz Lehmann — Heinrich-Heine-Universität, Düsseldorf

Plasma density gratings are periodic structures allowing the manipulation of high-power laser pulses with intensities far beyond the damage threshold level of solid state material. Such structures can be used as e.g. Bragg-type mirrors, polarizers, wave-plates and holographic lenses. The gratings are driven by beating laser pulses in underdense plasma and exist on the timescale of tens of pico-seconds, i.e. sufficiently long to manipulate high-power femto-second pulses. Since they can be re-created for every shot of the high-intensity pulse, they are usually considered as damageless optics.

However, the optical properties of density gratings depend on their periodic structure. Period and modulation amplitude determine their transmissive and reflective properties. Sufficiently strong laser pulses can manipulate the density distribution via their ponderomotive force and thus change the optical properties. The presented work aims to identify the intensity limit at which the gratings can not be anymore considered static and describe the underlying physical processes going along with the degradation of their structure.

P 25.2 Thu 16:30 ELP 6: Foyer

Uncertainty Quantification for Magnetohydrodynamic Equilibrium Reconstruction: A data driven approach — •Robert Köberl[1,2], Robert Babin[3], and Christopher G. Albert[3] — [1]MPI for Plasma Physics, Garching, Germany — [2]CIT, TU Munich, Garching, Germany — [3]Fusion@ÖAW, ITPcp, TU Graz, Graz, Austria

We report on progress towards a probabilistic framework for uncertainty quantification and propagation in analysis and numerical modeling of physics in magnetically confined plasmas in the stellarator configuration. A frequent starting point in this process is the calculation of a magnetohydrodynamic equilibrium from plasma profiles. Profiles and therefore the equilibrium are typically reconstructed from experimental data. What sets equilibrium reconstruction apart from usual inverse problems is that profiles are given as functions over a magnetic flux derived from the magnetic field, rather than spatial coordinates. This makes it a fixed-point problem that is traditionally left inconsistent or solved iteratively in a least-squares sense. The aim here is towards a straightforward and transparent process to quantify and propagate uncertainties and their correlations for function-valued fields and profiles in this setting. We propose a Bayesian inference framework that utilizes a low dimensional prior distribution of equilibria, constructed with principal component analysis. Additionally, neural-network- and polynomial-regression-surrogates of the forward model for synthetic diagnostics are trained. This enables faster sampling when approximating the posterior distribution of equilibria via Markov chain Monte Carlo sampling.

P 25.3 Thu 16:30 ELP 6: Foyer

Adding fluid neutrals to the gyrokinetic turbulence code GENE-X — •Sabine Ogier-Collin, Philipp Ulbl, Wladimir Zholobenko, and Frank Jenko — Max Planck Institute for Plasma Physiscs, Garching bei München, Germany.

Key objectives in the design of future magnetic confinement fusion reactors are the management of heat and particle exhaust to the wall, as well as optimal core confinement. Understanding the turbulent transport at the boundaries of the confined region, i.e. the plasma edge and the scrape-off layer (SOL), is critical in assessing these objectives. In addition to the main plasma, several ionic impurity species along with molecules and neutral atoms (neutrals) are present, especially in the SOL, and interact with the plasma through a complex set of collision processes. This has several non-negligible effects on the plasma parameters and confinement, e.g. changes in the radial plasma profiles and particle transport across the last closed flux surface.

GENE-X is a gyrokinetic code dedicated to the study of the edge and SOL turbulence in realistic geometries. To improve its predictive capabilities, a neutrals model and the plasma-neutrals interactions are added. The neutrals are evolved using a pressure-diffusion equation and interact with the gyrokinetic plasma through ionisation, recombination and charge exchange channels. The evolution of neutrals has been implemented using a 4th order central finite difference scheme. In a verification study, the order of accuracy has been recovered in multiple geometries including slab, circular and s-alpha. This allows for first test simulations in realistic geometries.

P 25.4 Thu 16:30 ELP 6: Foyer

structure-preserving hybrid code, STRUPHY: energy-conserving hybrid MHD-driftkinetic models. — •Byung Kyu Na[1,2], Stefan Possanner[1], Xin Wang[1], Dominik Bell[2], Yingzhe Li[1], and Nathan Marín[1,2] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technical University of Munich, Garching, Germany

A Python package STRUPHY (STRUcture-Preserving HYbrid codes) features a collection of PDE solvers based on Geometric finite element method (FEEC) and Particle-in-cell method (PIC). One of the main applications of the STRUPHY is a simulation of hybrid MHD-kinetic systems in curved three-dimensional spaces where the bulk plasma is treated as a MHD fluid and energetic particles(EPs) are described kinetically. We introduce energy-conserving hybrid MHD-driftkinetic models which were newly implemented in STRUPHY. Existing hybrid MHD-kinetic models often suffer from not conserving the total energy, especially when reduced kinetic models are used to describe EPs such as driftkinetic or gyrokinetic. However, this property was recently recovered by adding additional terms derived from variational principles. The investigation of the conservation laws on the discrete level will be considered with the preliminary results of the ITPA benchmark case.

P 25.5 Thu 16:30 ELP 6: Foyer

Numerical methods for stellarator simulations in BOUT++ — •David Bold[1], Brendan Shanahan[1], Jessica Bold[2], and Ben Dudson[3] — [1]Max Plank Institute for Plasma Physics, Greifswald, Germany — [2]University of Greifswald, Greifswald, Germany — [3]Lawrence Livermore National Laboratory, Livermore, California, USA

There is a significant need for reliable modelling of the scrape-off layer of fusion devices, which is challenging for stellarators due to the complex geometry involved. As field aligned approaches are challenging, the Flux Coorinate Independent (FCI) method is often employed.

In the FCI grid generator, Zoidberg, the fidelity to the experimental geometry has been improved, and several improvements have been made to ensure the grid is feasible even with such challenging conditions. At the same time options have been added to reduce the fidelity and improve runtime.

For the BOUT++ framework, a new finite volume operator has been implemented that does not fail in the case of non differentiable contours. The parallel FCI operators have also been rewritten to allow MPI parallelisation of the perpendicular slices, in addition to OpenMP. Scaling will be presented, showing the improved scaling using the new PETSc-based operators. The parallel boundary conditions generally rely on points within the domain to extrapolate into the boundary. However, this breaks down in the case of short connection lengths, where a field line is outside of the domain in the previous and next plane. In this case a lower order scheme is used automatically.

P 25.6 Thu 16:30 ELP 6: Foyer

Linear extended mhd equations in struphy — •Nathan Marin[1,2] and Stefan Possanner[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technische Universität München, Garching, Germany

In this project, a Finite Elements Exterior Calculus discretization for the linearized homogeneous extended mhd equations is developed and implemented to obtain a solver of arbitrary degree of convergence that simulates plasma behavior. The discretization has been implemented as the newly available LinearExtendedMHD model in struphy ('A python package for energetic particles in plasma, developed since 2019 at Max Planck Institute for Plasma Physics in the Numerical Methods for Plasma Physics division'. Look at https://struphy.pages.mpcdf.de/struphy/index.html for more information about struphy).

The discretization was devised to preserve critical physical quantities that the continuous model conserves (magnetic helicity, energy, and magnetic field's divergence) so the simulation adequately describes the relevant physical phenomena. Finally, the analytical dispersion relation for the extended mhd equation was derived to use it as a test case for the code.

P 25.7 Thu 16:30 ELP 6: Foyer

The STØR experiment - a spherical toroidal magnetic confinement concept applied as a radiation source — •Nils Fahrenkamp, Sebastian Haag, Stefan Knauer, and Peter Manz — Institute of Physics, University of Greifswald, Greifswald, Germany

Extreme Ultraviolet (EUV) lithography is a crucial technology nowadays. EUV light is used to project high-resolution patterns onto silicon wafers, enabling the production of smaller and more powerful microchips. At the desired wavelength lasers are no longer available as light sources, so plasma sources have to be used. They need to generate extremely high power emitted in a very narrow spectral band around 13.5 nm (±0.135 nm, the so-called in-band) in a small source volume necessary for efficient radiation. Laser-produced plasmas (LPPs) prevailed because the discharge-produced plasmas (DPPs) did not achieve the desired parameters of $n_e \sim 10^{24}$ m^{-3} and $T_e \sim 30$ eV. Current state-of-the-art sources use laser irradiated tin (Sn) droplets as emitter because it has strong in-band emission. But a single unit weighs over 180 tons, consumes more than 1 MW electrical power and costs more than 100 million dollars. The inevitable high cost of LPPs means that low-cost or table-top systems will continue to rely on DPPs. Alternative magnetic confinement concepts are particularly well suited as radiation sources, as they contribute to reducing costs and improving accessibility for various research institutions. We present here an experimental setup allowing for magnetically confined compact plasma tori without external toroidal and poloidal magnets. These are ideal properties for a radiation source.

P 25.8 Thu 16:30 ELP 6: Foyer

Overview of mode observations at the Wendelstein 7-X stellarator — •Kian Rahbarnia[1], Ksenia Aleynikova[1], Tamara Andreeva[1], Jan-Peter Bähner[2], Charlotte Büschel[1], Christian Brandt[1], Neha Chaudhary[1], Dario Cipciar[1], Mykola Dreval[3], Carsten Killer[1], Ralf Kleiber[1], Axel Könies[1], Andreas Krämer-Flecken[4], Sara Vaz Mendes[1], Christoph Slaby[1], Adrian von Stechow[1], Henning Thomsen[1], Gavin Weir[1], and Wendelstein 7-X[1] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]MIT Plasma Science and Fusion Center, Cambridge, MA, USA — [3]Kharkov Institute of Physics and Technology, Kharkov, Ukraine — [4]Forschungszentrum Jülich GmbH, Jülich, Germany

During the recent operational phase OP2.1 at the optimized stellarator Wendelstein 7-X in Greifswald, Germany, a large variety of mode activity in a broad frequency range from about 1-1000 kHz has been observed. This work provides an overview of measurements, which are partly accompanied by theoretical calculations. The focus lays on Alfvénic activity around 200 kHz and potentially fast ion driven modes in plasmas heated by neutral beam injection or ion cyclotron resonance heating. Additionally observations of trapped electron modes are discussed. Mode activity around 10-50 kHz, which is specifically observed in higher beta plasmas, is related to theoretically predicted kinetic ballooning modes and finally low frequency island localized modes around 1 kHz are investigated. Both last aspects might have impact on confinement properties in future highest beta plasmas.

P 25.9 Thu 16:30 ELP 6: Foyer

Development of advanced accumulation techniques for a multi-cell Penning-Malmberg trap — •Martin Singer[1,2], Eve Stenson[3], and Lutz Schweikhard[2] — [1]Institut für Plasma Physik, Greifswald, Germany — [2]Institut für Physik, Universität Greifswald, Germany — [3]Institut für Plasma Physik, Garching, Germany

Penning-Malmberg (PM) traps are employed to accumulate large quantities of charged particles. However, this accumulation in single PM traps is often limited by the space charge. The multi-cell PM trap (MCT) avoids large space charges by distributing the particles into many traps [1]. These small-diameter storage traps are arranged on and off axis next to a large-diameter master trap that is used to catch and bunch of charged particles and to transfer them to the storage traps. The APEX ("A Positron Electron eXperimet") collaboration plans to use the MCT to accumulate unprecedented amounts of positrons. Subsequently, these positrons will be used to form the first confined electron-positron plasma either in the magnetic field of a levitating dipole magnet, or in an optimized tabletop stellarator [2]. This contribution will detail the latest MCT developments, and the techniques developed for the off-axis transfer [3]. We aim for the accumulation of 3×10^9 positrons in each off-axis cell. This will function as a proof of principle for the MCT concept and allow for the accumulation of up to 1×10^{10} positrons, the number needed for the positron-electron plasma creation. [1] D.R. Wittemann, et al. J. Plasma Phys. 89.4 (2023). [2] M.R. Stoneking, et al. J. Plasma Phys. 86.6 (2020). [3] M. Singer, et al. J. Plasma Phys. 89.5 (2023).

P 25.10 Thu 16:30 ELP 6: Foyer

Dynamics of impurity injection events in Wendelstein 7-X stellarator analysed by tomography — •Henning Thomsen, Thomas Wegner, Christian Brandt, Charlotte Büschel, Sara Mendes, Kian Rahbarnia, and W7-X team — Max-Planck Institute for Plasma Physics, Greifswald, Germany

The soft-X-ray tomography system [1] installed in the Wendelstein 7-X stellarator is capable of tracing the spatio-temporal dynamics of plasma perturbations in a poloidal plasma cross-section. The diagnostic has more than 300 lines of sight and a high bandwidth of more than 100 kHz. In this contribution we analyse the dynamics of a laser blow-off injection [2] of a high-Z impurity species into the plasma by means of tomographic inversion of the line-integrated soft-X-ray data. A singular value decomposition of the time sequence of tomographic images clearly shows the poloidal motion of the perturbation following the injection. We find that the propagation is following the direction of the ExB-rotation of the core plasma (the radial electric field in stellarators is predominantly governed by neoclassical transport processes). For sufficiently small plasma perturbation, this technique could be used to experimentally constrain the estimation of the radial electric field profile.

[1] C Brandt et al., Plasma Phys. Control. Fusion 62 (2020) 035010
[2] Th. Wegner et al., Rev. Sci. Instrum. 89 (2018) 073505

P 25.11 Thu 16:30 ELP 6: Foyer

Development of real-time control scheme for power exhaust via impurity seeding in Wendelstein 7-X — •Anastasios Tsikouras[1,3], Felix Reimold[3], Gabriele Partesotti[3], Matthijs van Berkel[2], Jesse T.W. Koenders[1,2], Victoria Winters[3], Valeria Perseo[3], Daihong Zhang[3], Marco de Baar[1,2], and W7-X Team[3] — [1]Eindhoven University of Technology, Eindhoven, Netherlands — [2]DIFFER, Eindhoven, Netherlands — [3]Max Planck Institute of Plasma Physics, Greifswald, Germany

In Wendelstein 7-X (W7-X) real-time control of operational parameters is crucial for the performance of the stellarator. The radiated power is such an operational parameter that can be controlled with injection of gaseous impurities (seeding). This contribution identifies the seeding-radiation dynamics, from the latest W7-X experiments, and optimizes controller parameters for specific operating conditions.

In W7-X, bolometers are used for calculating the total radiated power, which is assessed for control purposes. First, the seeding-radiation response is identified and modelled, by analysing square wave seeding pulses. Then simulations on the dynamics models, show the response of the system and its limits. An error of less than 1% in under 200 milliseconds in tracking a unit step reference is possible for optimized controller parameters, whereas different operational conditions require different control parameters to achieve optimal performance in terms of tracking accuracy and speed. Finally, we outline proposals for the input signal in perturbative experiments to accurately identify the W7-X radiation dynamics in future experiments.

P 25.12 Thu 16:30 ELP 6: Foyer

Theoretical investigation of impurity turbulent transport in W7-X — •Hugo Isaac Cu Castillo[1], Alejandro Bañón Navarro[1], Thilo Romba[2], Felix Reimold[2], Oliver Ford[2], Sebastian Bannmann[2], Péter Zsolt Pölöskei[2], Markus Wappl[2], Adrian von Stechow[2], Frank Jenko[1], and the W7-X team[2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

The presence of impurities in the core of fusion plasmas has a detrimental effect on the overall plasma performance via fuel dilution and core cooling through increased radiative losses. While steepened density profiles of the main plasma species, i.e. electrons and hydrogen ions, correlate with high-performance plasmas [1], these scenarios also lead to an undesired accumulation of impurities within the core. Previous experiments conducted under these conditions in the stellarator Wendelstein 7-X (W7-X) appear to indicate that for $\rho < 0.5$, impurity transport can be fully described by neoclassical transport in contrast to the turbulence-dominated transport observed for the main plasma species [2]. This work investigates the physical mechanism for this suppression of turbulent transport of impurities under steep density gradients of the main species using the gyrokinetic code GENE.

[1] S.A. Bozhenkov, et al. Nuclear Fusion 2020, 60: 066011
[2] T. Romba, et al. Nuclear Fusion 2023, 63: 076023

P 25.13 Thu 16:30 ELP 6: Foyer

Plasma termination due to tungsten TESPEL injection in large stellarators — •Hjördis Bouvain[1,2], Andreas Dinklage[1], Naoki Tamura[3], Hiroshi Kasahara[3], Kieran McCarthy[4], Daniel Medina-Roque[4], Hiroe Igami[3], and The LHD Experiment Team[3] — [1]Max-Planck-Institut for Plasma Physics, Greifswald, Germany — [2]Universität Greifswald, Greifswald, Germany — [3]National Institute for Fusion Science, Toki, Japan — [4]Centre for Energy, Environmental and Technical Research, Madrid, Spain

Tungsten is being assessed to replace carbon as material for plasma-facing components in W7-X. In stellarators, it is assumed that exposure to massive amounts of tungsten may lead to thermal quenches but not to current quenches like in tokamaks. Still, a thermal quench releases energy rapidly and localised heat loads may affect the integrity of the plasma facing components. For first quantitative assessments of the impact of thermal quenches in helical devices, the plasma response to massive tungsten TESPEL injections ultimately leading to plasma termination was analysed in LHD. Above a threshold, plasma termination within one energy confinement time is due to the formation of cold fronts propagating from the injection point inwards to the plasma centre. We could show that the application of additional ECRH mitigates the termination process.

P 25.14 Thu 16:30 ELP 6: Foyer

Reduction of maximum gyrokinetic instability growth in maximum-J stellarators — •Paul Costello, Gabriel G. Plunk, and Per Helander — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald, Germany

For the last decade, it has been known that the growth of many local gyrokinetic instabilities, which cause turbulence, is greatly reduced in stellarators which possess the maximum-J property [1]. This a result from linear, normal mode theory.

Here, we show that this benefit of the maximum-J property is also reproduced by gyrokinetic optimal mode theory [2,3]. In this analysis, upper bounds on the maximum allowable growth of instabilities are derived by finding the perturbations which can instantaneously maximise the growth of an energy measure of the gyrokinetic system. These optimal modes may not maintain their growth indefinitely, but their growth rate is greater than any normal mode in the system. Moreover, the optimal mode growth also bounds the total growth of instabilities in the nonlinear system. We apply this optimal mode analysis to a gyrokinetic system with gyrokinetic ions and bounce-averaged electrons. We construct the optimal modes of the generalised free energy [3] of this system in toy-model magnetic fields and find that those which possess the maximum-J property show a reduced optimal growth rate.

[1] J. H. E. Proll, P. Helander, J. W. Connor, and G. G. Plunk. PRL 2012.
[2] G. G. Plunk and P. Helander. JPP 2022.
[3] G. G. Plunk and P. Helander. JPP 2023.

P 25.15 Thu 16:30 ELP 6: Foyer

Onto Island Localized Modes in the Wendelstein 7-X scrape off layer — •Dario Cipciar[1], Carsten Killer[1], Jiri Adamek[2], Olaf Grulke[3], Kian Rahbarnia[1], Christian Brandt[1], and W7-X Team[1] — [1]Max- Planck-Institut für Plasmaphysik Greifswald, Germany — [2]IPP of the CAS Prague, Czech republic — [3]Technical University of Denmark, Lyngby, Denmark

In the Wendelstein 7-X stellarator scrape off layer, magnetic islands are present and partly intersected by divertor targets. Around the "O-point" of the islands, a region of uninterrupted, closed field lines can remain. Measurements with electric probes indicate that low frequency mode activity, which is also seen by other plasma diagnostics such as magnetics and X-ray tomography, is associated to this particular region. These modes challenge the current picture of the magnetic islands as stationary resonances of the external magnetic field. We investigate the possibility of local currents existing in the islands, which periodically modify the magnetic structure of the islands (compress and expand). These changes in the shape of the islands can lead to self-regulation of island transport channels might and provide an explanation to the observed low-frequency modulation of island density electron and ion temperature, and plasma potential.

P 25.16 Thu 16:30 ELP 6: Foyer

A high power, galvanically isolated power supply for current drive in the STØR experiment — •Sebastian Haag[1], Nils Fahrenkamp[1], Stefan Knauer[1], Simone Mannori[2], Alessandro Lampasi[2], and Peter Manz[1] — [1]Institute of Physics University of Greifswald, Greifswald, Germany — [2]ENEA, Rome, Italy

Extreme Ultraviolet (EUV) lithography is a crucial technology for projecting high-resolution patterns onto silicon wafers, enabling the production of smaller and more powerful microchips. At the desired wavelength, lasers are no longer available as light sources, so plasma sources have to be used. Laser-produced plasmas (LPPs) prevailed as radiation source because the discharge-produced plasmas (DPPs) did not achieve the desired parameters. The STØR experiment introduces an alternative magnetic confinement concept which is particularly well suited as radiation source, as it contributes to reducing costs and size. To ignite the plasma and drive the helical plasma current, a power supply has to be designed. It is capable of applying a voltage high enough to ignite the plasma and drive currents of up to 2 kA. By utilizing Supercaps as energy storage devices, we can achieve a high power system which is galvanically isolated to minimize plasma interactions with the vessel and provide a steady input voltage over the operating time. Voltage and current are controlled via a high-side and a low-side IGBT module in a buck converter configuration. Together with a custom design of the electrodes this allows for the setup of a magnetically confined compact plasma tori without external toroidal and poloidal magnets, which are ideal properties for a radiation source.

P 25.17 Thu 16:30 ELP 6: Foyer

Influence of collisionality on the electron dynamics in CCRF discharges — •Jens Kallähn, Denis Eremin, and Ralf Peter Brinkmann — TET, Ruhr University Bochum

In this contribution we investigate the influence of the pressure on the power absorption dynamics and electron transport in an rf cylindrical magnetron plasma.

Kinetic PIC simulations were utilized to gain insight into the electron heating and transport across the magnetic field.

They revealed the Hall heating to be a new magnetized electron heating mechanism different from the Ohmic heating it was classified as before. This mechanism is caused by an electric field at the edge of the sheath during the sheath expansion and by a reversed electric field during the sheath collapse. The related new operation mode was proposed to be called "mu-mode", because of its dominance in magnetized CCRF discharges and to differentiate it from other modes in rf plasmas.

While the Hall heating is dominant at low pressures, the collisional heating mechanism prevails in the high-pressure regime with a transition region where both are important.

The reversed electric field is generated for the charge balance at the powered electrode to be maintained during the sheath collapse via enhancing the electron flux. This increase occurs due to three different mechanisms: collisionless transport of electrons due to the polarization drift, collisional drift in the reversed electric field, and collisional diffusion through Hall heating.

P 25.18 Thu 16:30 ELP 6: Foyer

Tungsten Observation at Wendelstein 7-X — •Birger Buttenschön[1], Daihong Zhang[1], Thomas Pütterich[2], and W7-X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [2]Max-Planck-Institut für Plasmaphysik, Garching, Germany

In the first part of the second operation phase of the Wendelstein 7-X (W7-X) stellarator, some 280 wall and divertor tiles were made from tungsten or a tungsten-coated material. Those tiles were located in differently loaded regions of the wall. The purpose was to investigate how plasma-wall interaction might lead to contamination of the plasma with tungsten. As a tool to assess the tungsten concentration in the plasma, vacuum-ultraviolet (VUV) spectroscopy is used in combination with 2D bolometry.

While a detailed analysis requires somewhat advanced fitting methods (e.g. for the 5nm quasi-continuum), first - mostly qualitative - results can be readily obtained from the measured VUV spectra. For example, the acquired data allows to roughly determine the tungsten concentrations in specific plasma discharges, and it is used to define a minimum tungsten concentration at which the VUV spectrometer registers a signal above noise.

This contribution shows a number of different tungsten experiments performed in W7-X, the corresponding VUV spectra and what can be learned from the existing data set.

P 25.19 Thu 16:30 ELP 6: Foyer

Computer Vision Deep Learning-Based Shattered Pellet Injection (SPI) Shard Tracking at ASDEX Upgrade — •Johannes Illerhaus[1,2], Paul Heinrich[1,2], Mohammad Miah[1,2], Gergely Papp[1], Tobias Peherstorfer[3], Wolfgang Treutterer[1], Bernhard Sieglin[1], Udo von Toussaint[1], Hartmut Zohm[1], Frank Jenko[1], and the ASDEX Upgrade Team[4] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Technische Universität München, Garching, Germany — [3]Technische Universität Wien, Vienna, Austria — [4]see the author list of U. Stroth et al. 2022 \textit{NF} 62 042006

A computer vision deep learning pipeline was constructed to automate the analysis of the more than 1000 videos created in lab experiments on the SPI test bench at ASDEX Upgrade. Our machine learning (ML) models provide highly accurate segmentation of the fragments shown in these videos. This allows for the labeling of the entire dataset, of which previously only 177 videos had been labeled using a pipeline based on traditional computer vision. The ML models eliminate the previously necessary human supervision, reduce the run time from months to a few hours and increase the accuracy and robustness of labeling. The shards are then tracked between frames with the goal of estimating their size and speed distributions. This enables using the experimental results to validate theoretical models predicting the right system setup and pellet attributes to produce the fragment distributions for optimal disruption mitigation. This will ultimately help inform design decisions for the ITER SPI, ITER's primary disruption mitigation system.

P 25.20 Thu 16:30 ELP 6: Foyer

Spatially and temporally resolved simulations of the Cs dynamics in large negative hydrogen ion sources assisted by TDLAS measurements — •Daniele Mussini, Adrian Heiler, Dirk Wünderlich, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik (IPP), Boltzmannstr. 2, 85748 Garching

Negative hydrogen ion sources for the ITER neutral beam injectors rely on the production of negative hydrogen ions on a low work function surface (plasma grid). To reduce the surface work function, a Cs layer is formed on the plasma grid by steadily evaporating Cs into the source. However, mainly due to plasma-surface interaction and Cs redistributions, it is not straightforward to generate a temporally stable and homogeneous Cs layer. In particular, this is a major challenge for the long pulse operation required for ITER (1000 s in H, 3600 s in D). To gain insight into the Cs dynamics by numerical modeling, the Monte-Carlo Test-particle code CsFlow3D was developed at IPP. The code uses many input parameters such as EM fields, plasma temperature and density profiles to determine the Cs dynamics within sources of different sizes. The current main objective is to investigate the Cs behavior during long pulses for both H or D operation. To do so, an updated version of input parameters must be implemented. In addition, the synthetic laser absorption diagnostic (TDLAS) needs to be simulated to benchmark the code against experimental results. This contribution is intended to show some preliminary results and to provide an outlook on future steps for the further development and improvement of the code.

P 25.21 Thu 16:30 ELP 6: Foyer

Deuterium Uptake in Tungsten Damaged at High Temperature — •Laurin Hess, Mikhail Zibrov, and Thomas Schwarz-Selinger — Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching b. München

Retention of hydrogen fuel in the tungsten wall of future fusion reactors is an essential area of research, as it is an integral part of modelling the tritium inventory. It has been shown that hydrogen retention significantly increases due to displacement damage produced by 14 MeV neutrons. Until now, many experiments have simulated the displacement damage in a reactor by damaging the tungsten at low temperatures using high energy ions. However, recent experiments have shown that retention behaves differently when the damaging happens at high temperatures, as in a fusion reactor. One possible explanation for this would be the formation of nm-sized voids. It has been suggested that the formation of vacancy clusters depends on the damaging rate. To account for this, two damaging modes have been compared. One with a high intermittent damaging rate using a raster scanned focused beam and one with a low continuous damaging rate using a wobbled defocused beam. In addition, the lateral homogeneity of the two modes has been examined using proton Elastic Backscattering Analysis of gold implantation. Then, the deuterium uptake of tungsten damaged at 1350 K has been studied by decorating the samples with 5 eV deuterium ions.

P 25.22 Thu 16:30 ELP 6: Foyer

A Gyrokinetic Electron Model for BSL6D — •Maximilian Pelkner — Max Planck Institute for Plasma Physics, Garching

The goal of numerical plasma physics is to understand the behaviour of plasmas numerically, since analytical tools for solving the underlying Vlasov equation are limited. Only in recent years has computing power increased to the point where fully kinetic simulations of plasmas, i.e. simulations of the full phase space, are within reach. The BSL6D code is an example of such a "fully kinetic" code, but for computational reasons it so far simulates only fully kinetic ions with adiabatic electrons. The main goal of my work is to improve the simulation by implementing a drift kinetic electron model. In my poster I will present the principle of BSL6D, how the electron model will be implemented and also some comparisons between the code and existing analytical solutions (e.g. Ion Sound Wave).

P 25.23 Thu 16:30 ELP 6: Foyer

Atomic hydrogen density measurements with TALIF above a sample surface — •Julian Hörsch, Christan Wimmer, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2D-85748, Garching bei München, Germany

Two photon Absorption Light Induced Fluorescence (TALIF) is a diagnostic technique that will be used in an upcoming research program in combination with other diagnostics to characterize the production of negative hydrogen ions in negative ion sources. These negative hydrogen ions can be produced by surface conversion of neutral hydrogen atoms on a low work function material as cesium. As TALIF allows the direct determination of the density and temperature of neutral hydrogen atoms it is of particular interest for characterizing the negative ion production mechanisms. In this project TALIF is applied to a small-scale experiment to study the available density of neutral hydrogen atoms for negative ion production above a sample, but without negative ion production itself. The TALIF signal is measured with varying distance to the surface of the sample and for various sample materials. In particular, the influence of the distance to the surface on the hydrogen properties and the isotopic differences between hydrogen and deuterium are investigated.

P 25.24 Thu 16:30 ELP 6: Foyer

heat conduction in the vicinity of an island — •Gregor Pechstein and Per Helander — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald

In magnetically confined fusion plasmas, energy is transported across flux-surfaces toward the plasma edge and the surrounding vessel. It is a challenge to control and limit the wall loads since the tolerable energy flux onto plasma facing component is limited by a number of technical constraints. In order to control and reduce the loads, tokamaks and stellarators exploit divertor magnetic fields guide the heat flux onto target plates, and try to maximise radiation from the edge plasma. When the radiative losses are particularly high, the plasma sometimes "detaches" from the walls and the energy flux to the latter drops dramatically.

The key feature of plasma energy transport that allows for the use of a divertor is the fact that the transport is highly anisotropic. As a result, if the magnetic field is shaped in such a way that different field lines have different topology, the the heat flux can vary greatly across any surface across which the topology changes. We consider anisotropic heat conduction and radiation in the simplest possible mathematical setting in which the field lines change topology, namely, in the geometry of a single chain of magnetic islands. The aim is to shed light on the basic question of how a variation in field-line topology affects the location and amount of plasma radiation.

P 25.25 Thu 16:30 ELP 6: Foyer

Design of a new imaging diagnostic at ASDEX Upgrade for divertor fluctuation studies — •Manuel Herschel[1,2], Michael Griener[2], Tim Happel[2], Daniel Wendler[1,2], Ulrich Stroth[1,2], and The ASDEX Upgrade Team[3] — [1]Technical University of Munich, Physics Department, Chair for Plasma Edge and Divertor Physics, 85747 Garching, Germany — [2]Max-Planck-Institute for Plasma Physics, Garching, Germany — [3]See author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

The divertor will play a critical role in future fusion power plants. The ASDEX Upgrade tokamak experiment (AUG) is currently being equipped with a flexible divertor that will offer new magnetic configurations such as compact radiative or snowflake divertors. To investigate the plasma exhaust in this divertor, good diagnostic coverage is required.

Gas Puff Imaging (GPI) is a well-established technique to observe the microscopic structures that constitute plasma turbulence. Active injection of thermal helium gas creates a spatially localized light emission depending on the local plasma conditions, while a fast camera captures the image with high spatial and temporal resolution.

In this work, an improved GPI diagnostic is designed for the new AUG divertor. A fast in-vessel piezo valve is combined with an optimized line-of-sight geometry and optics to image multiple spectral lines simultaneously, which is necessary for the correct interpretation of the data. This promises better understanding of the X-point and divertor region.

P 25.26 Thu 16:30 ELP 6: Foyer

Hybrid kinetic-MHD simulations of runaway electron beam termination events in realistic 3D tokamak geometry — •Hannes Bergstroem[1], Matthias Hoelzl[1], and Vinodh Bandaru[2] — [1]Max Planck Institute for Plasma Physics, Garching b. M. — [2]Indian Institute of Technology Guwahati, Assam

Disruption events and the associated generation of highly energetic runaway electrons (REs) remain one of the largest threats to future high current tokamak reactor designs like ITER and DEMO. Studies have indicated that even with systems in place to mitigate these events, a multi-MA RE beam may be unavoidable during the nuclear phase of ITER operation. The transport of REs in 3D MHD fields is however difficult to model and presents one of the largest uncertainties for these estimates, since it can have a substantial impact on the beam formation and the details of the ensuing termination. This is particularly challenging since REs carry most of the current at these stages and therefore dominate the dynamics of the plasma, rendering test particle approaches insufficient.

In this work we present a newly implemented hybrid kinetic-MHD model in JOREK, where the kinetic RE population is coupled to the MHD equations in realistic 3D tokamak geometry using a particle-in-cell approach. At first, results from analytical validation with respect to the force balance in a plasma with high RE current are shown. In addition we present results from a RE beam termination scenario in JET, as it occurs due to a burst of 3D MHD activity.

P 25.27 Thu 16:30 ELP 6: Foyer

Towards a stochastic variational principle for quasi-neutral two fluids — •Sayyed Amin Raiessi Toussi[1], Tomasz Tyranowski[2], and Omar Maj[1] — [1]Max Planck Institute for Plasma Physics, D-85748 Garching, Germany. — [2]Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente, 7522NH Enschede, The Netherlands

Quasi-neutral multi-fluid models are commonly used to describe particle and energy transport in the edge and scrape-off layer (SOL) of magnetically confined fusion plasmas [R. Schneider, Contrib. Plasma Phys., 46, 2006].

For the purpose of developing particle schemes, a variational formulation is desirable and useful. In this work we use stochastic Euler-Poincaré reduction [Chen, Cruzeiro & Ratiu, J Nonlinear Sci 33, 5 (2023)] in order to formulate a variational principle for quasi-neutral two-fluid models, including non-ideal effects such as viscosity and heat fluxes. In this approach, the quasi-neutrality condition is treated as a constraint, the electric potential being the corresponding Lagrange multiplier. Therefore this variational principle combines elements from the theory of compressible non-ideal flows with Lagrangian constraints [Morrison, Andreussi, Pegoraro, J.Plasma Phys. 86 (2020)]. As a proof of concept, we discuss here simple models of viscosity and heat fluxes, together with some preliminary considerations about generalization to more realistic physics.

P 25.28 Thu 16:30 ELP 6: Foyer

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

Magnetic confinement fusion requires high $\beta = \langle p\rangle/(B^2/2\mu_0)$, the ratio of plasma pressure to magnetic pressure, to access high performances. Moderate β can be beneficial for ion-temperature-gradient (ITG) driven turbulence. However, as β is increased above a certain threshold, the so-called kinetic-ballooning-mode (KBM) can be destabilized. This is a plasma pressure gradient driven instability which is inherently electromagnetic and can lead to strong outwards directed heat fluxes, degrading plasma confinement in the process. While, linearly, KBMs have been successfully studied in the stellarator Wendelstein 7-X with flux-tube simulations, it was also shown that the instability tends to be most unstable while developing a global structure on the magnetic surface. While investigating linear simulations in Wendelstein 7-X geometry with the global gyrokinetic code Euterpe both KBMs and high-β trapped electron modes have been observed. Using this code non-linear simulations are conducted on the MareNostrum supercomputer to investigate the turbulent behaviour of these electromagnetic instabilities.

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In-situ spectral calibration of the Thomson scattering system at W7-X using Rayleigh scattering — •Jannik Wagner, Golo Fuchert, Ekkehard Pasch, Jens Knauer, Kai Jakob Brunner, Sergey A. Bozhenkov, Marcus Beurskens, Matthias Hirsch, Robert C. Wolf, and W7-X Team — Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald

In most high temperature fusion experiments, Thomson scattering is one of the main diagnostics for measuring electron temperature and density. So far, the spectral calibration at W7-X uses the light of a supercontinuum laser in combination with a monochromator scattered diffusively by a plate in front of the observation optics. Using this approach, however, the window between the plasma vessel and the observation optics is not part of the calibration and its transmission can vary during an experimental campaign due to coating.

To overcome these issues, a new in-situ calibration has been developed in recent years. Using an optical parametric oscillator (OPO), Rayleigh scattering inside the plasma vessel acts as tunable volumetric light source that can be observed with the exact same setup used for the Thomson scattering measurements. A proof-of-principle was demonstrated in 2018/19, but so far the quality was not sufficient to replace the existing calibration method.

In this work, improvements of the optical setup and in particular a more reliable energy measurement are presented. These measures reduce the experimental uncertainties in a new Rayleigh scattering experiment from which improved calibration curves could be determined.

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Design of a dispersion interferometer at ASDEX Upgrade for disruption studies — •Andrew Moreau[1,2], Alexander Bock[2], Kai Jakob Brunner[3], Andres Cathey[2], Matthias Hoelzl[2], Jens Knauer[3], Jens Meineke[3], and Thomas Puetterich[2] — [1]Ludwig Maximilian University of Munich, Faculty of Physics, 80799 Munich, Germany — [2]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [3]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany

Disruptions significantly challenge the successful utilization of future tokamak-class fusion power plants which are predicted to be larger and operate at higher magnetic fields and plasma currents. The electron density is a key quantity needed in the investigation of plasma dynamics to understand the mechanisms of thermal and current quenches, the generation and suppression of runaway electrons and the mitigation or control of disruption effects. At ASDEX Upgrade (AUG) there are currently no interferometer diagnostics which can explore disruption or disruption mitigation scenarios free of fringe jumps, low signal-to-noise or vibration errors. We present work towards the commissioning of a dispersion interferometer at AUG which would harness the coherence conservation principle of second-harmonic generation in order to alleviate the need for a reference beam path. This reduces the complexity significantly and becomes intrinsically free of vibrational errors. With state-of-the-art nonlinear crystals, we increase the capabilities of this system in signal-to-noise. We then show how JOREK simulations can contribute to diagnostic modelling.

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Modelling ion orbits in the W7-X neutral beam box — •Lucas van Ham[1], Samuel Lazerson[1], Björn Hamstra[2], Paul McNeely[1], Norbert Rust[1], and Dirk Hartmann[1] — [1]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany — [2]Eindhoven University of Technology, 5612 AZ Eindhoven, The

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Neutral beam injection (NBI) on Wendelstein 7-X (W7-X) is limited in duration by the heat loads experienced by the NBI components. Deposition patterns on these components have been observed to shift upwards when the main magnetic field of W7-X is on, suggesting stray magnetic fields are penetrating the neutral beam box. We aim to investigate the cause of this shift and how to mitigate this issue. In this work, ion orbits inside the W7-X NBI box will be investigated using the Monte Carlo particle following code BEAMS3D. Simulations will be performed to estimate calorimeter heat loads which will be compared against experimental results. Next, the bending magnet will be included in simulations and a similar investigation will be carried out for the H+ and H2+ ion dumps. Future simulations will focus on including the effect of the magnetization of the magnetic material inside the NBI box on the orbits of the ions.