Plasma Physics Division
Fachverband Plasmaphysik (P)

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Overview of Invited Talks and Sessions

(Lecture halls P-H11 and P-H12; Poster P)

Invited Talks

P 1.1	Mon	11:00–11:30	P-H11	**Plasma Physics in EUV Lithography** — •Iris Pilch
P 1.2	Mon	11:30–12:00	P-H11	**Optical emission spectroscopy of spokes in magnetron sputtering discharges** — •Julian Held, Philipp A Maass, Volker Schulz-von der Gathen, Achim von Keudell
P 1.3	Mon	12:00–12:30	P-H11	**Functional coatings by atmospheric pressure plasma technology** — •Kristina Lachmann, Thomas Neubert, Annika Mann, Marvin Omelan, Michael Thomas
P 6.1	Tue	11:00–11:30	P-H11	**Laser diagnostics on atmospheric pressure plasmas: From basic to fancy** — •Volker Schulz-von der Gathen, the CRC 1316 team
P 6.2	Tue	11:30–12:00	P-H11	**Liquid tin interaction with deuterium plasmas** — •Armin Manhard, Martin Balden, Thomas Schwarz-Selinger, Rudolf Neu
P 6.3	Tue	12:00–12:30	P-H11	**Plasma jets on surfaces** — •Ana Sobota
P 10.1	Wed	11:00–11:30	P-H11	**AI in fusion: assisting plasma exhaust modelling by machine-learning techniques** — •Sven Wiesen
P 10.2	Wed	11:30–12:00	P-H11	**COMPACT - A new complex plasma facility for the ISS** — •Christina A. Knapek
P 10.3	Wed	12:00–12:30	P-H11	**Optical diagnostics of vacuum arc discharges for switching applications** — •Sergey Gortschakow, Ralf Methling, Steffen Franke, Diego Gonzalez, Dirk Uhrlandt, Sergey Popov, Alexander Batrakov
P 16.1	Thu	11:00–11:30	P-H11	**Effect of the green energy revolution on circuit breakers and switches in electrical power distribution systems** — •Erik D. Taylor
P 16.2	Thu	11:30–12:00	P-H11	**Plasma-beta effects on the island divertor of Wendelstein 7-X** — •Alexander Knieps, Yasuhiro Suzuki, Joachim Geiger, Andreas Dinklage, Song Zhou, Henning Thomsen, Marcin Jakubowski, Ralf König, Michael Endler, Yu Gao, Yunfeng Liang
P 16.3	Thu	12:00–12:30	P-H11	**Surface modification of inorganic materials by atmospheric-pressure plasmas** — •Claus-Peter Klages, Vitaly Raev
P 20.1	Fri	11:00–11:30	P-H11	**On the hunt for a reactor-relevant scenario for W7-X** — •Golo Fuchert
P 20.2	Fri	11:30–12:00	P-H11	**Plasma für die Gaskonversion: Power-to-X** — •Andreas Schulz, Katharina Wiegers, Matthias Walker, Günter Tovar
P 20.3	Fri	12:00–12:30	P-H11	**Combined Phase Contrast Imaging and Small-Angle X-Ray Scattering Diagnostic of Relativistic Plasmas at the High Energy Density Instrument at European XFEL** — •Alejandro Laso Garcia, Toma Toncian, Hauke Hoeppner, Alexander Pelka, Carsten Baehtz, Erik Brambrink, Jan-Patrick Schwinkendorf, Motoaki Nakatsutsumi, Johannes Hagemann, Thomas Preston

Invited talks of the joint symposium Plasmas in the Universe (SYPU)

See SYPU for the full program of the symposium.

SYPU 1.1	Wed	9:00– 9:30	Audimax	**Recent progress in simulations of dense quantum plasmas and warm dense matter** — •Michael Bonitz, Paul Hamann, Tobias Dornheim, Zhandos Moldabekov, Alexey Filinov, Jan Vorberger, Pavel Levashov
SYPU 1.2	Wed	9:30–10:00	Audimax	**The quark gluon plasma: from the laboratory to neutron stars** — •Jan Steinheimer
SYPU 1.3	Wed	10:00–10:30	Audimax	**Characterizing the QCD Plasma** — •Andrea Dubla

Sessions

P 1.1–1.3	Mon	11:00–12:30	P-H11	**Invited talks I**
P 2.1–2.5	Mon	14:00–15:15	P-H11	**Low Pressure Plasmas I**
P 3.1–3.6	Mon	14:00–15:30	P-H12	**Laser Plasmas I**
P 4.1–4.4	Mon	16:00–17:00	P-H11	**Low Pressure Plasmas II / Laser Plasmas II**
P 5.1–5.3	Mon	16:00–17:05	P-H12	**Helmholtz Graduated School HEPP I**
P 6.1–6.3	Tue	11:00–12:30	P-H11	**Invited talks II**
P 7.1–7.6	Tue	14:00–15:30	P-H11	**Atmospheric Pressure Plasmas I**
P 8.1–8.3	Tue	14:00–15:15	P-H12	**Helmholtz Graduate School HEPP II**
P 9.1–9.49	Tue	16:00–17:30	P	**Poster I**
P 10.1–10.3	Wed	11:00–12:30	P-H11	**Invited talks III**
P 11.1–11.6	Wed	14:00–15:30	P-H11	**Codes and Modelling**
P 12.1–12.6	Wed	14:00–15:30	P-H12	**Magnetic Confinement / Plasma Wall Interaction I**
P 13.1–13.5	Wed	16:00–17:15	P-H11	**Dusty Plasmas**
P 14.1–14.4	Wed	16:00–17:10	P-H12	**Plasma Wall Interaction II / HEPP III**
P 15	Wed	17:30–18:30	P-MV	**Annual General Meeting**
P 16.1–16.3	Thu	11:00–12:30	P-H11	**Invited talks IV**
P 17.1–17.5	Thu	14:00–15:15	P-H11	**Astrophysical Plasmas**
P 18.1–18.3	Thu	14:00–15:15	P-H12	**Helmholtz Graduate School HEPP IV**
P 19.1–19.48	Thu	16:00–17:30	P	**Poster II**
P 20.1–20.3	Fri	11:00–12:30	P-H11	**Invited talks V**
P 21.1–21.7	Fri	14:00–15:45	P-H11	**Atmospheric Pressure Plasmas II**
P 22.1–22.3	Fri	14:00–15:15	P-H12	**Helmholtz Graduate School HEPP V**

Annual General Meeting of the Plasma Physics Division

Wednesday 17:30–18:30 P-MV

P 1: Invited talks I

Time: Monday 11:00–12:30 Location: P-H11

Invited Talk P 1.1 Mon 11:00 P-H11
Plasma Physics in EUV Lithography — •Iris Pilch — Carl Zeiss SMT GmbH, Oberkochen, Germany

Extreme Ultraviolet (EUV) lithography is a technology for high volume manufacturing of semiconductors. The scanners operate at a wavelength of 13.5 nm. The main parts of a scanner are the EUV light source, the illumination optics, the mask, the projection optics and the wafer stage.

The EUV source of a scanner is a laser-produced plasma (LPP) delivering high power, which is needed to ensure productivity of the maschine. For metrology applications, EUV sources with moderate or even low powers are sufficient, and both technologies LPP and discharge-produced plasmas (DPP) are common.

In this talk, an overview on EUV lithography and its next development will be given, and the different EUV source types as well as the challenges of EUV light generation will be described.

Invited Talk P 1.2 Mon 11:30 P-H11
Optical emission spectroscopy of spokes in magnetron sputtering discharges — •Julian Held, Philipp A Maass, Volker Schulz-von der Gathen, and Achim von Keudell — Experimental Physics II, Ruhr University Bochum, Germany

Spokes are patterns of increased light emission, observed to rotate in front of the cathode of magnetron sputtering discharges. They move through the plasma at velocities of several km/s in or against the ExB direction of the discharge. The often distinctly triangular shape of these features has captivated many scientists. Nevertheless, the reason for this curious shape is still not fully understood. This is because the high velocity of spokes and their initial creation at arbitrary positions render measurements challenging. Thus, more demanding plasma diagnostic techniques that require data acquisition over multiple discharge pulses require synchronization between measurement and spoke movement. In this contribution, we present optical emission spectroscopy of spokes in both high power impulse magnetron sputtering (HiPIMS), as well as direct current magnetron sputtering (DCMS). A gated camera is combined with optical filters, isolating emission lines of metal and working gas neutrals and ions. The camera is then triggered on the spoke movement, allowing us to accumulate light from several acquisitions without averaging out the spoke signal. These measurements reveal the dynamic of electrons drifting through spokes in both DCMS and HiPIMS and explain how the distinct spoke shape is formed.

Invited Talk P 1.3 Mon 12:00 P-H11
Functional coatings by atmospheric pressure plasma technology — •Kristina Lachmann, Thomas Neubert, Annika Mann, Marvin Omelan, and Michael Thomas — Fraunhofer Institute for Surface Engineering and Thin Films IST, Bienroder Weg 54E, 38108 Braunschweig, Germany

Atmospheric pressure plasma technology is well known for surface activation, functionalization and cleaning. It is also a versatile method to deposit thin films in the range of several 10 - 100 nm.

The main objective of such coatings is to achieve a higher functionality. Depending on the application, this ranges from a tailored surface tension to adhesion control or chemically reactive surfaces or antimicrobial properties. In the past, film deposition was focussed on the use of small molecules such as (silicon) organic compounds with high vapour pressures. More recently, more complex organic molecules such as fatty acids or polyphenols have also been investigated to achieve higher process sustainability and further functionalities such as soil repellency. To determine surface characteristics the analysis of these films is essential. Here, (derivatisation methods in combination with) FTIR-ATR spectroscopy, staining, investigations into soiling behaviour and the determination of surface tension by contact angle measurements are suitable methods.

In this work, we will demonstrate various applications for complete and area-selective atmospheric pressure plasma coatings not only on flat samples, but also on three-dimensional shapes.

P 2: Low Pressure Plasmas I

Time: Monday 14:00–15:15 Location: P-H11

P 2.1 Mon 14:00 P-H11
Influence of a remote plasma on the chemical vapour deposition of ZrO2 based layers — •Philipp A. Maass[1], Vitali Bedarev[1], Sebastian M. J. Beer[2], Marina Prenzel[1], Marc Böke[1], Anjana Devi[2], and Achim von Keudell[1] — [1]Experimental Physics II, Ruhr-University, Bochum, Germany — [2]Inorganic Chemistry II, Ruhr-University, Bochum, Germany

Chemical vapour deposition (CVD) is a widely applied technique used for thin film deposition. The combination with a plasma source (PECVD) enables the fine-tuning of parameters, opening new possibilities for the fabrication of functional coatings, such as thin thermal barrier coatings.

A metalorganic precursor is transported into the reaction chamber by a 50 sccm N2-flow at pressures of 100 Pa. A ZrO2 layer is deposited onto a heated substrate in the centre of the chamber with a growth rate of several 100 nm/h. To influence and improve the reaction chemistry, a microwave plasma source is mounted opposite the substrate surface. It interacts with the incoming precursor molecules, with the aim to reduce the reaction temperature and change the deposition properties.

During this process, the growth rate and substrate temperature are monitored by in-situ ellipsometry. The deposited layers are characterised in stoichiometry and crystallinity, using X-ray photoelectron spectroscopy (XPS) and X-ray diffraction (XRD).

Depositions are carried out with and without the use of the plasma source. The different growth characteristics are investigated and compared.

P 2.2 Mon 14:15 P-H11
High-resolution terahertz spectroscopy with quantum-cascade lasers for atomic oxygen density measurements — •Jente Wubs, Uwe Macherius, Klaus-Dieter Weltmann, and Jean-Pierre van Helden — Leibniz Institute for Plasma Science and Technology (INP), Felix-Hausdorff-Straße 2, 17489 Greifswald, Germany

Absorption spectroscopy in the terahertz (THz) spectral region between 0.3 and 6 THz provides access to energies that correspond to molecular and atomic transitions involving rotational mode changes and fine structure splitting, respectively. In addition, THz frequencies lie well above typical values for the plasma frequency, allowing the electron density to be determined from a phase shift of transmitted THz radiation. Knowledge about the electron density as well as atomic and molecular densities in plasmas is highly relevant for technological and scientific applications. A promising diagnostic for measuring these densities is THz time-domain spectroscopy. It is based on the ultrafast generation and detection of broadband THz pulses; however, the spectral resolution is limited to approximately 1 GHz. THz quantum-cascade lasers (QCLs) operating in continuous-wave mode are therefore better suited for the detection of sharp absorption lines. Although these lasers have a relatively small tuning range, their narrow linewidth (below 10 MHz) makes them an excellent THz source for high-resolution spectroscopy. In this contribution, first results are presented on the absolute density of ground state oxygen atoms, measured in a low-pressure RF plasma using a QCL operating at 4.75 THz.

P 2.3 Mon 14:30 P-H11
Operando FTIR monitoring of silicon nanoparticle treatment in a low-pressure plasma — •Oguz Han Asnaz and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Germany

With their unique physical, mechanical, electrical and optical properties, nanoparticles have found a wide range of applications ranging from drug carriers in bio-medicine over catalysts to batteries and solar cells. Control of the particle's bulk and surface properties is required in many of these applications. In this contribution, we present results for Silicon nanoparticles generated in a capacitively coupled low-pressure plasma. The particles are then confined in a secondary discharge for further treatment with monitoring during operation by means of in situ time-resolved FTIR spectroscopy with a multipass cell for 24 passes. Using different reactive gasses, surface passivation by hydrogen or oxygen treatment as well as deposition of thin carbon films is possible. Additionally, using an electrostatic particle extractor system (EPEX) developed in our group, particle samples are extracted at multiple moments during the treatment for further analysis with negligible disturbance of the plasma system.

P 2.4 Mon 14:45 P-H11

Plasma diagnostics combination: Calorimetric Probe and Retarding Field Analyser — •Felix Schlichting and Holger Kersten — Christian-Albrechts-Universität, Kiel, Deutschland

A recently developed plasma diagnostic, which combines a retarding field analyser (RFA) and a passive thermal probe (PTP), has been used for the characterization of different plasma environments. The PTP serves as the collector of the RFA, in front of which three centrally aligned grids are operated as the retarding field system. In this setup the collector does not only measure the incoming ion current depending on the voltage applied to the grids of the RFA, but also the incoming energy flux density of the impinging ions or neutrals, respectively. In this study the combined diagnostic is used in an RF plasma, where the probe is embedded into the grounded electrode, as well as in a DC Magnetron sputtering system, where the probe is located at substrate position. The ion energy distribution (IED) is determined regarding the energy exchange of the neutral background gas with the ions extracted from the plasma source. Furthermore, with suitable voltage applied to the grids of the RFA, the secondary electron emission from the collector can be quantified in regard to the ion energies and the material used for the collector plate.

P 2.5 Mon 15:00 P-H11

Selbstkonsistente Modellierung einer linearen Mikrowellenplasmaquelle in einem Magnetfeld — •Stefan Merli[1], Andreas Schulz[1], Matthias Walker[1], Yannick Kathage[2], Stefan Hanke[2] und Christian Day[2] — [1]IGVP, Universität Stuttgart — [2]Karlsruhe Institute of Technology (KIT), Karlsruhe

In diesem Beitrag wird der Einfluss von magnetischen Feldern auf die Eigenschaften einer linearen Mikrowellenplasmaquelle, der sogenannten Duo-Plasmaline, numerisch und experimentell untersucht. Bei dem FEM-basierten Simulationsmodell werden die Transportgleichungen für die Elektronen und der schweren Teilchen selbstkonsistent mit der elektrischen Feldverteilung der eingestrahlten Mikrowelle gelöst. Das betrachtete Plasmagas ist H_2, welches durch insgesamt 44 Elektronenstoß-, Schwerteilchenstoß- und Wandrekombinationsreaktionen in das Modell implementiert wurde. Das zeitlich konstante und homogene Magnetfeld, welches über die Diffusivitäts- und Mobilitätstensoren in die Transportgleichungen eingeht, wurde in paralleler und senkrechter Orientierung zur Plasmaquelle untersucht. Die magnetische Flussdichte wurde über einen weiten Bereich von 0 T über 87,5 mT (ECR) bis hin zu 1 T variiert. Das Hauptaugenmerk lag auf der Untersuchung des Einflusses des Magnetfeldes auf den Heizmechanismus, der Form des Plasmas, den Änderungen in der Dichte und Temperatur sowie in der Dissoziationsrate für H_2. Die Ergebnisse aus den Simulationen werden mit Untersuchungen aus dem Experiment FLIPS, bei welchem homogene Magnetfelder bis zu 250 mT parallel oder senkrecht zur Plasmaquelle erzeugt werden können, verglichen.

P 3: Laser Plasmas I

Time: Monday 14:00–15:30 Location: P-H12

P 3.1 Mon 14:00 P-H12

Pump-probe XUV platform for ultrafast laser-matter interaction research — •Milenko Vescovi[1], Marvin E.P. Umlandt[1,2], Karl Zeil[1], and Ulrich Schramm[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [2]Technische Universität Dresden, 01062 Dresden, Germany

Interaction of ultrafast relativistic intensity laser pulses with matter has shown to be a promising field for the study of matter at extreme conditions, electromagnetic fields generation/amplification, high energy radiation emission and particle acceleration. For most of the aforementioned applications, advanced proposed schemes require stringent tailoring and monitoring of the target/plasma parameters during the interaction. The short (fs) temporal and small (sub-micron) spatial scales of the evolution of these parameters make direct measurements a challenging task, even more considering that these plasmas are usually overdense for conventional optical diagnostics.

Currently, a pump-probe set up is being developed at HZDR to gain insight into the internal evolution of overdense laser driven plasmas. The XUV beam generated by one of the arms of the Draco laser, through Relativistic Oscillating Mirror High Harmonic Generation, will be used to probe a plasma driven by a second arm of the laser system. The initial set up for these experiments will be shown and probing options of the platform will be discussed.

P 3.2 Mon 14:15 P-H12

Study of x-ray emission from proton acceleration targets at Draco PW laser facility — •Radka Štefaníková[1,2], Niklas Meckel[1,2], Xiayun Pan[1,2], Michal Šmíd[1], Hans-Peter Schlenvoigt[1], Irene Prencipe[1], Michaela Kozlová[1,3], Lennart Gaus[1,2], Marvin E. P. Umlandt[1,2], Milenko Vescovi[1,2], Marvin Reimold[1,2], Tim Ziegler[1,2], Florian Kroll[1], Stephan Kraft[1], Ulrich Schramm[1,2], Karl Zeil[1], Josefine Metzkes-Ng[1], and Katerina Falk[1,2,3] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]Institute of Physics of the ASCR, Prague, Czech Republic

Laser plasma-based ion accelerators are very promising candidates for many applications. In order to ensure the reliability of such accelerators a comprehensive set of diagnostics is required. X-ray emission spectroscopy allows us to directly measure the plasma conditions of the laser-plasma interaction and also provides information about the hot electron population through the cold K-α emission production.

Here, we present preliminary results from two new x-ray spectrometers used to study interaction regimes relevant for laser-driven ion acceleration at ultra-short pulse PW-class laser facility. We acquired the emission spectra from flat Ti targets for a range of target thicknesses and laser energies. Additionally, artificial laser pre-pulses were added to alter the laser absorption efficiency.

P 3.3 Mon 14:30 P-H12

Investigation of laser reflectivity and transmissivity of laser-plasma interaction with thin foil targets — •Marvin E. P. Umlandt[1,2], Tim Ziegler[1,2], Constantin Bernert[1,2], Marco Garten[1,2], Lennart Gaus[1,2], Ilja Göthel[1,2], Thomas Kluge[1], Stephan Kraft[1], Florian Kroll[1], Josefine Metzkes-Ng[1], Irene Prencipe[1], Martin Rehwald[1,2], Marvin Reimold[1,2], Hans-Peter Schlenvoigt[1], Milenko Vescovi[1,2], Karl Zeil[1], and Ulrich Schramm[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [2]Technische Universität Dresden, 01062 Dresden, Germany

Ion acceleration by compact laser-plasma sources promises a variety of applications ranging from medical relevance to fusion experiments. Reaching the required beam quality parameters for those applications demands a very high level of understanding and control over the laser-plasma interaction process. Central components in this context are the absorption of the electromagnetic laser field by the plasma and the quality of the resulting acceleration field structure.

Measuring and analyzing unabsorbed light - as transmitted and/or specularly reflected parts - thus allows insight into properties of the underlying laser-plasma interaction. We experimentally investigate these interactions for high and low-contrast laser pulses with thin solid density foil targets at the Draco PW laser system (HZDR). The results of spectral, spatial, and energy analysis of transmitted and reflected light indicate changes in the plasma interaction and will be presented.

P 3.4 Mon 14:45 P-H12

Optimized laser ion acceleration at the relativistic critical density surface — •Thomas Kluge[1], Ilja Göthel[1,2], Constantin Bernert[1,2], Michael Bussmann[3], Marco Garten[1,2], Thomas Miethlinger[1,2], Martin Rehwald[1,2], Karl Zeil[1], Tim Ziegler[1,2], Thomas E. Cowan[1,2], and Ulrich Schramm[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Technische Universität Dresden — [3]Center for Advanced Systems Understanding (CASUS)

In the effort of achieving high-energetic ion beams from the interaction of ultrashort laser pulses with a plasma, volumetric acceleration mechanisms beyond Target Normal Sheath Acceleration have gained attention. A relativisticly intense laser can turn a near critical density plasma slowly transparent, facilitating a synchronized acceleration of ions at the moving relativistic critical density front. While simulations promise extremely high ion energies in in this regime, the challenge resides in the realization of a synchronized movement of the ultrarelativistic laser pulse (a0 >* 30) driven reflective relativistic electron front and the fastest ions, which imposes a narrow parameter range on the laser and plasma parameters. We present an analytic model for the relevant processes, confirmed by a broad parameter simulation study in 1D- and 3D-geometry. By tayloring the pulse length plasma density profile at the front side, we can optimize the proton acceleration performance and extend the regions in parameter space of efficient ion acceleration at the relativistic relativistic density surface.

P 3.5 Mon 15:00 P-H12

Simulation of optimized TNSA via temporal pulse shaping under realistic laser contrast conditions — •Marco Garten[1,2], Jakob Wetzel[1,2], Tim Ziegler[1,2], Marvin E. P. Umlandt[1,2], Ilja Goethel[1,2], Thomas Pueschel[1], Stefan Bock[1], Karl Zeil[1], Ulrich Schramm[1], and Thomas Kluge[1] — [1]Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany

Controlling the spatio-temporal coupling of laser energy into plasma electrons is crucial for achieving predictable beam parameters of ions accelerated from ultra-high intensity (UHI) laser-driven solid density plasmas. Especially for highest maximum energies, promising targets are foils of a few ten to hundred nanometers thickness. When working with targets of such small scales, meticulous control and precise metrology of the driving UHI laser pulses are paramount to avoiding premature plasma expansion that would lead to losses in absorption efficiency as well as lower accelerating fields. Recently, significant proton beam quality enhancement was reported from the Draco PW facility at HZDR via spectral phase control of the driving laser pulse. In support of these experiments, we present a particle-in-cell simulation study taking into account realistic temporal intensity contrast features. In particular, we focus on the influence of laser spectral phase term manipulations on the acceleration of ions. We furthermore show how the transient femtosecond plasma dynamics and state of the target are encoded into the spectral content of reflected and transmitted light, giving more insight into the previously obtained experimental results.

P 3.6 Mon 15:15 P-H12

Isochoric Heating in Multilayer Targets upon Ultra High Intensity Laser Irradiation by Density Oscillation — •Franziska Paschke-Bruehl[1,2], Lisa Randolph[3], Mohammadreza Banjafar[2,4], Motoaki Nakatsutsumi[4], Lingen Huang[1], Christian Gutt[3], Ulrich Schramm[1], Thomas E. Cowan[1,2], and Thomas Kluge[1] — [1]Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]Universität Siegen, Siegen, Germany — [4]European XFEL, Schenefeld, Germany

Reaching higher ion and electron temperatures in laser-solid plasma interaction can be done by either increasing laser intensity or changing target design. We will show how a multilayer target behaves under ultra high intensity laser irradiation, based on a PIC simulation study. There we observe density oscillation, a dynamic, that has not been mentioned in plasma physics yet. It describes how neighboring layers repeatedly compress each other, causing the ion and electron density of each layer to oscillate over time. During this process, the particles gain kinetic energy and temerpature, thus heat differently compared to a non layered target. Based on that, we will show how the density oscillation affects the isochoric heating of the target. In addition to that we present a method of confirming these computational results in an experiment by applying a GISAXS (grazing- incidence small-angle scattering) technique.

P 4: Low Pressure Plasmas II / Laser Plasmas II

Time: Monday 16:00–17:00 Location: P-H11

P 4.1 Mon 16:00 P-H11

Secondary electron induced effects in the ion energy distribution of a symmetrical capacitively coupled plasma — •Christian Schulze[1], Zoltán Donkó[2], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Hungary

The Particle in Cell/Monte Carlo Collisions (PIC/MCC) approach is established as a widespread simulation tool in low pressure plasma science since it offers access to a variety of plasma parameters and - in conjunction with experiments - can provide information about surface properties that are not directly measurable in experiments. However, PIC/MCC simulations are based on simplifications. For example, secondary electron emission (SEE) is usually described by an effective yield for ion (γ_{eff}) and electron (r_{eff}) impact that include other effects leading to SEE like photoemission or kinetic SEE by fast atoms. In order to describe experimental conditions correctly experimental validations are necessary to estimate realistic input parameters. Here, ion flux-energy distributions are measured with an energy-selective mass spectrometer in a geometrically symmetric capacitively coupled plasma and compared with data obtained from 1d3v PIC/MCC simulations. Surface induced effects are studied with Al_2O_3 coated electrodes in comparison to uncoated stainless steel electrodes. The observed changes can be explained by altered plasma properties due to an increase in SEE in the case of an oxidized surface. With this comparative approach, the effective SEE coefficients γ_{eff} and r_{eff} are estimated.

P 4.2 Mon 16:15 P-H11

Toroidal electron beam source for electron-induced processes at atmospheric pressure — •Lars Dincklage[1], Burkhard Zimmermann[1], Gösta Mattausch[1], and Ronny Brandenburg[2,3] — [1]Fraunhofer Institute for Org. Electr., EB and Plasma Technol. FEP, Dresden, Germany — [2]Leibniz-Institute for Plasma Science and Technology, Greifswald, Germany — [3]University of Rostock, Germany

Accelerated electrons can be utilized to induce chemical reactions in gases. A toroidal electron beam (EB) source has been developed for optimum treatment of fluids in tubes as well as to generate EB-sustained atmospheric plasmas for plasma-chemical conversion processes. Electrons are created at a cooled metal cathode by the impact of ions from a low pressure wire anode (WA) plasma, accelerated in the electric field of the cathode and then emitted through an electron exit window (EEW) into the reaction space at the center of the torus. The energy of the electrons (typically 120 keV) and the EB current density at the EEW (about 100 μA/cm^2) are controlled by the cathode potential and the electric properties of the WA discharge. In order to identify stable operation parameter windows, the WA discharge characteristics as well as its effect on the EB properties were investigated for helium and hydrogen. In case of operation at low pressure and with insufficient plasma current, limiting factors such as the contraction of the plasma and a high ignition voltage were determined. Whereas the first issue was handled by pulsing the plasma, the second was met by applying an external magnetic field. Furthermore, the current efficiency of the source was determined for different states of the metal cathode.

P 4.3 Mon 16:30 P-H11

Start to End simulations with 20 J Laser in relativistically induced transparency regime — •Ilja Göthel[1,2], Tim Ziegler[1,2], Marco Garten[1,2], Constantin Bernert[1], Karl Zeil[1], Marvin E.P. Umlandt[1,2], Thomas Miethlinger[1,2], Sergei Bastrakov[1], Ulrich Schramm[1], and Thomas Kluge[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden — [2]Technische Universität Dresden, 01069 Dresden

TNSA has proven the experimentally most robust mechanism for accelerating ions with ultraintense laser pulses. In experiments at the Draco-PW laser we achieved the promising RIT regime, known for enhancing the performance beyond normal TNSA (several shots of 100MeV protons). Also, advanced pulse and beam characterization techniques enable us to deepen our understanding by simulations.

We present here a start-to-end simulation campaign with a hybrid code approach - hydrodynamic preexpansion in the time 100ps-1ps before the peak, and a 3d PIC mainpulse interaction with input from the hydro code. The scan reproduces the experimentally found behaviour of reflected and transmitted beam diagnostics with thickness.

The enhancement in the RIT regime is known from literature. For a predictive simulation, however, the hybrid code approach is necessary due to the decisive effect of preexpansion by the intrinsic contrast of the laser. Reaching these high energies reproducibly without pulse contrast cleaning devices opens the way to high repetition rate usage; deeper understanding the dynamics by predictive simulations may prove crucial for further progress.

P 4.4 Mon 16:45 P-H11

Characterization of fast electrons accelerated into matter by laser-solid interaction — •Nico Potzkai, Bastian Hagmeister, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Intense laser pulses create plasma on solid surfaces and accelerate electrons into the vacuum as well as into the target. We investigated the latter electrons concerning numbers and energy. Sub 10-fs-laser pulses on different bilayer targets did induce the plasma. The characteristic x-ray line emissions of the two materials were used to quantify the electron population traveling though the material. Our experimental results have been compared with PIC simulations and yield information of details of the laser-surface interaction.

P 5: Helmholtz Graduated School HEPP I

Time: Monday 16:00–17:05 Location: P-H12

P 5.1 Mon 16:00 P-H12

From Idea to Virtual Design: Systems Studies of Stellarator Fusion Power Plants — •Jorrit Lion, Felix Warmer, and Robert C. Wolf — Max Planck Institute for Plasma Physics, D-17491, Greifswald, Germany

Stellarators are attractive candidates for fusion power plants: They operate inherently in steady-state, lack current driven instabilities and do not rely on current drive and or poloidal field coils. To design and model such a power plant, so called systems codes can be applied, which aspire to model all relevant features and constraints of the power plant within a single framework by imposing simplified 0D or 1D models. We report on a new version of the fusion reactor power plant systems code PROCESS, applicable to general stellarator configurations, based on its coil set and the 3D plasma shape [1]. This is achieved by introducing a pre-calculation step to determine effective parameters, which are then being passed to new stellarator specific models in PROCESS. This way, 3D coil-forces, 2D thermal wall loads or stellarator specific operational boundaries can now be modelled within PROCESS. Using these modifications, PROCESS now allows for a combined technological, physical and economical assessment of a very general class of stellarator power plants within a systems code framework. This opens up a new paths to speed up the design cycle and potentially accelerate the deployment of fusion.

[1] J. Lion, et al., "A general stellarator version of the systems code PROCESS", Nucl. Fus. 61 (2021)

P 5.2 Mon 16:25 P-H12

Analysis of multiple MMC submodules operation for future ASDEX Upgrade power supply system integration — •Antonio Magnanimo[1], Markus Teschke[1], Gerd Griepentrog[2], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Technische Universität Darmstadt, 64283 Darmstadt, Germany

The modular multilevel converter (MMC) has become one of the most attractive converters for high-power applications such as High Voltage DC (HVDC) Power transmission, but also fusion devices power supplies. This converter, thanks to the discrete-leveled output voltage and its identical submodules (SMs) by which it is composed, represents a promising alternative to replace the flywheel generator (FG) that actually provides electrical power to ASDEX Upgrade (AUG) device toroidal field (TF) coils. Due to the pulsed DC operation of these coils and their high power needs (up to 150 MW) for each experiment, a small-scale adapted version of the MMC is under development with some differences compared to conventional ones being used in HVDC systems: SM capacitors have been replaced with supercapacitors (SC) modules to increase the amount of available stored energy while SMs belonging to different arms are interconnected to simplify their control and increase the reliability of the converter. This work shows the operation of four SMs connected in series, parallel and combined series/parallel to demonstrate the scalability of the project, highlighting its advantages, challenges and limits.

P 5.3 Mon 16:50 P-H12

Non-Resonant Divertor Design for Compact Toroidal Hybrid (CTH) — •Kelly Garcia[1], Aaron Bader[1], Heinke Frerichs[1], Gregory Hartwell[2], John Schmitt[2], and Oliver Schmitz[1] — [1]University of Wisconsin-Madison, Madison, WI USA — [2]Auburn University, Auburn, AL USA

Non-resonant divertors separate the confined plasma from surrounding structures with the resulting boundary region comprised of cantori and/or stochastic regions, but without the presence of large islands. Compact Toroidal Hybrid (CTH) can serve as a test-bed for non-resonant divertor solutions. The background field coils and the ohmic current drive system of CTH are used to alter the rotational transform between $0.3 < \iota < 0.75$. Utilizing the FLARE field-line following code, we show the presence of a chaotic edge fieldline structure which evolves with current. These chaotic structures are related to topologically relevant transport mechanisms which we aim to explore. We calculate strike point locations for the exiting plasma for multiple ohmic current values. The calculated strike point locations enable us to design and numerically test an instrumented divertor plate with FLARE which can then be used to experimentally measure non-resonant divertor resiliencies with respect to equilibrium changes. The test plate configuration is designed to intercept most of the divertor flux over a wide range of currents. A physical plate is planned to be placed in CTH where we expect to calculate expected heat flux on this plate. We attempt to calculate optimal plate position locations within CTH.

P 6: Invited talks II

Time: Tuesday 11:00–12:30 Location: P-H11

Invited Talk P 6.1 Tue 11:00 P-H11

Laser diagnostics on atmospheric pressure plasmas: From basic to fancy — •Volker Schulz-von der Gathen and the CRC 1316 team — Ruhr-University Bochum, Bochum, Germany

Atmospheric pressure plasmas are one of the main research topics of the CRC 1316 'Transient atmospheric pressure plasmas: From plasmas to liquids to solids'. An overlaying goals is to understand the interaction of plasmas and species either in gas or liquid form to improve e.g. plasma catalysis or in plasma medical applications. Due to the atmospheric pressure condition most of the investigated plasmas are in the mm or even sub-mm dimensions or show strongly transient behaviour. This covers micro discharges in cavities of only 100 μm dimension to pulsed ns devices in pure noble gases or with more complex molecular admixtures. This poses challenges for many diagnostics. Here we describe a set of laser diagnostics applied allowing for enough spatial and temporal resolution to yield information on the dynamics of species, fields or population densities in some exemplary jet devices. By this we cover schemes from nowadays standard techniques to examples of only recently introduced ones. We will exemplarily discuss some of the advantages and drawbacks for the various schemes involved in particular at atmospheric pressure.

Invited Talk P 6.2 Tue 11:30 P-H11
Liquid tin interaction with deuterium plasmas — •Armin Manhard, Martin Balden, Thomas Schwarz-Selinger, and Rudolf Neu — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

Plasma-facing components based on low-melting liquid metals such as tin are currently being investigated. They potentially alleviate some issues arising with conventional designs using solid metals (e.g., tungsten), such as embrittlement or permanent damage due to transient thermal overloading. This presentation will first briefly review the current status of the conceptual design for liquid metal divertor components (e.g., [1, 2]). It will then focus on the interaction with hydrogen isotope plasmas, which has recently been investigated by several groups of researchers (e.g., [3, 4]). In contrast to hydrogen gas, against which tin is practically inert, atoms and ions from the plasma show a considerable reactivity both with solid and liquid tin. The effects depend strongly on temperature and range from strong chemical erosion at low temperatures to growth of sponge-like structures just below the melting point. In liquid tin, the formation of gas bubbles can lead to the ejection of tin droplets as well as to the formation of large gas pockets [3, 4, 5]. Some of these adverse effects could be mitigated by containing the liquid tin in capillary porous systems (e.g., [5]).

[1] P. Rindt et al, Fusion Eng. Des. 173 (2021) 112812 [2] S. Roccella et al, J. Fusion Energy 39 (2020) 462-468 [3] A. Manhard et al, Nucl. Fusion 60 (2020) 106007 [4] W. Ou et al, Nucl. Fusion 60 (2020) 026008 [5] W. Ou et al, Nucl. Fusion 61 (2021) 066030

Invited Talk P 6.3 Tue 12:00 P-H11
Plasma jets on surfaces — •Ana Sobota — Technische Universiteit Eindhoven, Postbus 513, 5600MB Eindhoven, The Netherlands

Non-thermal atmospheric pressure plasma jets are an outstanding model in studies of the interaction of non-thermal plasmas and substrates. With their underlying physics based on streamer discharges, but featuring reproducibility in time and space, we are able to experimentally study their behaviour resolved in space and time and measure properties like electric fields and electron densities. Special interest is given in their interaction with targets of varying electrical properties, moving away from metals and into dielectrics and liquid. The talk is going to present recent studies on this topic.

P 7: Atmospheric Pressure Plasmas I

Time: Tuesday 14:00–15:30 Location: P-H11

P 7.1 Tue 14:00 P-H11
Towards *in situ* plasma surface interaction studies utilizing a microplasma in a TEM — •Luka Hansen[1], Niklas Kohlmann[2], Ulrich Schürmann[2], Lorenz Kienle[2], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics, Kiel Univeristy, Kiel, Germany — [2]Institute for Material Science, Kiel University, Kiel, Germany

The idea of *in situ* investigating a microplasma in a transmission electron microscope (TEM) was first successfully demonstrated in 2013 [1]. Since then no attempts have been taken to observe the plasma surface interaction in real time. Various technical challenges, e.g. size limitations, gas sealing and handling of high voltages, have to be overcome to enable the *in situ* imaging.
A stable atmospheric pressure microplasma discharge was developed and studied *ex situ* in advance to gain insight in the plasma surface interaction by several diagnostics [2]. Prototypes of the vacuum-proof microplasma cell have been build and preparations for the *in situ* studies are ongoing right now.
In the contribution the microplasma and its vacuum-proof encapsulation is addressed and a report on the current state of the *in situ* experiments will be given.

[1] K. Tai *et al.*, 2013 *Scientific Reports* **3** 1325
[2] L. Hansen *et al.*, *PSST* **(Submitted)**

P 7.2 Tue 14:15 P-H11
Breakdown and quasi-DC phase of a nanosecond discharge — •Nikita Lepikhin[1], Jan Kuhfeld[1], Zoltán Donkó[1,2], Dirk Luggenhölscher[1], and Uwe Czarnetzki[1] — [1]Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany — [2]Wigner Research Centre for Physics, Budapest, Hungary

A nanosecond Atmospheric Pressure Plasma Jet (ns-APPJ) is studied by picosecond Electric-Field Induced Second Harmonic generation (E-FISH) and spatially/temporally resolved Optical Emission Spectroscopy (OES). Two distinct phases of the discharge are identified: fast breakdown at high electric field is followed by a quasi-DC phase at lower permanent electric field and high electron density. The spatial structure of the discharge after the breakdown is found to be similar to that of a DC-glow discharge. It is demonstrated that the bulk electric field in the quasi-DC phase is independent of the amplitude of the voltage applied to the discharge and, consequently, the electric field strength during breakdown. It is also shown that the voltage and current waveforms and the discharge morphology weakly depend on the gas mixture. The experimental results are compared with the results of PIC/MCC simulations and an analytical model. Good agreement is found throughout.

P 7.3 Tue 14:30 P-H11
Investigations on the impact of electrode proximity on streamer breakdown and development of pulsed dielectric barrier discharges — •Hans Höft, Jente R. Wubs, Manfred Kettlitz, Markus M. Becker, and Klaus-Dieter Weltmann — Leibniz Institute for Plasma Science and Technology (INP), Felix-Hausdorff-Straße 2, 17489 Greifswald, Germany

The impact of the electrode proximity on the streamer breakdown and development of pulsed-driven dielectric barrier discharges (DBDs) in a single-filament arrangement was investigated in a gas mixture of 0.1 vol% O_2 in N_2 at 0.6 bar and 1.0 bar. To this end, the gap distance was varied from 0.5 mm to 1.5 mm, while the applied voltage was adapted correspondingly to create comparable breakdown conditions in the gap. The development of the DBDs was recorded by an iCCD and a streak camera system, which enabled sub-ns temporal and μm spatial resolution. Simultaneously, fast electrical measurements provided insight into relevant discharge characteristics such as the transferred charge and consumed energy. The results demonstrate that breakdown in a smaller gap is characterised by a slower streamer propagation but a significantly higher acceleration. It can therefore be concluded that the proximity of the cathode has a strong impact on the characteristics of the streamer breakdown. However, after the streamer has crossed the gap, the discharge structure in front of the anode was found to be the same independent of the actual gap distance.

This work was funded by the DFG in the framework of the MultiFil project (project number 408777255).

P 7.4 Tue 14:45 P-H11
CO_2 Konversion und Energieeffizienz eines Mikrowellen-Plasmabrenners — •Katharina Wiegers, Andreas Schulz, Matthias Walker und Günter Tovar — Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie IGVP, Universität Stuttgart, Stuttgart, Deutschland

Die Menschheit ist heutzutage stark vom fortschreitenden Klimawandel betroffen, der hauptsächlich durch den zunehmenden Ausstoß von Kohlendioxid (CO_2), z. B. durch Verkehr, Kohlekraftwerke und die Industrie, verursacht wird. Ein grundlegendes Problem der Energieerzeugung durch erneuerbare Energiequellen wie Photovoltaik und Windkraftanlagen ist die häufig zu beobachtende Diskrepanz zwischen der tatsächlichen Energieproduktion und dem Energiebedarf aufgrund ihrer diskontinuierlichen Verfügbarkeit. Die so genannte überschüssige Energie kann zum Betrieb eines Mikrowellen-Plasmabrenners bei Atmosphärendruck verwendet werden. Das CO_2-Plasma führt zur Bildung von Kohlenmonoxid (CO) und Sauerstoffradikalen (O·). Um die thermodynamisch erzwungene Rekombination beider zu CO_2 beim Abkühlen zu verhindern, ist ein effektives Trennverfahren erforderlich. Keramische Hohlfasern sind ideal dafür geeignet. Das verbleibende CO kann als C_1-Baustein in der chemischen Industrie verwendet werden.

Diese Arbeit konzentriert sich auf die Konversion- und Energieeffizienz des CO_2-Plasmas in Abhängigkeit von verschiedenen Prozessparametern wie Mikrowellenleistung, Gasfluss und der Position im Abgaskanal. Die Effizienzen werden mittels FT-IR und Massenspektrometrie bestimmt.

P 7.5 Tue 15:00 P-H11

Electric field strengths within a micro cavity plasma array measured by Stark shifting and splitting of a helium line pair — •Sebastian Dzikowski[1], Judith Golda[2], Marc Böke[1], and Volker Schulz-von der Gathen[1] — [1]Experimentalphysik II, Ruhr-Universität Bochum — [2]Plasma Interfache Physics, Ruhr-Universität Bochum

The electric field is a key parameter in discharge sources. Its knowledge allows to optimize promising applications by controlling plasma processes such as fluxes of charged particles onto surfaces. Especially, for plasma-enhanced catalysis in microplasmas, high electric fields provide intense ionization rates and with this high ion and electron densities. However, due to limited optical access, experimental data of electric fields in micro-structured plasmas are rare. Here, we exploit the Stark shifting and splitting of the allowed 492.19 nm and forbidden 492.06 nm helium lines on a metal-grid array. This layer-structured array consists of a nickel foil that serves as a high voltage supplied electrode and contains four different sized cavity arrangements in the 100 microns range. This nickel foil is separated from an electrically grounded magnet by a 40 microns thick dielectric. By using a combination of a 2 m long plane grating spectrometer and an attached ICCD camera, electric fields up to 70 kV/cm can be measured and controlled by parameters as cavity sizes and excitation features as polarity, voltage and frequency. As an example, smaller cavities yield to higher electric field strengths. For a better understanding a simple Townsend-model is built-up. This research is supported by DFG within SFB1316 (A6).

P 7.6 Tue 15:15 P-H11

CO_2 conversion in barrier discharges with and without packed bed filling at elevated pressures — •Rezvan Hosseini Rad[1], Milko Schiorlin[1], Volker Brüser[1], and Ronny Brandenburg[1,2] — [1]Leibniz-Institute for Plasma Science and Technology — [2]University of Rostock, Institute of Physics

A coaxial dielectric barrier discharge (DBD) reactor operated at elevated pressures up to 2 bar is investigated for the splitting of carbon dioxide. Electrical plasma parameters as well as concentraions of carbon monoxide as the main chemical product is studied without and with a packed bed (partially or fully) filling the reactors volume. A mixture Ar:CO_2 = 4:1 is used as feed gas. Argon is admixed in order to reduce the breakdown voltage, thus, enabling also a stable plasma operation at the higher pressures. Increasing the pressure leads to an increase of the CO_2 conversion and energy efficiency in case of empty as well as packed bed reactor. The energy efficiency is improved up to 31 % if the reactors volume is fully filled with glass beads with a CeO_2 coating compared with the empty reactor. The chemical performance is correlated with the discharge distribution in the DBD reactor, deduced from electrical diagnostics.

P 8: Helmholtz Graduate School HEPP II

Time: Tuesday 14:00–15:15 Location: P-H12

P 8.1 Tue 14:00 P-H12

PIC-Simulations of Perpendicular Collisionless Shocks in Multiple-Ion GRB Plasmas — •Jonas Graw, Martin Weidl, and Frank Jenko — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Deutschland

Ultra-high-energy cosmic rays (UHECRs) are electrically charged particles, which move throughout the universe with energies greater than about 1 EeV. One likely source of UHECRs is a gamma-ray burst (GRB). The latter eject gas parallel to the axis of rotation with high velocities. Shocks are formed in these jets, in which particles are believed to be accelerated to extremely high velocities. Due to such high energies, protons and neutrons fuse to alpha particles. In our research, we simulate an astrophysical plasma consisting of multiple ion species in a mildly relativistic shock.

We simulate perpendicular collisionless shocks with multiple ion species in a mildly relativistic ($\gamma\beta = 2$) 2D3V PIC setup and we analyze in how far these shocks differ compared to single ion shocks. We observe alternating maxima of the two ion species in real space. When analyzing the highest-energetic particles, we observe that they are accelerated by shock-drift acceleration. We conduct research on how multiple-ion shocks affect the electron acceleration efficiency ϵ_e - a quantity that is observable by astronomers due to synchrotron emission and notice that ϵ_e is only slightly influenced by multiple-ion shocks. Furthermore, we analyze how the shock physics changes when using in-plane and out-of plane shock simulations and when using different magnetizations $\sigma = 1, 0.1, 0.01$.

P 8.2 Tue 14:25 P-H12

TALIF on H_2 Plasmas and its Application to Negative Ion Sources — •Frederik Merk, Christian Wimmer, Stefan Briefi, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik, Garching, Germany

Two-photon absorption laser induced fluorescence (TALIF) is a tool to determine both the density and the velocity distribution function of ground state H atoms in H_2 plasmas. This is done by using a pulsed, frequency tripled dye laser (resulting in 205.08 nm radiation) in order to excite the atoms. The subsequent fluorescence radiation is collected for diagnostic purposes.

In H^-/D^- ion sources, the main mechanism of H^- production is the H atom conversion at a (caesiated) low work function surface. This raises the need for a deeper understanding of the H atom dynamics close to that surface. Therefore a TALIF setup is newly installed at the H^-/D^- ion source BATMAN Upgrade (plasma created with 100 kW of RF power) which comes with multiple challenges due to the high voltage environment of the ion source (45 kV) and the complexity of the diagnostic itself. Thus, to gain experience beforehand, TALIF was installed at a planar ICP (600 W, 13.56 MHz). In order to give context to the TALIF measurements, optical emission spectroscopy is performed on the experiment and evaluated with a collisional radiative model for the determination of basic plasma parameters.

Results of TALIF measurements are presented for the planar ICP unsing H_2, a H_2/He mixture and D_2 as working gases as well as results of the applications to BATMAN Upgrade.

P 8.3 Tue 14:50 P-H12

Investigations into the confinement of positrons in a magnetic dipole trap — •Stefan Nissl[1,2], Eve Stenson[1,2,3], Jens von der Linden[1], Adam Deller[1,3], Juliane Horn-Stanja[1], Uwe Hergenhahn[1,7], Thomas Sunn Pedersen[1,4], Haruhiko Saitoh[6], Christoph Hugenschmid[2], Markus Singer[1,2], Matthew Stoneking[1,5], and James Danielson[3] — [1]Max-Planck-Institute for Plasma Physics — [2]Technische Universität München — [3]University of California, San Diego, La Jolla, CA, USA — [4]University of Greifswald — [5]Lawrence University, Appleton, WI, USA — [6]The University of Tokyo — [7]Fritz-Haber-Institut der Max-Planck-Gesellschaft

The APEX (A Positron-Electron Experiment) collaboration aims to create a strongly magnetized, low-temperature, electron-positron plasma in a magnetic trap. This *pair plasma* is predicted to have unique characteristics and excellent stability properties due to the equal masses of the participating species. In order to achieve plasma densities using the available rate of positrons, it is beneficial to confine positrons for as long as possible and to be able to add them to the trap in multiple batches. Previous experiments in a prototype dipole trap already demonstrated a lifetime of >1s. Single-particle simulations helped to identify the main loss mechanisms and guided key improvements to the trap structure and experiment parameters. Upcoming experiments with significantly improved gamma detection capabilities will focus, among other objectives, on the confirmation of longer confinement times as well as the feasibility of accumulating multiple positron pulses in the trap.

P 9: Poster I

Time: Tuesday 16:00–17:30 Location: P

P 9.1 Tue 16:00 P

Wavenumber analysis of the quasi coherent mode in EDA-H-mode discharges — •Joey Kalis[1,2], Gregor Birkenmeier[1,2], Peter Manz[3], Luis Gil[4], Michael Griener[1], and Ulrich Stroth[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Garching — [2]Physik-Department E28, TUM, Garching — [3]Institut für Physik, Universität Greifswald, Greifswald — [4]Instituto de Plasmas e Fusão Nuclear, Universidade de Lisboa, Lisboa, Portugal

For future reactors based on the tokamak concept, it is necessary to establish high confinement modes without type-I ELMs. In the past years, several natural ELM-free operation scenarios, such as the EDA-H-mode, have been achieved in ASDEX Upgrade. The most prominent characteristic of the EDA-H regime is the appearance of the quasi coherent mode (QCM) at the plasma edge, which may be responsible for the stabilization of the ELMs. For the comparison with theory, it is important to determine the properties of the QCM in detail to identify its underlying driving forces. Due to its high spatial and temporal resolution, the He-beam diagnostic is used to measure different QCM properties. By means of spectral methods and due to a 2D-grid of the He-beam diagnostic, the wavenumber of the QCM in radial and poloidal direction is determined and compared with theoretical predictions.

P 9.2 Tue 16:00 P

Non-Axisymmetric Generalization of the Gyrokinetic Turbulence Code GENE-X — •Marion Smedberg[1], Dominik Michels[1], Andreas Stegmeir[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

For both tokamaks and optimized stellarators, plasma turbulence drives a major part of the heat loss. Thus realistic simulations of plasma turbulence, especially in the edge and scrape-off layer (SOL), are a key step towards a fusion power plant. The recent gyrokinetic turbulence code GENE-X uses a flux-coordinate independent (FCI) coordinate system; this approach has the advantage of remaining well-defined (singularity-free) even for the complex magnetic structures which appear in the edge and SOL, such as open field lines, X-points, islands, and stochastic regions. For this reason, GENE-X is well-equipped to simulate edge and SOL turbulence. However, the code can currently only simulate in axisymmetric geometries, such as tokamaks. In this work, progress towards a non-axisymmetric generalization of GENE-X is presented; this includes updating the grid generator, field line tracers, and fast elliptic solvers.

P 9.3 Tue 16:00 P

Extension of the Braginskii fluid model for edge turbulence simulations — •Christoph Pitzal, Andreas Stegmeir, and Frank Jenko — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

Fluid models are a useful tool for plasma turbulence simulations. They are computationally less intense than kinetic models, but they have limited predictive capabilities. This arises from the fact, that not all effects are captured, which are necessary to simulate a fusion device sufficiently. The effects which are not contained are primarily kinetic effects, which are lost due to the missing velocity space, e.g. Landau damping. Because of the missing Landau damping, fluid models significantly overestimate the parallel heat conductivity, whenever the collisionality is small. An approach to introduce Landau damping into a fluid model was already shown in [1]. This approach is formulated solely in k-space. A method to translate this approach into configuration space and thus make it applicable for fluid codes, which operate in configuration space, is presented in [2]. In this project a simple one-dimensional toy model has been implemented and tested to reproduce and understand the Landau fluid closure introduced in [2]. Further the Landau fluid closure will be implemented into the plasma turbulence code GRILLIX [3]. [1] G. W. Hammett and F. W. Perkins, Phys. Rev. Lett., vol. 64, pp. 3019-3022, Jun 1990. [2] J. Chen et al., Computer Physics Communications, vol. 236, pp. 128-134, 2019. [3] A. Stegmeir et al., Physics of Plasmas, vol. 26, no. 5, p. 052517, 2019.

P 9.4 Tue 16:00 P

Early stages of He cluster formation in tungsten — •Annemarie Kärcher[1,2], Vassily V. Burwitz[2], Thomas Schwarz-Selinger[1], Wolfgang Jacob[1], Lucian Mathes[2], and Christoph Hugenschmidt[2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Technische Universität München, 85748 Garching, Germany

In future fusion reactors, tungsten as plasma-facing material will be subjected to intense fluxes of helium (He). While the consequences of high He fluxes on the surface properties of tungsten have already been thoroughly studied, the mechanisms behind the early stages of the He cluster formation are still unclear. To understand the initial steps of the interaction of He with W, especially the impact of pre-existing defects, annealed, polycrystalline W samples were irradiation-damaged to various damage levels. Then, these were exposed to a low-temperature He plasma at low fluxes and fluences using an implantation energy of 100 eV. These He-implanted samples were measured by Doppler-broadening positron annihilation spectroscopy for defect quantification and elastic recoil detection analysis (ERDA) for quantification of He retention. To obtain information about the depth distribution of He, thin layers of the sample surfaces have been removed and ERDA measurements have been repeated subsequently until the signal intensity dropped to the sensitivity limit. In the irradiation-damaged samples, the He penetration into larger depth is significantly reduced compared with the depth penetration in undamaged samples, while their overall He retention is higher.

P 9.5 Tue 16:00 P

Study of LaB6-Cathodes in Neutral Pressure Gauges for Strong Magnetic Fields — •Bartholomäus Jagielski[1,2], Uwe Wenzel[1], Mirko Marquardt[1], Jiawu Zhu[1], and Thomas Sunn Pedersen[1] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]Physical Institute of the University Greifswald, Greifswald, Germany

The neutral gas pressure measurement is a key diagnostic for scrape-off-layer physics, that gives a direct indication of the exhaust rate. However, strong magnetic fields and the requirement for the longevity of diagnostics in increasingly longer lasting plasma pulses, is a major challenge. For this reason, we developed and tested new crystal-cathode pressure gauges with different cathode geometries made of lanthanum hexaboride (LaB6), which can permanently withstand the Lorentz-Forces. For the next campaign of Wendelstein7-X, mono- and polycrystalline LaB6-cathodes have been operated in a specially prepared laboratory, equipped with a superconducting magnet, which provides magnetic field strengths of up to 5.9 T, in a wide range of neutral pressure values, as well as several different working gases. NIR-thermionic investigations have been conducted, cross-checked with ANSYS simulations. The Anode potential has been optimized and we compared several different cathode lengths, ranging from 5mm to 8mm, for different electron emittances. A significant decrease of the required heating current of the shorter variants has been observed. Furthermore, we tested a new two-rod-cathode design, heated by three pyrolytic graphite blocks, showing noticeably improved performance.

P 9.6 Tue 16:00 P

Current Filamentation Instabilities of Proton Beams in Proton Driven Wakefield Accelerators — •Erwin Walter[1], Martin Weidl[1], John Farmer[2,3], Patric Muggli[2], and Frank Jenko[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Max Planck Institute for Physics, 80805 Munich, Germany — [3]CERN - 1211 Geneva 23 - Switzerland

Plasma wakefield accelerators can generate electric-field gradients magnitudes larger than conventional accelerators. Using this technology, particle-physics experiments could be performed in much more compact devices.

The Advanced Wakefield Experiment (AWAKE) is a proof-of-concept proton-driven wakefield accelerator located at CERN. Seeded self-modulation, a controlled excitation of the longitudinal self-modulation instability, is exploited to modulate the proton bunch into a train of multiple smaller bunches along its axis. For alternative beam parameters, the electromagnetic Weibel-like beam filamentation instability could result in magnetic field amplification, perpendicular scattering and emittance growth. The experimental parameters have been specifically chosen to avoid filamentation.

Our research investigates which beam parameters are required for filamentation to appear and whether this parameter regime is accessible in future experiments. We present results from full-PIC simulations and compare to linear theory.

P 9.7 Tue 16:00 P

Simulations of the penetration of RMP fields into ASDEX Upgrade plasmas — •Verena Mitterauer and Matthias Hölzl — Max Planck Institute for Plasma Physics, Boltzmannstrasse 2, 85748 Garching - Germany

A proposed mechanism for the mitigation of edge localized modes (ELMs) is the application of small non-axisymmetric magnetic fields by external coils, known as resonant magnetic perturbations (RMPs). Various effects are observed in the plasma in response to RMPs, among others, the stochastization of the edge region, the formation of magnetic islands and the reduction of the edge density and toroidal rotation. A combination of these responses is thought to cause either ELM mitigation or suppression. However, exact mechanisms and extrapolation to ITER are still uncertain such that non-linear simulations are needed. In this work, the JOREK-STARWALL code suite is used for the first time to simulate the effects of RMPs on plasmas with parameters relevant to RMP-ELM suppression experiments in ASDEX Upgrade. The use of the STARWALL extension allows to include the full plasma response to the perturbation field up to the boundary.

Simulations with realistic plasma parameters are compared to the experiment for a plasma configuration that is relevant for ELM suppression studies. A similar corrugation is observed in modelling and experiment. Further simulations are on the way to investigate the interaction of ELM instabilities with the perturbation fields. To capture experiments more accurately, a fluid model with kinetic closure will be developed that can describe neoclassical toroidal viscosity (NTV).

P 9.8 Tue 16:00 P

Tackling turbulence in the plasma edge pedestal with a revised version of the GENE code — •L. A. Leppin, T. Görler, F. Jenko, M. Cavedon, M. G. Dunne, and The ASDEX Upgrade Team — Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching b. München, Germany

A major challenge for future fusion power plants is the turbulent plasma dynamics on the microscale, which causes detrimental levels of outward transport of energy and particles. Many open questions on the properties of this dynamics remain in particular for the plasma edge pedestal, which is characterized by strong gradients of temperature and density, causing strong electromagentic fluctuations. An important approach to advance the understanding of turbulent plasma dynamics in the edge are high-fidelity simulations based on 5D gyrokinetic theory. Here we present ASDEX-Upgrade pedestal simulations using a new modification of the well-established gyrokinetic, Eulerian, delta-f code GENE (genecode.org), which enables numerically stable global, electromagnetic simulations at experimental beta values. We systematically investigate the present instabilities and resulting heat fluxes via local, linear as well as global, non-linear simulations. By using experimental temperature profiles and magnetic equilibria from four timepoints within an edge localized mode (ELM) of an ASDEX Upgrade discharge we aim to contribute to the understanding of ELM dynamics on the microscale. Furthermore, we demonstrate the applicability of the new GENE modifications to scenarios from other tokamaks.

P 9.9 Tue 16:00 P

Simulation of the neutral gas pressure in the subdivertor region of Wendelstein 7-X with ANSYS — •Victoria Haak[1], Hugo Cu Castillo[2], Dirk Naujoks[1], Uwe Wenzel[1], Georg Schlisio[1], and W7-X Team[1] — [1]Max-Planck Institute for Plasma Physics, Greifswald, Germany — [2]University of Greifswald, Greifswald, Germany

For low neutral gas pressures, the behaviour of the neutral gas in the subdivertor region of Wendelstein 7-X is governed by molecular flow conditions, i.e. collisions between particles can be neglected. After hitting the walls in the subdivertor region, the particle flux is emitted according to Lambert's cosine law. These similarities between particle flow in the molecular regime and radiation transport are used in order to simulate the neutral gas pressure in the subdivertor region with the steady-state thermal analysis module in ANSYS. This module uses the angular coefficient method to calculate the radiation flux on the individual surfaces. Using the analogy between particles and radiation, the heat flux can be converted into neutral gas pressure by a so-called scaling factor. The distribution of the neutral gas pressure on the walls of the subdivertor region as well as the influence of pumps and leaks can be studied. The results are compared to other simulation results, e.g. from EMC3-EIRENE and to experimental results obtained from neutral gas pressure measurements during OP1.2b using neutral gas pressure gauges.

P 9.10 Tue 16:00 P

Coupling of 3D-PIC and ion optics simulations for studies of H^- beam formation and co-extraction of e^- — •Max Lindqvist[1,2], Niek den Harder[1], Adrien Revel[2], Serhiy Mochalskyy[1], Tiberiu Minea[2], and Ursel Fantz[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Université Paris-Saclay, CNRS, LPGP, Orsay, France

The ITER Neutral Beam Injection system requires a beam of negative ions (NI) with low divergence and high current density. The NIs are produced in RF ion sources, and extracted by application of an electric field; co-extracted e^- are dumped onto the extraction grid. The equipotential surface between the plasma and extracted NI beamlet, referred to as the meniscus, determines the beamlet properties to a large extent. 3D PIC modeling is needed for self-consistent simulation of the meniscus formation, NI extraction and co-extraction of e^-. Due to the high computational cost of 3D PIC modeling, extending the simulation beyond the extraction region is unfeasable. To study the beam properties of NIs and co-extraction of e^- in the ELISE ion source, a half-size ITER-like ion source operated in IPP Garching, the 3D PIC-MCC code ONIX is coupled with the beam code IBSimu. This allows coupling of particle properties from the plasma, to the meniscus to the beamlet. It is shown that NIs extracted near the edge of the meniscus and with a large incident angle to the meniscus form a beam halo. The peak power load of e^- dumped onto the grid system depends on their distribution on the meniscus, the distribution calculated using ONIX results in a higher peak load than a uniform distribution.

P 9.11 Tue 16:00 P

Viability of NN-based Predictor-Corrector Schemes for Plasma Simulations — •Robin Greif[1], Frank Jenko[1], and Nils Thuerey[2] — [1]Boltz- mannstr. 2, 85748 Garching, Germany — [2]Boltzmannstr. 3, 85748 Garching, Germany

We investigate the viability of using neural network driven simulation methods based on novel predictor-corrector schemes developed for fluid and smoke simulations for turbulence in plasma. The approach builds on top of successful pioneering work on numerical schemes from Mantaflow and its successor, Phi-Flow, an open-source machine learnign framework aggregator for fluid dynamic simulations. In this project, we extend Phi-Flow to solve the Hasegawa-Wakatani equations as a proof-of-concept of the viability of modern neural-network based numerical simulation techniques for simple plasma models. The use of deep-learning based numerical integration schemes explored here has been shown to provide superior accuracy at coarser grids than classical methods in fluid simulations and is a promising candidate to reduce the computational cost for the next generation of plasma simulations.

P 9.12 Tue 16:00 P

Physics-informed neural network of the ideal-MHD model in Wendelstein 7-X configurations — •Andrea Merlo, Daniel Böckenhoff, Jonathan Schilling, Samuel Aaron Lazerson, Thomas Sunn Pedersen, and the W7-X Team — Max-Planck-Institute for Plasma Physics, 17491 Greifswald, Germany

In magnetic confinement fusion research, the achievement of high plasma pressure is key to reaching the goal of net energy production. The magnetohydrodynamic (MHD) framework is used to self-consistently calculate the effects the plasma pressure induces on the magnetic field used to confine the plasma. In stellarators (e.g., Wendelstein 7-X), the confining field is inherently 3D, making MHD calculations costly to compute ($\mathcal{O}(1)$ CPUh). In this work, we describe a Physics-Informed Neural Network which has been trained not only to reproduce ground-truth magnetic equilibria computed with a traditional solver (e.g., VMEC), but also to satisfy the flux surface averaged pressure balance equation characterizing ideal-MHD. The NN model is benchmarked against VMEC on a set of W7-X magnetic configurations at finite volume averaged beta, and the computation of a set of representative physics quantities of interests (e.g., magnetic well) is used to validate the model use in addressing magnetic equilibrium dependent physics questions.

P 9.13 Tue 16:00 P

Turbulence in stellarators with GENE-3D — •Felix Wilms, Alejandro B. Navarro, and Frank Jenko — Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching b. München, Germany

GENE-3D is a code that is capable of simulating gyrokinetic plasma turbulence in stellarators globally (Maurer et al., Journal of Computational Physics, 2020). It has recently been upgraded to an electromagnetic version, expanding the variety of turbulent features that can be studied with it (Wilms et al., Journal of Plasma Physics, 2021). In this work, we present a first application to realistic scenarios, by performing multiple simulations with different model complexities and comparing them against experimental measurements of an ECRH-discharge.

P 9.14 Tue 16:00 P

Reduced transport models for a Tokamak flight simulator — •Marco Muraca, Emiliano Fable, Clemente Angioni, Hartmut Zohm, and Teobaldo Luda — Max-Planck-Institut für Plasmaphysik, 85748, Garching bei München, Germany

A Tokamak flight simulator is a tool to predict the plasma behavior of a scheduled discharge, such that either actuator trajectories or plasma parameters satisfy the experimental goals, and to reduce probability of plasma disruptions and crossing of operational limits. It is based on the interaction between control system, plasma equilibrium and transport. The transport models have to be physics based to be reliable, but also fast to be used as an inter-discharge prediction tool. This compromise can be reached employing analytical models which are derived from first principle theories. An integrated model including every plasma region has been developed. The confined region is modeled in 1D, while the scrape-off-layer has a 0D structure. For the core region, a normalized temperature gradient threshold model has been adopted, while for the edge an average ELM model has been used. In the SOL a 2-point model for exhaust and a particle balance for the separatrix density have been implemented. All the models have been validated against several stationary cases, by fixing some parameters as boundary conditions and matching experimental data, exploiting the modular structure of the integrated model. A first fully integrated simulation has been matched in the flight simulator, including ramp-up and flattop phases. A stronger validation including more discharges and the ramp-down phase is planned for the future.

P 9.15 Tue 16:00 P

multi fidelity monte carlo (MFMC) sampling and application to plasma physics — •Patrick Storch — Max Planck Institut für Plasmaphysik Boltzmannstr. 2, 85748 Garching

In many situations across computational science and engineering, multiple computational models are available that describe a system of interest. These different models have varying evaluation costs and varying fidelities. Typically, a computationally expensive high fidelity model describes the system with the accuracy required by the current application at hand, while lower-fidelity models are less accurate but computationally cheaper than the high-fidelity model. Plasma physics simulations for e.g. turbulences in tokamak reactors rely on sophisticated gyrokinetic models which are very costly in terms of computing power and runtime. Standard Monte Carlo analyses on these models are highly expensive because a large number of particle trajectories need to be integrated over long time scales, and small time steps must be taken to accurately capture the features of the wide variety of trajectories. Therefore they provide an ideal candidate to apply MFMC sampling to a real world scenario. Numerical experiments with linear and nonlinear examples show that speedups by orders of magnitude are obtained compared to Monte Carlo estimation that invokes only a single model.

P 9.16 Tue 16:00 P

Characteristics of Alfvénic modes in ASDEX Upgrade disruptions — •Paul Heinrich, Gergely Papp, Philipp Lauber, Mike Dunne, Valentin Igochine, Oliver Linder, Marc Maraschek, the ASDEX Upgrade team, and the EUROfusion MST1 team — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

ASDEX Upgrade has developed multiple massive gas injection-induced scenarios to investigate runaway electron (RE) dynamics. During the current quench of these disruptions, Alfvénic activity is observed in the 300–800 kHz range. These modes are investigated as potential runaway electron mitigation candidates. With the help of a mode tracing algorithm, mode behaviour for 180 discharges was classified. The modes are potentially identified as global Alfvén eigenmodes (GAEs). Changes in the Alfvén continuum during the quench can explain the strong frequency sweep of these modes. A systematic statistical analysis revealed no significant effect of the mode characteristics on the dynamics of the subsequent runaway electron beam.

P 9.17 Tue 16:00 P

Modelling Magnetic Measurements of Tearing Modes in ASDEX Upgrade — •Magdalena Bauer, Marc Maraschek, Hartmut Zohm, Anja Gude, Wolfgang Suttrop, Felix Klossek, Louis Giannone, and the ASDEX Upgrade Team — Max Planck Institute for Plasma Physics, Garching

In future fusion devices, disruptions have to be avoided to prevent damage of the vessel. Locked modes, i.e. tearing modes that are at rest with the vessel due to electromagnetic interaction, are precursors of and significantly involved in disruptions. While rotating modes can be observed by Mirnov coils measuring the poloidal magnetic perturbation field tangential to the wall, locked modes require measuring the radial magnetic field, e.g. by saddle coils on the high-field side. The observed perturbation fields are affected differently by mirror currents induced by rotating modes. In order to model all measurements during a locking process, these mirror currents and their frequency dependence have to be described. Owing to the complexity of the real tokamak, neither the full geometry nor the exact conductivity of all structures can be considered. A recently developed three-dimensional finite element tool modelling the perturbation field for all coils is implemented using an effective conductivity of the wall and - for the saddle coils - an effective distance to the vessel. These two simulation parameters are optimized such that they best describe the ratio of measured mode amplitudes in Mirnov and saddle coils for all frequencies and discharge scenarios. Additional radial field coils are implemented to gain information on the poloidal mode structure of locked modes.

P 9.18 Tue 16:00 P

Analysis and modeling of momentum transport based on NBI modulation experiments at ASDEX Upgrade — •Carl Friedrich Benedikt Zimmermann[1,2], Rachael McDermott[1], Emiliano Fable[1], Basil Duval[4], Ralph Dux[1], Antti Salmi[3], Ulrich Stroth[1,2], Tuomas Tala[3], and Giovanni Tardini[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Physik-Department E28, Technische Universität München, 85747 Garching, Germany — [3]VTT, P.O. Box 1000, FI-02044 VTT, Finland — [4]EPFL, Swiss Plasma Center, CH-1015 Lausanne, Switzerland

Understanding momentum transport is crucial in reliably predicting the plasma rotation profiles of future fusion devices. At ASDEX Upgrade, momentum transport is studied to validate theoretical models and transport codes. The new momentum transport analysis framework uses neutral beam modulation experiments to determine the con tributions of diffusion, convection, and residual stress to momentum transport within the core plasma. The methodology was applied to a database of more than 90 phases from 50 varied discharges. A recent experimental campaign filled gaps in this database enlarging the probed parameter space to study the effect of the turbulence transition from trapped electron to ion-termperature-gradient modes on momentum transport. Such a large data set makes it possible to study the parameter dependencies of the transport coefficients. In ongoing experiments, the parameter space of the database will be further enlarged allowing more detailed validation of the methodology and theoretical predictions.

P 9.19 Tue 16:00 P

Experimental investigation of velocities and diameters of droplets generated by arcing — •Alberto Castillo Castillo[1,2], Martin Balden[1], Volker Rohde[1], and Rudolf Neu[1,2] — [1]Max-Planck Institute for Plasma Physics (IPP), Garching, Germany — [2]Technical University Munich (TUM), Garching, Germany

Droplet generation by arcing is one of the mechanisms that can generate dust in a fusion device. The metal droplets expelled by the arc can potentially introduce impurities in the plasma core and influence the operation of the device. The aim of this work is to study the velocities, diameters and direction of the droplets expelled by arcing from a metal target. Knowing the sizes and velocities distribution of the droplets would allow an estimation of their influence on plasma operation. Different target materials will be used relevant to fusion devices, with a focus on tungsten.

The experimental setup consist of a vacuum chamber in which an arc is ignited on a target. After an arcing event, the droplets expelled within a certain solid angle enter a vertical drift tube. Along the tube, the droplets pass through the line of sight of two detection systems. Each detector measures the light scattered by the droplet from a perpendicular light source. The amplitude of the signal can be converted to droplet diameter through the application of MIE scatter theory, and the signal length and time delay between both sensors allow the calculation of velocity. The orientation of the target is changed in order to measure the distributions of droplets expelled at different angles.

P 9.20 Tue 16:00 P

Uncertainty Quantification for Multiscale Turbulent Transport Simulations — •Yehor Yudin, Udo von Toussaint, and David Coster — Max Planck Institute for Plasma Physics, Boltzmannstrasse2, 85748 Garching, Germany

One of the challenges in understanding the energy and particle transport processes in the core plasma of a magnetic confinement fusion device is to quantify how it is effected by turbulent dynamics. This work considers a multi-scale approach of modeling this problem, where the numerical solution is obtained for coupled models describing processes on different spatial and temporal scales. Furthermore, the resulting model is used to investigate both epistemic and aleatoric uncertainties in the profiles of the transported quantities. This work proposes application of a surrogate modelling technique to reduce the computational cost of resolving a quasi-steady state solution on the miscro-scale when it is sufficient to capture only statistics of turbulent dynamics. We studied a Multiscale Fusion Workflow that utilizes turbulent energy and particle fluxes computed with a gyrofluid turbulence code GEM in flux tube approximation to calculate the transport coefficients for core transport code ETS. In this work, a data-driven probabilistic surrogate model based on Gaussian Process Regression is used to infer flux values computed by a turbulence code for given core profiles, and to calculate related uncertainties. For that, we use VECMA toolkit to perform uncertainty quantification, as well as to train, test and utilize surrogate models.

P 9.21 Tue 16:00 P

Bayesian Inference based Sensitivity Studies of Helium Atomic Models — •Erik Flom[1], Oliver Schmitz[1], Maciej Krychowiak[2], Ralf König[2], Stuart Loch[3], and Jorge Munoz-Burgos[4] — [1]University of Wisconsin - Madison, Madison, WI, USA — [2]3Max Planck Inst. for Plasma Physics, Greifswald, Germany — [3]Auburn University, Auburn, AL, USA — [4]Astro Fusion Spectre, San Diego, CA, USA

Understanding the basic plasma parameters of temperature and density, as well as their gradients in the scrape-off layer (SOL), is a topic critical for providing information about the performance of a divertor concept. In order to study the performance of the Wendelstein 7-X divertor concept, an active spectroscopy system on an atomic helium beam was developed and installed on the stellarator. A complete Bayesian treatment has been undertaken with the Minerva Bayesian modeling framework in two approaches. First, it has been shown through a sensitivity study that the diagnostic method is robust against random measurement errors and systematic calibration errors on the scales achievable with the current diagnostic setup. From this, it is concluded that the majority of the uncertainty in the reconstructed temperature and density arises from systematic uncertainties in the underlying collisional-radiative model (CRM) rather than from measurement errors. To demonstrate this, in the second approach, the diagnostic model is tested by inferring the plasma density and temperature using synthetic line intensities and applying different CR models (e.g. including high Rydberg states).

P 9.22 Tue 16:00 P

Work Function Measurements of the Cesiated Surface in a Negative Hydrogen Ion Source Using LEDs — •Jacob Maria Berner, Christian Wimmer, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany

The work function of a surface can be determined by measuring the nA-photocurrents arising from the irradiation by light of different wavelengths. When the chosen photon energies are close to the work function, this energy threshold can be calculated using the Fowler method. As a novelty for such a measurement, fiber coupled LEDs are used as a light source of sufficient power.

State of the art negative hydrogen ion sources, as used for the ITER neutral beam injectors, rely on the surface conversion process of H and H_x^+ from a low temperature plasma at cesiated surfaces with low work function. In order to reach longer extraction durations at high extraction currents, a stable work function, which is governed by cesium dynamics, impurities, and the interaction with the plasma, is crucial. Taking on the challenges of measuring small nA-photocurrents in a corresponding environment, the method is developed to determine the work function for the first time ever directly inside a high-performance negative ion source, namely BATMAN Upgrade. Monitoring the temporal stability of the work function is essential, as variations can worsen the extraction performance of H_x^- and countermeasures can be taken accordingly. The results from the feasibility study are expected to enable the establishment of this diagnostic tool for in-situ monitoring of the work function.

P 9.23 Tue 16:00 P

Effect of W7-X divertor geometry modifications on PFC heat load distribution — •Amit Kharwandikar, Dirk Naujoks, Thomas Sunn Pedersen, Felix Reimold, and The W7X Team — Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany

Wendelstein 7-X (W7-X) is an advanced stellarator device operated in Greifswald, Germany, to provide the proof of principle that the stellarator concept can meet the requirements of a future fusion reactor. It employs the island divertor concept to handle the heat and particle fluxes. In the recent experimental campaign OP1.2, ten adiabatically loaded test divertor units (TDUs) were installed in the plasma vessel along with baffles, toroidal/poloidal closures, etc. where high heat loads were observed onto the in-vessel components. Particularly, in the high-mirror magnetic configuration, undesired level of heat loads appeared on the baffles that limited the operation of the device. In some previous studies, it has been shown that the relative position of the divertor targets and the baffle affects the heat load distribution. This poster discusses the investigation of such geometry modifications via modelling. The diffusive field line tracing (DFLT) code - modified to also mimic plasma counter-flows - is used to simulate heat transport to the plasma facing components (PFCs). The aim of this activity is to understand the effect of these simple modifications (in terms of the relative position of targets and baffles) and optimize the same for an acceptable heat load distribution.

P 9.24 Tue 16:00 P

Gyrokinetic modelling of anisotropic energeticparticle driven instabilities in tokamak plasmas — •Brando Rettino[1], Thomas Hayward-Schneider[1], Alessandro Biancalani[2,1], Alberto Bottino[1], Philipp Lauber[1], Ilija Chavdarovski[3], Francesco Vannini[1], and Frank Jenko[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Leonard de Vinci Pole Universitaire, Research Center, 92916 Paris la Defense, France — [3]Korea Institute of Fusion Energy, 34133 Daejeon, South Korea

Energetic particles produced by plasma heating are observed to excite energetic-particle-driven geodesic acoustic modes (EGAMs) in tokamaks. We study the effects of velocity space anisotropy of the EP distribution functions on the excitation of such instabilities with ORB5, a gyrokinetic particle-in-cell code. Numerical results are shown for linear electrostatic simulations with ORB5. The growth rate is found to be sensitively dependent on the phase-space shape of the distribution function. The qualitative behavior of the instability is analyzed theoretically through dispersion relations. Realistic neutral beam energetic particle anisotropic distributions are obtained from the Fokker-Planck solver RABBIT and are introduced into ORB5 as input distribution function. Results show a dependence of the growth rate on the beam injection angle. A preliminary qualitative comparison to experimental measurements is presented,the differences are discussed, and further steps for quantitative non-linear analysis are outlined

P 9.25 Tue 16:00 P

Edge core coupling: physical parameters determining the pedestal width — •Lidija Radovanovic[1], Mike Dunne[2], Elisabeth Wolfrum[2], Friedrich Aumayr[1], and ASDEX Upgrade Team[2] — [1]Institute for Applied Physics, TU Wien, Vienna, Austria — [2]Max Planck Institute for Plasma Physics, Garching, Germany

The outer edge of the plasma, also called the pedestal, serves as a strong insulator between the plasma core and the reactor walls. The top of the pedestal serves as a boundary condition for the hot core plasma. Understanding the physical processes governing the pedestal is crucial for reliable prediction and control of the plasma conditions and its stability. Using the EPED framework as a basis, the pedestal can be considered as a combination of two limits: the pedestal width grows at a constant gradient to the ideal peeling ballooning limit. Understanding this width growth is crucial in order to accurately predict the pedestal for future machines. In this work the pedestal width is further investigated in experiments based on two methods. The first considers a recent analysis at the ASDEX Upgrade, which indicates that locally low magnetic shear at the pedestal top could cause ballooning modes, and it therefore limits the pedestal width. The experimental approach here is changing the shape and the magnetic field of the plasma to move the region of low local magnetic shear. The second method assumes that the turbulent motion of the ionized particles in the plasma edge region is suppressed due to the presence of a steep radial electric field. A comparison of these assumptions with the pedestal width will be shown.

P 9.26 Tue 16:00 P

Magnetic signature of ECCD induced crashes in the Wendelstein 7-X stellarator — •K. Rahbarnia, S. Vaz Mendes, C. Brandt, H. Thomsen, J. Schilling, K. Aleynikova, C. Slaby, A. Könies, and W7-X Team — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

Wendelstein 7-X is a stellarator-type fusion experiment. A strong toroidal plasma current is not needed for optimized confinement properties. Nevertheless, during the last operation campaign a number of experiments including an externally driven plasma current were conducted. The so-called electron cyclotron current drive (ECCD) was used to counteract any rising bootstrap current to completely nullify it. Alternatively, in the presence of co-driven ECCD, the increase of a naturally evolving bootstrap current was accelerated so that an equilibrated state could be reached faster. During ECCD experiments crashes in global plasma parameters have been observed, which sometimes even led to a total collapse of the plasma. Previous analysis mainly involving fast changes of the measured electron temperature caused by the crashes revealed a sawtooth-like behaviour similar to tokamaks. In this study the magnetic signature of these crash events measured by poloidal arrangements of in-vessel Mirnov coils is investigated generally supporting the previous results. Various ECCD scenarios are studied showing similar frequency (around 40kHz) and poloidal mode number (m<5) of the observed bursty magnetic fluctuations. The results are compared to theoretical predictions using the magnetic equilibrium code VMEC and the MHD continuum code CONTI.

P 9.27 Tue 16:00 P

Model based optimization of Advanced Tokamak scenarios — •Raphael Schramm[1], Alexander Bock[1], Emiliano Fable[1], Jörg Stober[1], Simon van Mulders[2], Maximilian Reisner[1], Hartmut Zohm[1], and the ASDEX Upgrade Team[1] — [1]Max-Planck Institut für Plasmaphysik, Garching, Germany — [2]École Polytechnique Fédérale de Lausanne, Switzerland

Advanced Tokamak scenarios aim to reduce the reliance on ohmic current of plasma discharges. This is done by increasing the bootstrap current ($j_{bs} \propto q\nabla p$) with manipulation of the safety factor profile q via external actuators. These can be turned on during the plasma ramp-up, which avoids the safety factor dropping below the desired value, compared to the conventional option to wait until the plasma reaches a stationary state. Last year an ASTRA model has been presented that can be used to the develop such a scenario.

The model has been used to analyze a counter-ECCD scenario with a higher current than the validation scenario. Results of this will be shown. An optimizer, working on a simplified model will be used to improve this scenario. It proposes a change, which is then cross-checked in the ASTRA model in an iterative learning approach. Results will be run in the next ASDEX-U campaign.

In this campaign, a system capable of calculating the safety factor profile in real-time will become available. This contribution will discuss, if accuracy and reliability of such scenarios can be improved by using feed-forward control based on q instead of time.

Real-time control of the q-profile based on this tool will be tested.

P 9.28 Tue 16:00 P

Identification of multiple mode contributions in tomography data from soft X-ray diagnostics — •Henning Thomsen, Christian Brandt, Rene Bussiahn, Sara Vaz Mendes, Kian Rahbarnia, Jonathan Schilling, Thomas Wegner, and W7-X Team — MPI f. Plasmaphysik, 17491 Greifswald

External actuators like impurity injection, density or temperature modulation as well as current drive affect the stability properties of the plasma equilibrium in the Wendelstein 7-X stellarator. The dynamics on the soft X-ray radiation distribution in a poloidal plane is studied by the soft-X ray tomography system XMCTS [1], which measures in the energy range 1-12 keV. The radiation in this energy range originates mainly from Bremsstrahlung of the confined plasma and line radiation from impurity species. In different experiments with impurity injection, a dominant m=1 mode with frequencies in the range of 1-2 kHz has been observed. An analysis of dominant modes is possible with a singular value decomposition. While the dynamics associated with sucb low-frequency modes can often be reconstructed in the tomograms, higher frequency components visible in the line-integrated raw data typically do not show up in the tomographically reconstructed time series. In this contribution the possible reasons and different analysis approaches are discussed.

[1] C Brandt et al Plasma Phys. Control. Fusion 62 (2020) 035010

P 9.29 Tue 16:00 P

Linear (non-)ideal MHD stability analysis of pedestals in axisymmetric and magnetically perturbed tokamak equilibria — •Jonas Puchmayr[1], Mike Dunne[1], Erika Strumberger[1], Branka Vanovac[1], Hartmut Zohm[1], and The ASDEX Upgrade Team[2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]See author list of H. Meyer et al. 2019 Nucl. Fusion 59 112014

In the H-mode, steep gradients of pressure, temperature and density build up at the plasma edge. These gradients can drive a type of instability, called Edge Localized Modes (ELMs). ELMs will lead to severe damage in future fusion devices. While ELMs are typically well-described as a pressure gradient and current density driven instability in the framework of ideal MHD, there are experimentally observed instabilities that can only be described including additional non-ideal effects in the stability calculation. Experimentally, ELMs are observed to be mitigated or suppressed by resonant magnetic perturbation (RMP) fields, which break the axisymmetry of tokamak equilibria.

In this work, the influence of non-ideal effects on linear MHD stability is analyzed using the code CASTOR3D. As a result, the experimentally observed mode frequency is in good agreement with the theoretical prediction only if resistivity, rotation, viscosity and gyroviscosity are simultaneously taken into account. In addition, we observe a strong influence of resistivity on the MHD stability threshold for several equilibria. Finally, new results on weakly toroidally coupled modes in magnetically perturbed tokamak equilibria are presented.

P 9.30 Tue 16:00 P

Data-driven non-intrusive reduced-order modeling via Operator Inference for the Hasegawa-Wakatani equations — •Constantin Gahr — Max-Planck-Institut für Plasmaphysik, Garching, Deutschland

Turbulence simulations play a crucial role in the plasma physics community as they give insight into the underlying nonlinear dynamics. However, these simulations are computationally expensive. Reduced-order models provide a computationally cheaper alternative to the high-fidelity model exploiting the fact that in most physics and engineering problems, the dominant dynamics live on low-dimensional manifolds.

We focus on the Hasegawa-Wakatani equations, a plasma model describing two-dimensional drift-wave turbulence, and approximate it with a reduced order model learned via Operator Inference. Operator Inference is a data-driven non-intrusive model reduction method that learns low-dimensional reduced models with polynomial nonlinearities from trajectories of high-dimensional high-fidelity simulations. In addition, it can handle arbitrary nonlinearities by employing lifting transformations that map the given states into states with polynomial nonlinearities. In the present work, we perform one of the first systematic reduced-order modeling studies in plasma physics to ascertain whether Operator Inference can provide accurate and predictive reduced models for the Hasagawa-Wakatani system.

P 9.31 Tue 16:00 P

Electric field structure and power coupled to the plasma in lattice vortex fields — •Christian Lütke Stetzkamp, Tsanko Vaskov Tsankov, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany

Recently a novel concept for collisionless electron heating and plasma generation at low pressures was theoretically proposed [1]. It is based on a lattice of vortex fields, which produces certain electron resonances in velocity space.

Here, the power coupled into the plasma is theoretically calculated for generalized lattices and coil forms. Also a way to obtain the power coupling from arbitrary electric field configurations is shown and the performance of the field structure used in the theoretical work [1] is compared to simulated and measured fields.

[1] U. Czarnetzki and Kh. Tarnev, Phys. Plasmas 21, 123508 (2014)

P 9.32 Tue 16:00 P

Dynamic structure factor of the correlated one-component plasma — •Hanno Kählert — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel

The dynamic structure factor (DSF) plays an important role for the analysis of x-ray scattering spectra of dense plasmas. Here, molecular dynamics simulations are used to obtain first-principle data for the DSF of the classical one-component plasma (OCP), in particular for intermediate coupling strengths. In this regime, a theoretical description is challenging due to strong coupling and collisional effects. The results are compared with theoretical models for the DSF and are used to compute the local-field correction, which measures the deviations of the DSF from the Vlasov (mean-field) result.

P 9.33 Tue 16:00 P

The effect of plasma parameters on the surface treatment of air cathode for zinc-air battery — •He Li, Christian Schulze, Sadegh Askari, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Germany

Plasma technology is of vital importance in the research field of nanomaterials which offers a green and efficient process for functionalization and treatment of surfaces. Most of the previous researches focus on the process parameters, but the relationship between plasma properties, such as ion energy or fluxes of reactive species, and materials properties is still unclear. In this work, a new reactor was assembled which is combining ICP plasma with CCP bias to control the plasma density and ion energy separately during the treatment, and transition metal oxides were used as the substrate to compare the electrochemical performance before and after plasma treatment. The plasma parameters during treatment were measured by the energy-resolved ion mass spectrometry which were analyzed with the corresponding catalytic performances to optimize the treatment process and fundamentally understand the reaction processes and mechanisms between plasma and material surfaces, thus providing a theoretical basis for the future application in the material researches.

P 9.34 Tue 16:00 P

ZrO2 based layers investigated by the 3ω method — •Vitali Bedarev, Philipp Alexander Maass, Marina Prenzel, Marc Böke, and Achim von Keudell — Experimental Physics II, Ruhr-University, Bochum, Germany

Aim of the project is to develop a diagnostic technique to measure the thermal conductivity of thin ZrO2 layers which are deposited via PECVD. The 3ω method was selected as a surface-sensitive technique with high accuracy and short equilibration time. This method can be applied to bulk amorphous solids and crystals as well as to amorphous films tens of microns thick. A thin electrically conductive wire is deposited onto the specimen to measure its thermal conductivity. The wire serves both, as a heater and as a temperature sensor. Joule heating at 2ω frequency occurs when an ac current with angular modulation frequency ω is applied to the wire. The generated thermal wave diffuses into the specimen. This causes a modulation of the resistance at 2ω due to the temperature dependence of the resistance. The voltage drop along the wire contains a contribution from a third harmonic that depends on the modulated temperature rise of the heater and could be used to calculate the samples thermal conductivity. We will present the setup, its characterization by using reference samples and first results on ZrO2 layers and the influence of the structure and morphology of these layers on the thermal conductivity.

P 9.35 Tue 16:00 P

Langmuir probe measurements in a dual-frequency capacitively coupled rf discharge — •Jessica Schleitzer, Thomas Trottenberg, Viktor Schneider, and Holger Kersten — Institute for Experimental and Applied Physics, Christian-Albrechts-University Kiel, Leibnizstr. 19, 24108 Kiel, Germany

The standard frequency for common rf plasmas used in technology is 13.56 MHz. A difference in the area of the electrodes result in a self-bias voltage at the powered electrode. The gas pressure in the device and the dc self-bias mainly determine the sheath potential and, thus, the ion current density and the ion energy towards the electrode surface. An independent control of these important properties - especially in industrial applications - is desirable but usually not possible. By adding a second frequency (27.56 MHz), a so-called electrical asymmetry effect (EAE) is created, which enables the control of the bias voltage and, thus, the ion energy almost independent of the ion flux by varying the phase angle between the two harmonics. Since the EAE is a relatively new approach to separately control these two parameters, the number of diagnostics performed in such a discharge amounts to a minimum. By using a specially designed Langmuir probe in this dual-frequency plasma, it can be determined to what extend the important plasma parameters, i.e. electron density and electron temperature, change with a variation of the phase between the two harmonics. This work aims to provide an initial insight into the differences between a single- and dual-frequency plasma based on Langmuir probe measurements and offers a comparison of theory and experiment.

P 9.36 Tue 16:00 P

Analysis of phase separation processes in dusty plasmas using a polarization camera — •Andre Melzer, Daniel Maier, and Stefan Schütt — Institute of Physics, University Greifswald

Binary dust mixtures provide an interesting system to study fundamental processes such as phase separation. There, two dust species of different sizes are trapped in the plasma of an rf discharge under microgravity conditions. These two species demix due to the difference in the forces exerted by the plasma on the differently sized particles, even if the size disparity is very small. So far, in these experiments, one of the two species has been marked by a fluorescent dye to distinguish between the species.

In a recent set of experiments, a camera equipped with a pixel-wise polarization filter is used to check whether the polarization-dependent scattering can be used to identify the two different species. Here, demixing processes under microgravity conditions are analyzed from the polarization camera data and compared with the information from the fluorescence technique.

P 9.37 Tue 16:00 P

Oxygen dependent etch rates of MF-particles in an RF-plasma — •Cassedyn Wirtz, Sören Wohlfahrt, and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Microparticles are the essential component of a complex plasma. The forces affecting these particles, as well as their accumulated charge, depend prominently on their size. Thus, a precise knowledge of the particle size is a key input for quantitative description and modelling. However, in interaction with the plasma, the size can change due to etching and surface processes. The precise knowledge of the etch rate is especially important for measurements ranging from several minutes to hours. Melamin-formaldehyde (MF) particles are widely used in complex plasmas and known for changing their size during plasma exposure. It was shown that the etch rate depends strongly on the presence of oxygen in the discharge. We use an advanced light scattering technique that uses angular- and polarization resolved light scattering (APRLS) [1], which allows to determine the particle size with high temporal resolution. Utilizing this resolution the etch rates of MF-particles dependent of the oxygen content are further investigated, with focus on the regime of low admixtures ($< 10\%$).

[1] S. Wohlfahrt, D. Block, "High-precision in-situ measurements of size and optical properties of single microparticles in an RF-plasma", Physics of Plasmas 28, 123701 (2021)

P 9.38 Tue 16:00 P

Experiments and Simulations of Phase Separation in Binary Dusty Plasmas — •Stefan Schütt and André Melzer — Institute of Physics, University of Greifswald

Three-dimensionally extended dusty plasmas containing mixtures of two particle species of different size have been investigated on parabolic flights. Phase separation was found even when the size disparity was below 5%. Uphill diffusion coefficients have been determined and lie in the expected range for a phase separation process driven by plasma forces. A measure for the strength of the phase separation is presented that allows to quickly characterize measurements. There is a clear correlation between size disparity and phase separation strength. Molecular dynamics simulations of binary dusty plasmas have been performed and their behavior with respect to the phase separation process has been analyzed. Here as well, it was found that even the smallest size disparities lead to phase separation. It was confirmed that the separation is due to the force imbalance on the two species. Additionally, it was found that in the simulations the separation becomes weaker with increasing mean particle size.

P 9.39 Tue 16:00 P

Pulse excitation method for the determination of microparticle properties — •Armin Mengel and Franko Greiner — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel

The fact that a microparticle trapped in the sheath of a radiofrequency plasma behaves like a harmonic oscillator is often employed for diagnostics of particle properties, like charge-to-mass ratio or neutral drag coefficient. While traditional resonance methods like the frequency sweep[1] or phase resolved resonance method(PRRM)[2] rely on a sequence of measurements at a set of individual frequencies, possibly resulting in low time resolution, excitation with a pulse signal offers the opportunity to obtain the same parameters from a single time-resolved trajectory of the particle response within a much shorter time. We present a comparative study of PRRM and pulse excitation method (PEM).

[1] A. Melzer et al., Phys. Lett. A, 191 (1994) 301-308, https://doi.org/10.1016/0375-9601(94)90144-9
[2] H. Jung et al., J. Plasma Phys. (2016), 82(3), 615820301, https://doi.org/10.1017/S0022377816000441

P 9.40 Tue 16:00 P

The shallow water accretion disk experiment SWADEX — •Peter Manz — Institute of Physics, University of Greifswald, Germany

Accretion disks are ubiquitous in astrophysics. In laboratory experiments, especially, the two-dimensional geometry, magnetohydrodynamic (MHD) and gravitational effects are difficult to study. An analogy to shallow water can be used to simulate the gravitational potential by a gravitational funnel. In MHD a magnetic tension force gives rise to a return force which is directly proportional to the displacement, like a spring under tension. The analogy to the spring motivated the approach using polymers to mimic the effect of the magnetic field. Using viscoelastic fluids instead of liquid metals, it is possible to perform cheaper and safer experiments. First results of studies related to the standing accretion shock instability [1] and the magneto-rotational instability [2] will be presented.

[1] S. Sebold et al. Phys. Rev. E 102, 063103 (2020) [2] F. Günzkofer, P. Manz Phys. Rev. Fluids 6, 054401 (2021)

P 9.41 Tue 16:00 P

Untersuchung der Laser-induzierten Plasmaausbildung im Wasser mit Doppelpuls-LIBS bei Drücken von bis zu 60 MPa — •Marion Henkel[1], Michelle Siemens[2], Benjamin Emde[2], Steffen Franke[1], Jörg Hermsdorf[2] und Ralf-Peter Methling[1] — [1]Leibniz-Institut für Plasmaforschung und Technologie e.V. (INP), Felix-Hausdorff-Straße 2, 17489 Greifswald, Deutschland — [2]Laser Zentrum Hannover e.V. (LZH), Hollerithallee 8, 30419 Hannover, Deutschland

Um Materialproben hinsichtlich ihrer chemischen Zusammensetzung zu analysieren, ist LIBS ein etabliertes Verfahren. Die Möglichkeit LIBS auch unter Wasser einzusetzen, macht es vor allem für die Rohstofferkundung in der Tiefsee interessant.

Die Doppelpulstechnik ist dafür ein vielversprechender Ansatz, bei der ein erster Laserpuls eine Kavität an der zu analysierenden Materialoberfläche erzeugt und der zweite Laserpuls das Plasma in der Kavität ausbildet.

Hohe Drücke in der Tiefsee haben dabei Auswirkungen auf das Plasma und seine Emission. Es wurde daher eine Druckkammer entwickelt, die Versuche sowohl mit Süß- als auch mit Salzwasser bei 60 MPa erlaubt. Ein Doppelpuls-Nd:YAG-Laser mit 2x400 mJ ermöglicht auch bei hohen Drücken eine Plasmaausbildung.

Spektrale und räumliche Diagnostiken mit einer Zeitauflösung von wenigen Mikrosekunden erlauben eine Untersuchung der Größe und Lebensdauer des Plasmas und der zeitlichen Entwicklung der Emission bei hohen Drücken unter Wasser.

P 9.42 Tue 16:00 P

Accelerating positron rings in a two-fold plasma column — •Lars Reichwein[1], Anton Golovanov[2], Igor Kostyukov[2], and Alexander Pukhov[1] — [1]Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany — [2]Institute of Applied Physics RAS, Nizhny Novgorod, Russia

We present a setup consisting of an electron driver and a short laser pulse which create a two-fold plasma column structure [1]. The obtained laser-augmented blowout allows for the stable acceleration of positron rings over long distances even when the driving beam's evolution is considered. The scheme is studied numerically by means of particle-in-cell simulations. Further, we derive expressions for the accelerating and focusing fields analytically and show that the witness bunch is being accelerated along equilibrium lines in the wakefield structure.

[1] L. Reichwein et al., arXiv:2110.05226v2 (2021)

P 9.43 Tue 16:00 P

OES characterization of the microwave plasma torch in different configurations — •Christian Karl Kiefer[1], Ante Hecimovic[1], Arne Meindl[1], David Rauner[2], and Ursel Fantz[1,2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]University of Augsburg, 86159 Augsburg, Germany

The microwave plasma torch, operated at under-pressure and atmospheric pressure, has already been tested for a wide range of applications from gas conversion over the decomposition of VOC in exhaust gases to plasma spraying. For the application of CO_2 conversion, axial scans of the rotational and vibrational temperature of the plasma were performed for a nozzle configuration (mixing the hot and cold gas as it exits the resonator) and a quencher configuration (allowing to admix additional cold gas into the effluent) via the analysis of the C_2 Swan emission spectrum. To further characterize the microwave plasma torch at atmospheric pressure via optical emission spectroscopy, spectra from a variety of different pure gases and gas mixtures were acquired and specific features were analyzed. Feasibility studies for the determination of different plasma parameters were performed.

P 9.44 Tue 16:00 P

Ignition and propagation of nanosecond pulsed plasmas in water with different polarities — •Katharina Grosse[1], Marina Falke[2], and Achim von Keudell[1] — [1]Experimentalphysik 2, Ruhr-Universität Bochum — [2]CLICCS, Universität Hamburg

Discharges in liquid enable a variety of applications ranging from wastewater treatment to nanoparticle formation. Pulsed plasmas in liquids ignited by voltage pulses with fast rise times and nanosecond pulse lengths yield a high degree of dissociation of the liquid, a high mass transport and efficient reaction rates with surfaces adjacent to the plasma. However, understanding of the ignition and propagation of these plasmas inside the liquid on these short timescales is still a matter of debate. An indirect method to analyze these processes is the comparison of different voltage polarities applied to the electrode. Different possible processes such as gas bubble or nanopore formation, field effects and the presence of a super critical fluid are evaluated and compared with optical emission spectra and ICCD imaging. A 10 ns long voltage pulse with amplitudes of ± 20 kV is applied to a 50 μm thin tungsten wire inside distilled water. The emission intensity, electron density and number of H emitters are similar for both polarities except in the first few ns. This indicates different electron generation mechanisms for different polarities at discharge breakdown. Based on these data, we postulate the ignition and propagation processes to result from electron generation from field effects inside a super critical fluid surrounding the electrode tip.

P 9.45 Tue 16:00 P

Hydrogen production in an atmospheric pressure argon methane microwave plasma — •Simon Kreuznacht, Marc Böke, and Achim von Keudell — Experimental Physics II, Ruhr University Bochum, Germany

Hydrogen is an important precursor in the chemical industry and may also serve as energy carrier, for energy storage, or as climate friendly fuel in the future. Today, hydrogen is produced mainly via steam reforming of methane, which emits a lot of CO_2. A promising alternative production method is the pyrolysis of methane in a microwave plasma, as it is an oxygen free technology.

Here, we present the analysis of the product gas stream of such a plasma. The plasma is operated at atmospheric pressure in an argon methane mixture (60 slm total flow rate up to 35 % methane admixture). Microwaves (2.45 GHz up to 6 kW) are used to sustain the plasma. The length of the plasma reaches up to 60 cm with a diameter of about 1.2 cm. In the center of the plasma the gas temperature reaches up to 4200 K. The main products are hydrogen (H_2), ethyne (C_2H_2), ethene (C_2H_4) and solid carbon. The methane conversion increases linearly with the specific energy input per methane molecule (SEI). Increasing the methane admixture at constant SEI leads to an increased methane conversion. Up to 73 % methane conversion and up to 87 % selectivity towards hydrogen are achieved.

P 9.46 Tue 16:00 P

2D spatially resolved atomic oxygen densities in a micro cavity plasma array — •David Steuer, Henrik van Impel, Volker Schulz-von der Gathen, Marc Böke, and Judith Golda — Experimental Physics II: Physics of Reactive Plasmas, Ruhr-University Bochum, D-44801 Bochum, Germany

Micro cavity plasma arrays have numerous applications, such as the treatment of volatile organic compounds (VOCs) or the generation of ozone. The key to these applications is the generation of reactive species such as atomic oxygen within the plasma. Typically, atomic oxygen densities can be measured by laser spectroscopic methods. In the case of the micro plasma array, which consists of thousands of cavities, optical access is limited. For this reason, an optical emission spectroscopy (OES) approach, energy resolved actinometry (ERA), is used. 2D resolved measurements can be performed by using an ICCD camera in combination with a tunable bandpass filter. The discharge is operated in helium with an oxygen admixture of 0.1%. The triangular voltage is varied at a frequency of 15 kHz between an amplitude of 400-800V. As the voltage increases, the number of ignited cavities rises. Furthermore, the atomic oxygen density per cavity increases with the power. This work is supported by the DFG via SFB 1316 (project A6).

P 9.47 Tue 16:00 P

3-dimensional density distributions of NO in the effluent of a micro atmospheric pressure plasma jet operated in He/N2/O2 mixture and the influence of surfaces — •Patrick Preissing[1], Ihor Korolov[2], Julian Schulze[2], Volker Schulz-von der Gathen[1], and Marc Böke[1] — [1]Ruhr-Universität Bochum, Experimentalphysik II — [2]Ruhr-Universität Bochum, Allgemeine Elektro- und Plasmatechnik

Plasma jets are known to generate a huge number of different reactive species. In that context Nitric Oxide (NO) is one of the key players, as it triggers many biological processes. In this study absolute ground state densities of NO are measured in the effluent of an RF-driven micro atmospheric pressure plasma jet (μAPPJ), that is operated in a He/N2/O2 mixture, by means of Laser Induced Fluorescence (LIF), with 3d spatial resolution. The densities are measured in two distinct atmospheres. In the first one, the jet is expanding into open air, whereas in the second configuration the jet is expanding into a controlled He/ synthetic air mixture. From the time resolved LIF signals the quenching coefficients for He, air, N2 and O2 are determined, as well as the intrusion of the ambient air into the He gas flow expanding from the jet. Parameter studies, varying different parameters such as plasma power, gas flow and gas mixture have been performed and the influence on the absolute NO densities as well as its distributions are investigated. Eventually the influence of surfaces in the effluent that interact with the reactive species is measured.

P 9.48 Tue 16:00 P

Atomic oxygen distribution in the interaction zone of a micro atmospheric pressure plasma jet and a surface — •Sascha Chur[1], David Steuer[1], Volker Schulz-von der Gathen[1], Marc Böke[1], and Judith Golda[2] — [1]EP2 chair Physics, Ruhr University Bochum, Germany — [2]Plasma Interface Physics, Ruhr University Bochum, Germany

The efficiency of catalysts is strongly dependent on the characteristics of the used catalytic surface. Key features are the morphology and nanostructure of the surfaces and its chemical composition. The combination of reactive species provided by a micro-scaled atmospheric pressure plasma jet, electric fields and energy input by laser irradiation can lead to very effective functionalisation and structuring of surfaces via complex laser-plasma-surface interactions. Here, we investigate the distribution of atomic oxygen (O) along treated substrates by means of two-dimensional two photon absorption laser induced fluorescence spectroscopy (TALIF) utilizing a red enhanced ICCD camera. The measurements were performed in the emerging gas beam of a micro atmospheric pressure plasma jet operated with a He/O admixture in the interaction zone of a metallic (Cu) surface. The O density (~10^16 m^-3) forms a maximum in front of the surface. Furthermore it could be shown that the size of the observed volume by the detector systems influences results like density or lifetime significantly. Supported by DFG within SFB1316 (TP B2)

P 9.49 Tue 16:00 P

Determination of hydrogen peroxide concentration in water treated by a capillary plasma jet — •Steffen Schüttler[1], Emanuel Jess[1], Marc Böke[2], Volker Schulz-von der Gathen[2], and Judith Golda[1] — [1]Plasma Interface Physics, Ruhr-University Bochum, Germany — [2]Experimental Physics II: Physics of Reactive Plasmas, Ruhr-University Bochum, Germany

A novel and promising approach to activate a biocatalyst is by use of an atmospheric pressure plasma jet that produces hydrogen peroxide [1]. Since the biocatalyst requires a well-defined portion of hydrogen peroxide, a plasma is ideally suited as it can be easily switched on and off. In the plasma-driven biocatalysis process, the biocatalyst is placed in a liquid, mainly water, and the plasma jet is in contact with the liquid via its effluent. In this work, a capillary plasma jet is used, which offers a wide range of control parameters and optimization possibilities. The hydrogen peroxide concentration in water was measured by UV absorption spectroscopy. This technique allows an in-situ measurement while the plasma is in operation and the spatial resolution of the hydrogen peroxide concentration can be obtained. Furthermore, a spectrophotometric approach was used. Ammonium metavanadate was added to the treated water. Its reaction with hydrogen peroxide leads to an absorption spectrum at 450 nm. This enables comparable measurements to the UV absorption measurements. This work is supported by the DPG within SFB1316 (Subproject B11).

[1] A. Yayci, T. Dirks, F. Kogelheide, M. Alcalde, F. Hollmann, P. Awakowicz, J. E. Bandow, ChemCatChem 2020, 12, 5893.

P 10: Invited talks III

Time: Wednesday 11:00–12:30 Location: P-H11

Invited Talk P 10.1 Wed 11:00 P-H11

AI in fusion: assisting plasma exhaust modelling by machine-learning techniques — •Sven Wiesen — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, D-52425 Jülich, Germany

Rapid computational design of future fusion power plants is usually compromised by a delicate balance between the required numerical effort, e.g. for running first-principle plasma simulations, and an increased complexity in the physics model for relevant operational tokamak plasma scenarios. State-of-the-art exhaust plasma design codes like SOLPS-ITER demand long convergence times when predicting next-step fusion devices like ITER or DEMO. Existing exhaust model frameworks suffer from uncertainties in the underlying atomic physics databases and incomplete sub-models for turbulent plasma transport.

This contribution reflects on the recent progress that enable AI-based model techniques for training of fast exhaust surrogate models. A conceptual basis for an enhanced model predictor scheme is developed that integrates calibrated machine-learning (ML) models like neural networks for 2D/3D edge plasma transport. This approach defers in parts the computational cost of first-principle simulations into the training phase of a surrogate edge plasma model. It is demonstrated how non-linear ML methods help to enhance transport models for the critical region between plasma core and edge taking experimental data as ground-truth. AI-based interpolators and generators are exploited for uncertainty quantification and ML regression analysis illustrate model discovery also for plasma-material interaction physics.

Invited Talk P 10.2 Wed 11:30 P-H11

COMPACT - A new complex plasma facility for the ISS — •Christina A. Knapek — Institute of Physics, University Greifswald, Greifswald, Germany

Complex plasma is a state of soft matter where micrometer-sized particles are immersed in a weakly ionized gas. The particles acquire negative charges of the order of several thousand elementary charges in the plasma, and they can form gaseous, liquid and crystalline states. Direct optical observation of individual particles allows to study their dynamics on the kinetic level even in large many-particle systems. Gravity restricts the research on ground to vertically compressed, inhomogeneous clouds, or two-dimensional systems. A microgravity environment, e.g. the International Space Station (ISS), is therefore essential to study large and homogeneous 3D many-particle systems. The complex plasma facility COMPACT to be operated onboard the ISS builds upon previous studies and hardware developments (PlasmaLab, Ekoplasma) and is envisaged as an international multi-purpose and multi-user facility that gives access to the full three-dimensional kinetic properties of the particles. The heart of COMPACT will be a novel plasma chamber: the Zyflex chamber. It includes a variety of innovations that allow to tune, control and manipulate plasma-particle and particle-particle interaction in various ways. We will present the overall design and research goals of COMPACT, with special focus on the characteristics of the new plasma chamber, supported by plasma simulations and results of experiments performed on ground and during parabolic flights.

Invited Talk P 10.3 Wed 12:00 P-H11
Optical diagnostics of vacuum arc discharges for switching applications — •Sergey Gortschakow[1], Ralf Methling[1], Steffen Franke[1], Diego Gonzalez[1], Dirk Uhrlandt[1], Sergey Popov[2], and Alexander Batrakov[2] — [1]Leibniz institute for plasma science and technology, Greifswald, Germany — [2]Institute of high-current electronics, Tomsk, Russia

Optical diagnostics offers numerous methods for characterization of arc plasmas. The contribution presents selected methods used for determination of arc plasma temperature, anode surface temperature and densities of plasma species during the current pulse and after it termination. The vacuum arcs have been investigated under typical switching conditions - ignition by CuCr contact separation during the AC current flow at several kA magnitude. High-speed cinematography is usually used for observation of arc dynamics and characterization of the anode activity. Optical emission spectroscopy can be applied for determination of dynamics of spectral lines from various species during the active phase, as well as for determination of plasma temperature and electron density. For quantitative characterization of the anode surface temperature, NIR spectroscopy and high-speed camera techniques enhanced by narrow-band filters have been used. Broad band absorption spectroscopy is a suitable techniques for determination of the vapour density close to the current zero crossing and in the early post-arc phase. Advantages and drawbacks of each method along with examples of their application will be presented and discussed.

P 11: Codes and Modelling

Time: Wednesday 14:00–15:30 Location: P-H11

P 11.1 Wed 14:00 P-H11
Modelling of streamer inception in pulsed-driven dielectric barrier discharges at atmospheric pressure — •Aleksandar P. Jovanović, Hans Höft, Detlef Loffhagen, and Markus M. Becker — Leibniz Institute for Plasma Science and Technology (INP), Felix-Hausdorff-Str. 2, 17489 Greifswald, Germany

A pulsed-driven dielectric barrier discharge (DBD) in a symmetric single-filament configuration with hemispherical electrodes is the object of interest of the analysis. The Townsend pre-phase and streamer propagation in Ar and N_2 with an admixture of 0.1 vol.% of O_2 have been investigated by a time-dependent, spatially two-dimensional fluid model. It consists of a set of balance equations for the particle number densities, the electron energy density, and the surface charge density, coupled with Poisson's equation for the determination of electric potential and field. The evolution of the spatial profiles of the electron number density and the electric field showed earlier streamer inception in Ar in comparison to the N_2-O_2 mixture, while qualitatively similar behaviour of the discharge during the streamer propagation was observed in both gases. The streamer propagation and consequently the current rise was slower in Ar (reaching a maximum streamer velocity of 0.43 mm/ns) compared to N_2-O_2 (1.23 mm/ns). An analysis of the electron particle and energy budget was performed to find out how the different gain and loss processes in these two gases affect the pre-phase and the streamer propagation.

Funded by the Deutsche Forschungsgemeinschaft (DFG) – project numbers 407462159 and 408777255.

P 11.2 Wed 14:15 P-H11
Implementation and Validation of Guiding Centre Approximation into ERO2.0 — •Sebastian Rode[1], Juri Romazanov[1], Dirk Reiser[1], Sebastijan Brezinsek[1], Christian Linsmeier[1], and Alexander Pukhov[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster(TEC), 52425 Jülich, Germany — [2]Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Germany

The Monte-Carlo code ERO2.0 uses full orbit resolution to follow impurity particles throughout the plasma volume to determine the local erosion and deposition fluxes on the plasma-facing components of fusion devices. For this work, the theory of guiding centre approximation (GCA) was implemented into ERO2.0, enabling direct comparisons to other transport codes and accelerating the code. First, the implementation of GCA theory into the code is described in detail. Additionally, a hybrid simulation mode for ERO2.0 was developed, in which the advantages of both full orbit resolution and guiding centre approximation are used. The GCA implementation was tested in an inner-code benchmarking, using a plasma background corresponding to a deuterium limiter plasma used in JET pulse #80319. Analysing a multitude of output metrics of the code and comparing them between pure full orbit simulations and hybrid simulations, the quality of the GCA implementation was confirmed while a significant code speed up was measured in large scale simulations.

P 11.3 Wed 14:30 P-H11
Simulation results of a plasma lens as a capturing device for the ILC positron source — •Manuel Formela[1], Niclas Hamann[1], Gudrid Moortgat-Pick[1], Klaus Floettmann[2], and Gregor Loisch[2] — [1]Universität Hamburg — [2]DESY

The ILC is an ambitious international collaboration with its positron source especially being at the forefront of pushing technological boundaries. Part of this enterprise has to be the optical matching device responsible for capturing positrons exiting a target and transforming them from a highly divergent beam with a small effective cross-section to a wide, parallel beam to be appropriate for the succeeding accelerator section. For many years this problem has been approached by different types of sophisticated coils. Today considerations exist to utilize an electric current-carrying plasma. This so called plasma lens creates a magnetic field, which is potentially especially qualified for the usage as a so called optical matching device due to its pronounced azimuthal component in contrast to the radial component of conventional devices. Simulations of various tapered plasma lens designs have been conducted to find an optimal device for the ILC positron source. Designs with linear and quadratic tapering, but also with tapering growing with the square root have been examined. Furthermore, the parameter space for the optimization included a wide range of values for entrance and exit radius, length and electric current.

P 11.4 Wed 14:45 P-H11
Surrogate Modeling of Ion Acceleration in the Near-Critical Density Regime with Invertible Neural Networks — •Thomas Miethlinger[1,2], Marco Garten[1,2], Ilja Gothel[1,2], Nico Hoffmann[1], Ulrich Schramm[1], and Thomas Kluge[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Deutschland — [2]Technische Universitat Dresden, 01069 Dresden, Germany

The interaction of near-critical plasmas with ultra-intense laser pulses presents a promising approach to enable the development of very compact sources for high-energetic ions. However, current records for maximum proton energies are still below the required values for many applications, and challenges such as stability and spectral control remain unsolved to this day. In particular, significant effort per experiment and a high-dimensional design space renders naive sampling approaches ineffective. Furthermore, due to the strong nonlinearities of the underlying laser-plasma physics, synthetic observations by means of particle-in-cell (PIC) simulations are computationally very costly, and the maximum distance between two sampling points is strongly limited as well. Consequently, in order to build useful surrogate models for future data generation and experimental understanding and control, a combination of highly optimized simulation codes (we employ PIConGPU), powerful data-based methods, such as artificial neural networks, and modern sampling approaches are essential. Specifically, we employ invertible neural networks for bidirectional learning of parameter and observables, and autoencoder to reduce intermediate field data to a lower-dimensional latent representation.

P 11.5 Wed 15:00 P-H11

Application of surrogate models for tokamak edge plasma simulations — •Stefan Dasbach and Sven Wiesen — Forschungszentrum Jülich GmbH, Institut für Energie-und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany

The effect of operational parameters on the exhaust in a tokamak can be adequately simulated by plasma edge codes like SOLPS-ITER. These simulations suffer from two main limitations: a) due to their complexity these transport codes suffer from long convergence times, and b) each simulation yields only a result for a single tokamak scenario with fixed parameters. However for rapid design studies of future fusion power plants systems codes require fast simplified models for the exhaust in many different scenarios (machine size, field, heating, etc.). Promising candidates for such surrogate models are machine learning models trained on simulation data. The development of such surrogate models is however limited by the high computational requirements for creating a sufficient training database. This work discusses several different pathways of how this limitation might be overcome and shows first steps in their implementation. The approaches shown include the generation of a simulation database based on less numerically demanding fluid neutral simulations and first trials on a surrogate model only replacing the numerically more demanding kinetic neutral part of SOLPS-ITER.

P 11.6 Wed 15:15 P-H11

Atomic Physics for Transient Relativistic Plasmas — •Brian Edward Marre[1,2], Sergei Bastrakov[1], Axel Huebl[3], Marco Garten[1,2], Pawel Ordyna[1,2], Rene Widera[1], Michael Bussmann[4], Ulrich Schramm[1], and Thomas Kluge[1] — [1]Helmholtz Zentrum Dresden-Rossendorf — [2]TU Dresden — [3]Lawrence Berkley National Laboratory — [4]Center for Advanced Systems Understanding

Experiments for laser-driven ion acceleration create extreme states of matter, in particular relativistic solid-density plasmas undergoing transient, non-equilibrium physics. Especially the formation of such plasmas is heavily influenced by collisional and radiative effects. However, state-of-the-art simulations do not model transitions to and from excited atomic states self consistently. As these transitions are now becoming experimentally accessible on fs-nm scales, e.g. at HIBEF at the European XFEL, modelling can be improved by including excited states dynamics in simulations.

We are developing such an extension for the Particle-In-Cell(PIC) simulation code PIConGPU, to model atomic state distributions self consistently in transient plasmas. This extension is based on a reduced atomic state model directly coupled to the existing PIC-simulation, for which the atomic rate equation is solved explicitly in time.

Via the prediction of atomic state populations, this will allow us to predict plasma self-emission and XFEL probing, and improve our understanding of isochoric heating processes and plasma expansion.

P 12: Magnetic Confinement / Plasma Wall Interaction I

Time: Wednesday 14:00–15:30 Location: P-H12

P 12.1 Wed 14:00 P-H12

Experimental observation and modelling of heat loads in W7-X and implications for transport — •David Bold, Felix Reimold, Holger Niemann, Yu Gau, Marcin Jakubowski, Carsten Killer, and the W7-X team — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Modelling the scrape-off layer of a stellarator is challenging due to the complex magnetic 3D geometry. The here presented study analyses simulations of the scrape-off layer (SOL) of the stellarator Wendelstein 7-X (W7-X) using the EMC3-EIRENE code. Comparing with experimental observations, the transport model is validated.

Based on the experimentally observed strike line width, the anomalous transport coefficients, used as input to the code are determined to around $0.2\,\mathrm{m^2/s}$. This is however in disagreement with upstream measurements, where such small cross-field transport leads to temperatures higher than measured experimentally. Agreement can be improved by using spatially varying transport coefficients.

Even with spatially varying transport coefficients, differences remain, for example the toroidal heat flux distribution or the hollow temperature profile is not reproduced. Some of the differences could be explained by drifts. The future implementation of drifts into the transport model is expected to help overcome the discrepancies, and thus the development of SOL transport models including drifts is a necessary next step to study the SOL transport of the W7-X stellarator.

P 12.2 Wed 14:15 P-H12

Scaling Behavior of the Weakly Coherent Mode in ASDEX Upgrade I-mode Plasmas — •Manuel Herschel[1,2], Tim Happel[1], Joey Kalis[1,3], Gregor Birkenmeier[1,3], Michael Griener[1], Klara Höfler[1,3], and The ASDEX Upgrade Team[1] — [1]MPI für Plasmaphysik, Garching, Germany — [2]Universität Ulm, Germany — [3]Physik Department E28, TUM, Garching, Germany

Improved confinement regimes are fundamental in the operation of current and future fusion devices. Among these regimes, the I-mode combines the beneficial properties of an H-mode like energy confinement with the absence of ELMs. The physical origin of the I-mode is still not fully understood, but the so-called weakly coherent mode (WCM) dominant in the turbulence spectrum at the plasma edge is often considered to be a key player for I-mode.

To investigate the WCM in detail, turbulence measurements from multiple diagnostics (Doppler reflectometry, thermal helium beam emission spectroscopy) on ASDEX Upgrade are combined in order to characterize the mode better. These measurements include the radial localization, frequency and wavenumber of the WCM, along with important local plasma parameters such as the magnetic field strength, density and temperature.

To ensure statistical significance and enable comparisons over multiple discharges, these measurements are collected in a database consisting of various I-mode plasmas. With this database, the scaling of parameters of the WCM depending on typical plasma variables is examined and compared with proposed theories.

P 12.3 Wed 14:30 P-H12

Post mortem ion beam analysis of the 13C tracer experiment at Wendelstein 7-X — •Christoph Kawan[1], Sebastijan Brezinsek[1], Timo Dittmar[1], Sören Möller[1], and W7-X Team[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]Max-Planck-Institut für Plasmaphysik, D-17491 Greifswald, Germany

Future fusion reactors will operate under extreme thermal conditions. A key challenge for preserving a safe operation and low maintenance is the mitigation of erosion, transport and deposition of wall material and impurities. To analyze the deposition and transport of impurities, two dedicated experiments were carried out at the end of Wendelstein 7-X campaign 1.2b. $1.1*10^{21}$ molecules $^{13}CH_4$ were injected in standard magnetic divertor configuration through a dedicated gas puff head attached to the multi purpose manipulator directly into the plasma island structures. In the second part, $4.2*10^{22}$ molecules of $^{13}CH_4$ have been injected from a divertor gas injection system at a position where the magnetic island intersects with the horizontal target plate. After the experiment, the wall components were changed and parts of the test divertor unit (TDU) target elements cut for post-mortem analysis. In this work, the deposition of ^{13}C in different locations of W7-X via 1 MeV deuteron ion beam analysis is reported.

P 12.4 Wed 14:45 P-H12

Double-pulse laser ablation molecular isotopic spectroscopy with picosecond laser pulses: Swan band analyses for ^{13}C-^{12}C distinction in graphite — •Erik Wüst, Jannis Oelmann, and Sebastijan Brezinsek — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany

Laser-based methods for spatially and depth resolved measurements of material composition are well-established. Laser ablation molecular isotopic spectroscopy or spectrometry (LAMIS) is a technique for the determination of isotope concentrations in material mixtures. A laser-induced plasma on the material's surface is used to derive the material isotope composition by optical emission spectroscopy (OES). In double-pulse LAMIS (DP-LAMIS) a second laser pulse is focussed into the laser-induced plasma to enhance the plasma's emission and thus improve the limit of detection for isotopes with smaller concentrations. Laser pulses from a Nd:YAG-laser with 35 ps pulse duration were used to induce the plasma and a second laser pulse from the same laser was used to enhance the plasma's emission. Both laser pulses arrive at the sample with a relative delay of 50 ns. A Littrow spectrometer (focal length: f=750 mm, spectral resolution at 473 nm: A=6000, étendue: E=62 $\frac{\mu\ \mathrm{m}^2}{\mathrm{sr}}$) was used to analyse the band structure. The analysed materials were graphite either with only natural amounts of ^{13}C or coated with a ^{13}C rich layer. The isotopic composition was determined with the aid of the C_2 molecule's Swan band with Δv=1 at 473.7 nm.

P 12.5 Wed 15:00 P-H12

Investigation of hydrogen retention in beryllium and beryllium-tungsten alloys — •Meike Flebbe, Timo Dittmar, and Christian Linsmeier — FZJ, Jülich, Germany

ITER will use beryllium (Be) as first wall material and tungsten (W) as divertor material. Alloys can form due to erosion of beryllium and tungsten particles and their redeposition elsewhere. In the course of the plasma-wall interaction, tritium from the plasma can be deposited in the plasma facing material. For safety and for tritium breeding and economy considerations, the understanding of hydrogen retention in Be-W-alloys is of central importance for the fusion research in order to be able to realize a fusion reactor.

Fundamental experiments are required to understand the processes involved in hydrogen retention in Be-W-alloys. These can be executed with the help of in-situ ion beam experiments. A suitable system for this is ARTOSS, a high vacuum device from the FZJ, in which Be-W-alloys can be produced, loaded with deuterium and examined using analysis diagnostics like thermal desorption spectroscopy (TDS) and ion beam analysis (IBA). Recent studies have shown a low temperature desorption peak at around 400 K for beryllium, which shows a splitting into a fine structure from a threshold fluence of $1 \cdot 10^{21}$ m^{-2} with a sufficiently high resolution. The mechanism behind this split is still unknown. To test whether hydrides are the reason for the fine structure, ramp-and-hold TDS experiments are used.

In this contribution, I will show ramp-and-hold experiments with beryllium and will give an outlook on Be-W experiments.

P 12.6 Wed 15:15 P-H12

Application of a spatially resolved emission model to sputtered tungsten atoms at the linear plasma device PSI-2 — •Marc Sackers, Oleksandr Marchuk, Stephan Ertmer, Philippe Mertens, Arkadi Kreter, and Sebastijan Brezinsek — Forschungszentrum Jülich GmbH - Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Deutschland

Highly charged atomic species in the core of a fusion plasma are detrimental to the successful operation of the reactor because they lead to significant cooling of the plasma due to radiation losses. For example, at ITER, the divertor will consist of tungsten blocks [1]. The main erosion channel of these blocks is physical sputtering, which needs to be understood at a fundamental level to estimate tungsten concentration in the plasma core for different operating scenarios.

In this work, the PSI-2 plasma-surface interaction test-bed provides divertor-like conditions. Its plasma source is an arc discharge between a hollow ring-shaped cathode and anode. This geometry allows the acquisition of high-resolution emission spectra ($\lambda/\Delta\lambda \approx 7 \cdot 10^5$) for lines of sight parallel and perpendicular to the surface normal of a target exposed to the plasma. A spatially resolved emission model was fitted to spectra of the 498.26 nm neutral tungsten line obtained during sputtering of mono- and polycrystalline tungsten targets. The angular and energy distribution were derived for bombardment with argon ions from 40 eV to 160 eV.

[1] R.A. Pitts *et al.*, J. Nucl. Mater. 2011, **415**, S957-S964

P 13: Dusty Plasmas

Time: Wednesday 16:00–17:15 Location: P-H11

P 13.1 Wed 16:00 P-H11

The sticking machine: measuring electron sticking coefficients using dusty plasmas — •Armin Mengel and Franko Greiner — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel

In many plasma-surface interactions, the electron sticking coefficient is, due to lack of better knowledge, assumed to be 1. However, recent quantum-mechanical calculations[1] hint at significantly smaller values for dielectric surfaces. The goal of the presented project is to experimentally determine the particle charge and thus (via a relative measurement scheme) the low-energy electron sticking coefficient. In order to achieve this, a new approach using microparticles of the material of interest confined in the sheath of a radiofrequency plasma is introduced, employing long-distance microscopy and an improved phase resolved resonance method.

[1] F.X.Bronold et al., Plasma Phys. Cont. Fusion **59** (2017) 014011, https://iopscience.iop.org/article/10.1088/0741-3335/59/1/014011

P 13.2 Wed 16:15 P-H11

Studying the feasibility to observe turbulence in fluid complex plasmas — •Prapti Bajaj[1], Alexei Ivlev[2], Christoph Räth[1], and Mierk Schwabe[1] — [1]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR) — [2]Max-Planck-Institut für Extraterrestrische Physik

Turbulence is a phenomenon observed in a dissipative system far away from thermodynamic equilibrium with many degrees of freedom and it has been studied in fields varying from microscopic to macroscopic scales[1]. In this work, we study the feasibility to observe turbulence in fluid complex plasmas, i.e., a system of micrometer-sized particles embedded in a low-temperature plasma. We performed an experiment in the ground-based setup of PK-3 Plus, where microparticles were injected in a capacitively coupled RF-plasma chamber and a laser illuminated a vertical cross-section of the microparticle cloud. Below a critical pressure, we observed self-excited Dust Acoustic Waves, which we then used to study the properties of turbulence in our system. These waves are generated due to the ion-streaming instability, i.e., motion of ions past the microparticles. Using high-speed imaging, we were able to track individual microparticles to perform a robust spatial and temporal analysis. We use novel analytical tools to study the energy spectrum in the space and time domains. Our aim is to study the spectrum of short-scale disturbances generated due to the cascade of different wave modes[1], and their isotropisation, even in the presence of a background friction force, as in the case of complex plasmas.

[1] "Wave Turbulence" by S. Nazarenko, Springer(2011).

P 13.3 Wed 16:30 P-H11

Decoupling of dust cloud and embedding plasma for high electron depletion in nanodusty plasmas — •Andreas Petersen, Oguz Han Asnaz, Benjamin Tadsen, and Franko Greiner — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel

Understanding how dust particles can grow in a reactive plasma discharge and change its behavior, is an interesting topic, since nanoparticles (nps) have become key technological products, e.g. as coatings with tunable optical gap in third generation solar cells, as nanocrystals for photonic applications, and as pharmaceutical nanocarriers.

We have been able, to characterize an argon discharge with embedded amorphous hydrocarbon nps of different size and density, using self excited dust density waves (DDW) as a diagnostic tool.

Our results show, that the comparably high dust density (high Havnes parameter) leads to electron depletion and governs the charge of dust grains, while the size of the particles has only a weak influence on their charge. The ion density and electric potential profile are almost independent of both, dust size as well as dust density. This suggests, that the ion generation and the dust cloud coexist and the coupling of both is weak.

P 13.4 Wed 16:45 P-H11

Stereoscopic Investigation of Particle Chains in Dusty Plasmas — •Daniel Maier, Michael Himpel, Stefan Schütt, and André Melzer — Institut für Physik der Universität Greifswald, Greifswald, Deutschland

In dusty plasmas under microgravity conditions stable chains of charged dust particles can be observed. These chains are stabilized by an outward ion stream and appear near the mid-plane and around the particle free zone (void) of the plasma. So far only 2-dimensional investigations of these chains have been done, with difficulties in proofing the authenticity of a chain, observing it at full length or separating chains from each other. The use of our experimental set-up, with four high-speed cameras allows stereoscopic, 3-dimensional observation and investigation of chains and the interaction of the included particles with high temporal resolution. Here first results of these investigations will be shown.

P 13.5 Wed 17:00 P-H11

Artificial voids in nanodusty plasmas — Ulrike Küst and •Franko Greiner — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel

Artificial voids are an interesting and frequently studied phenomenon in dusty plasmas [E. Thomas POP 2004, M. Klindworth RSE 2007, O. Arp PRE 2011, M. Schwabe NJP 2017]. Voids are created by projectiles shot into the dust cloud or by electrostatic probes. We investigated artificial voids created in nanodusty plasmas at high electron depletion. By variation of the probe voltage, the size of the void can be varied. The voids are not stable at probe potentials near the local plasma potential. Instead, the whole cloud is destabilized and strong dust streaming is observed. We present a simple force balance that explains the linear increase of the void radius for probe bias variation in the dust repelling regime (negative probe voltage in reference to the plasma potential). The ability to use this force model to estimate the plasma potential and the consequences for credible Langmuir probe measurements in nanodusty plasmas are discussed (see video https://youtu.be/Nmz2nR8uTrE or search the internet for "nanodustcloud").

P 14: Plasma Wall Interaction II / HEPP III

Time: Wednesday 16:00–17:10 Location: P-H12

P 14.1 Wed 16:00 P-H12

Surface Segregation of Cr in the WCrY SMART Alloy — •Pawel Bittner[1], Hans Rudolf Koslowski[1], Andrey Litnovsky[1,2], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung, 52425 Jülich, Germany — [2]Institute of Laser and Plasma Technologies, National Research Nuclear University MEPhI, 115409 Moscow, Russia

Self-passivating Metal Alloys with Reduced Thermo-oxidation (SMART) are promising candidates for the first wall of the DEMOnstration power plant (DEMO). These materials aim at having an increased oxidation resistance during accidental conditions and acceptable plasma performance during regular operation of the power plant. In this work, the effects of surface segregation, diffusion and sputter erosion on the Cr concentration of a tungsten-chromium-yttrium SMART alloy (WCrY) with a composition of 68 at% of W, 31 at% of Cr and 1 at% of Y are studied with low energy ion scattering (LEIS) measurements and numerical calculations.

A three-parameter phenomenological model to describe the time and temperature dependent surface concentration of Cr is proposed. Further, temporally resolved ion scattering measurements during thermal annealing between 800 K and 1100 K were conducted. The parameters of the model were changed in consecutive numerical calculations to fit these measurements best. The calibrated model is applied to conditions in which the samples were sputtered during annealing and the similarities and differences between theoretical prediction and experimental results are discussed.

P 14.2 Wed 16:15 P-H12

Secondary electron emission from metals at low impact energies — •Franz Xaver Bronold and Holger Fehske — Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany

The interaction of electrons with the walls of discharges is an important surface process in low-temperature plasmas. It affects, for instance, the operation modii of barrier discharges, Hall thrusters, and divertor plasmas in fusion devices. Little is known quantitatively about the process because it typically occurs at energies below 50 eV which are hard to access experimentally. There are thus only a few attempts to measure secondary emission yields in this energy range. A few years ago, we presented therefore an approach, based on an embedding principle, for calculating the complement of the emission yield, the absorption probability, from a microscopic model and applied it to dielectric walls at impact energies below the band gap, where backscattering due to electron-electron collisions is absent. We now generalized the approach to account for it. In addition, we developed a scheme to solve numerically the full nonlinear embedding equation (not only its linearized version), and included–depending on the crystallinity of the surface–Bragg gaps due to coherent scattering on the crystal planes parallel to the interface or incoherent scattering on the ion cores of the bulk. Applying this approach to metal surfaces, we find for impact energies up to 20 eV good agreement with measured emission yields. Depending on the metal and surface quality, the yields are around 10-30 %. Hence, even metal surfaces turn out to be not perfect absorber for electrons.

P 14.3 Wed 16:30 P-H12

Surface charge diagnostics by infrared multiple internal reflection spectroscopy — Kristopher Rasek, •Franz Xaver Bronold, and Holger Fehske — Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany

We propose to measure the surface (wall) charge accumulating at a floating plasma-dielectric interface via infrared multiple internal reflection spectroscopy [1]. The negative charge deposited into the plasma-facing dielectric, forming the negative part of an electric double layer (the positive part being the plasma sheath), leads to a change of the reflection coefficient, when the interface is subjected to infrared radiation. Based on the Boltzmann equations for the charge kinetics of the double layer and nonlocal surface response functions to calculate the reflection coefficient in the presence of the charge inhomogeneity at the plasma-solid interface, we show theoretically and numerically that a local, Drude-like expression is in fact sufficient to describe the optical response. It contains only the integrated surface charge, enabling thus a straightforward analysis of measured data. To amplify the charge-induced change in the reflectivity, we suggest an experimental setup utilizing the plasma-solid interface as a multiple internal reflection element. Numerical results indicate that in such a setup the magnitude of the wall charge can directly be determined from the change it causes in the transmitivity of the optical element. [1] K. Rasek, F.X. Bronold, and H. Fehske, Phys. Rev. E 104, 015204 (2021)

P 14.4 Wed 16:45 P-H12

Effects of thin surface oxide films on deuterium uptake and release from ion-damaged tungsten — •Kristof Kremer, Maximilian Brucker, Thomas Schwarz-Selinger, and Wolfgang Jacob — MPI for Plasma Physics, Garching, Germany

In a fusion reactor, the uptake of deuterium (D) and tritium fuel into the plasma-facing tungsten (W) components is a critical issue with respect to fuel loss and radioactive inventory. However, the possible influence of natural surface oxides on the D uptake in W is not fully understood yet.

Therefore, we investigated the D uptake into W through 33 to 55 nm thick oxide films in dependence of D fluence, D ion energy and sample temperature. To trace the D, we created a 2 micron thick layer of self-ion-damaged W underneath the oxide. It acts as a getter layer and traps any D that permeates the oxide film. We measured the depth-resolved concentration of D and oxygen with ion beam analysis and the surface modifications of the oxide film with scanning electron microscopy. To study D release through the oxide we filled the self-damaged layer with D prior to oxidation and measured the D release with thermal desorption spectroscopy.

We observed a strong influence of surface oxide films on D uptake and release. Uptake: The oxide films block D uptake into metallic W. We explain this by the different heat of solution of D in W oxide and metallic W. At high ion energies, however, D partly reduces the oxide film and enters the metallic W. Release: The oxide film delays the D release until it is chemically reduced under formation of heavy water.

P 15: Annual General Meeting

Time: Wednesday 17:30–18:30 Location: P-MV

Annual General Meeting

P 16: Invited talks IV

Time: Thursday 11:00–12:30 Location: P-H11

Invited Talk P 16.1 Thu 11:00 P-H11

Effect of the green energy revolution on circuit breakers and switches in electrical power distribution systems — •Erik D. Taylor — Siemens AG, Berlin, Germany

Green energy and the general energy revolution are widely discussed as key components in reducing the magnitude of climate change. Most discussions focus on converting to electrical power produced from green sources. However, an important piece of this puzzle is the electrical distribution and transmission systems required to enable this transformation. Green energy and the increased use of electrical power creates new demands on the circuit breakers and switches in electrical distribution systems. The first part of this talk will describe why you need circuit breakers and switches on electrical distribution systems, and what they do. The second part will look at what requirements and applications have changed for these circuit breakers. This includes new requirements from increased usage and the replacement of SF6-based circuit breakers, new conditions created by green energy sources, and the switching of DC currents. The final part will look at how these problems are being solved using vacuum interrupters and vacuum switchgear and look at the plasma physics problems involved with their use.

Invited Talk P 16.2 Thu 11:30 P-H11

Plasma-beta effects on the island divertor of Wendelstein 7-X — •Alexander Knieps[1], Yasuhiro Suzuki[2], Joachim Geiger[3], Andreas Dinklage[3], Song Zhou[1,4], Henning Thomsen[3], Marcin Jakubowski[3], Ralf König[3], Michael Endler[3], Yu Gao[3], and Yunfeng Liang[1,4] — [1]Forschungzentrum Jülich, Jülich — [2]Graduate School of Advanced Science and Engineering, Hiroshima University, Higashi-Hiroshima, Japa — [3]Max-Planck-Institut für Plasmaphysik, Greifswald — [4]Huazhong University of Science and Technology, Wuhan, China

The Wendelstein 7-X Stellarator relies on an island divertor to control its heat- and particle-exhaust. In this divertor concept, the scrape-off layer is formed by a magnetic island chain between the divertor plates and the main plasma.

It is important to conserve the divertor topology in the up- coming steady-state experimental campaign. However, the magneto-hydrodynamic plasma response driven in finite-beta plasmas can substantially effect the magnetic topology in the plasma edge. Depending on the configuration, the plasma response have distinctly different effects.

This presentation will showcase finite-beta MHD equilibrium simulations for finite-beta plasmas in different magnetic configurations of W7-X, calculated with the 3D MHD equilibrium code HINT. Based on these simulations, we then extrapolate the heat-loads on plasma-facing components using an anisotropic diffusion model.

Invited Talk P 16.3 Thu 12:00 P-H11

Surface modification of inorganic materials by atmospheric-pressure plasmas — •Claus-Peter Klages and Vitaly Raev — Institute for Surface Technology, Technische Universität Braunschweig, Braunschweig, Germany

As far as applications in surface technology are concerned, atmospheric-pressure plasmas such as dielectric barrier discharges (DBDs) are frequently associated with polymeric surfaces and plasma polymer deposition. In the present contribution it will be demonstrated, however, that DBDs can also be applied to achieve practically useful modifications of inorganic surfaces utilizing processes which are also of scientific interest.

Examples are the reduction of metal compounds like oxides or sulfides as well as the oxidation of metals, hydrolysis of siloxane bonds on silica surfaces, and the pretreatment of silicon surfaces for low-temperature direct wafer bonding. The focus of the lecture is on recent studies on a "dry" silanization process for the preparation of quartz fibers for applications as optical sensors and on low-temperature oxidation of aluminum using DBDs in argon-water and argon-oxygen mixtures, respectively.

P 17: Astrophysical Plasmas

Time: Thursday 14:00–15:15 Location: P-H11

P 17.1 Thu 14:00 P-H11

Electron acceleration at supernova remnants — •Artem Bohdan — Deutsches Elektronen-Synchrotron DESY, Platanenallee 6, 15738 Zeuthen, Germany

Supernova remnants (SNRs) are believed to produce the most part of the galactic cosmic rays (CRs). SNRs harbor non-relativistic collisionless shocks responsible for acceleration of CRs via diffusive shock acceleration (DSA), in which particles gain their energies in repetitive interactions with the shock front. As the DSA theory involves pre-existing mildly energetic particles, a means of pre-acceleration is required, especially for electrons. Electron injection remains one of the most troublesome and still unresolved issues and our physical understanding of it is essential to fully comprehend the physics of SNRs. To study any electron-scale phenomena responsible for pre-acceleration, we require a method capable of resolving these small kinetic scales and Particle-in-cell (PIC) simulations fulfill this criterion. Here I report about the latest achievements on kinetic simulations of non-relativistic high Mach number shocks. I discuss how the physics of SNR shocks depends on the shock parameters (e.g., the shock obliquity, Mach numbers, the ion-to-electron mass ratio), which processes are responsible for the electron pre-acceleration and how these shocks can be studied using in-situ satellite measurements. Finally, I outline future perspectives of the electron injection problem and other complementary ways to solve it.

P 17.2 Thu 14:15 P-H11

Suppression of the TeV pair-beam plasma instability by a weak intergalactic magnetic field — •Mahmoud Alawashra[1] and Martin Pohl[1,2] — [1]Institute for Physics and Astronomy, University of Potsdam, D-14476 Potsdam, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Platanenallee 6, 15738 Zeuthen, Ger-

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We constrain the intermediate-scale intergalactic magnetic field (IGMF) through its suppression of the electrostatic instability for blazar-induced pair beams. IGMF of femto-Gauss strength are sufficient to significantly deflect the TeV pair beams, which reduces the flux of secondary cascade emission below the observational limits. A similar flux reduction may result from the electrostatic beam-plasma instability, which operates the best at zero IGMF. We study the effect of sub-fG level IGMF on the electrostatic instability of the blazar-induced pair beam. Considering IGMF with correlation lengths smaller than a few kpc, we find that such fields increase the transverse momentum of the pair beam particles, which dramatically reduces the linear growth rate of the electrostatic instability and hence the energy-loss rate of the pair beam. Our results show that the IGMF eliminates the beam-plasma instability as an effective energy-loss agent at a field strength three orders of magnitude below that needed to suppress the secondary cascade emission by magnetic deflection. For intermediate-strength IGMF, we do not know a viable process to explain the observed absence of GeV-scale cascade emission.

P 17.3 Thu 14:30 P-H11

Analysis of Ball Lightning observations aiming at an experimental verification — •Herbert Boerner — Mainz

Ball Lightning (BL) is still an unexplained phenomenon of atmospheric physics. There is no accepted theory explaining it, and there are no experiments that produce such objects in a laboratory. The only evidence available is through reports by accidental observers. In order to make progress in selecting theories that are consistent with the observations and in defining suitable experiments, it is important to select from the thousands of anecdotal reports those that are both reliable and that contain information on the physics involved. With this in mind, the following reports and properties will be considered: properties of BL objects that have been recorded consistently over many years, single, very well documented events, and individual reports by reliable observers. The first result is that Bl objects cannot be based on matter, they have to be a form of electromagnetic radiation. This conclusion is motivated by the fact that they can pass through dielectric objects like glass panes, and that they can move with velocities higher than the speed of sound. 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 rather good definition of the conditions under which such objects can be created. The importance of some properties of negative corona in air, mainly of Trichel pulses, and the role of free electrons is highlighted and an experimental setup is proposed.

P 17.4 Thu 14:45 P-H11

PIC simulations of SNR's shock waves with a turbulent upstream medium — •Karol Fułat[1], Martin Pohl[1,2], Artem Bohdan[2], and Paul Morris[2] — [1]Insitute of Physics and Astronomy, University of Potsdam, 14476 Potsdam, Germany — [2]DESY, 15738 Zeuthen, Germany

Investigation of astrophysical shocks has a major importance in understanding physics of the cosmic rays acceleration. Electrons to be accelerated at shocks must have an injection energy, which implies that they should undergo some pre-acceleration mechanism. Many numerical studies examined possible injection mechanisms, however most of them considered homogenous upstream medium, which is unreal assumption for astrophysical environments. We will to investigate electron acceleration at high Mach number and low plasma beta shocks using 2D3V particle-in-cell simulations with a turbulent upstream medium. Here we discuss the method of the generation of the compression-dominated turbulence and its quasi-seamless insertion into the upstream medium in the shock simulation. The modelled turbulence is sufficiently long-lived, and its parameters represent the high-Mach-number and low-beta regime.

P 17.5 Thu 15:00 P-H11

Pre-acceleration in the Electron Foreshock: Electron Acoustic Waves — •Paul Morris[1], Artem Bohdan[1], Martin Weidl[3], and Martin Pohl[1,2] — [1]Deutsches Elektronen-Synchrotron DESY, Platanenallee 6, 15738 Zeuthen, Germany — [2]Institute of Physics and Astronomy, University of Potsdam, D-14476 Potsdam, Germany — [3]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, DE-85748 Garching, Germany

To undergo diffusive shock acceleration, electrons need to be pre-accelerated to increase their energies by several orders of magnitude, else their gyro-radii are smaller than the finite width of the shock. In oblique shocks, electrons can escape to the shock upstream, creating a region called the electron foreshock. To determine the pre-acceleration in this region, we undertake PIC simulations of oblique shocks while varying the obliquity angle. We show that while the proportion of reflected electrons is negligible for $\theta_{Bn} = 74.3°$, it increases to $R \sim 3\%$ for $\theta_{Bn} = 30°$, and that these electrons power electrostatic waves upstream with a wavelength around $2.5\lambda_{\rm se}$, where $\lambda_{\rm se}$ is the electron skin length. While the initial reflection mechanism is a combination of shock surfing acceleration and magnetic mirroring, once the electrostatic waves have been generated upstream they themselves can increase the momenta of upstream electrons parallel to the magnetic field. In $\lesssim 1\%$ of cases, upstream electrons are turned away from the shock and never injected downstream. In contrast, a similar fraction are re-directed back towards the shock after reflection and cross into the downstream.

P 18: Helmholtz Graduate School HEPP IV

Time: Thursday 14:00–15:15 Location: P-H12

P 18.1 Thu 14:00 P-H12

Microstructure and deformation behaviour of drawn W wires — •Maximilian Fuhr[1,2], Nuttawan Ketkao[1,3], Till Höschen[1], Nico Hempel[2], Martin Balden[1], Wolfgang Pantleon[4], Jürgen Almanstötter[5], David Rafaja[3], Johann Riesch[1], and Rudolf Neu[1,2] — [1]Max-Planck-Insitut für Plasmaphysik, Garching, Deutschland — [2]Technische Universität München, Garching, Deutschland — [3]TU Bergakademie Freiberg, Freiberg, Deutschland — [4]Technical University of Denmark, Lyngby, Dänemark — [5]OSRAM GmbH, Schwabmünchen, Deutschland

Tungsten (W) shows a pronounced transition from ductile deformation behaviour at high temperatures to brittle behaviour at low temperatures (ductile-to-brittle transition). Standard, coarse-grained W exhibits transition temperatures T_{DBT} around $300° C$, rendering it unsuitable for structural applications below T_{DBT}. The transition is shifted to lower temperatures by cold-working W in wire drawing, rolling or a severe plastic deformation process. Sufficiently cold-worked W materials deform plastically at room temperature and below. The reasons for the shift of T_{DBT} are connected to the deformation-induced microstructural changes. Thus, we performed the first systematic study focusing on the structure-property relations of a series of sequentially drawn potassium-doped W wires. The combination of careful microstructural investigations (electron backscatter diffraction (EBSD), X-ray diffraction (XRD)) and various mechanical tests performed at room and elevated temperatures allow for new insights into the deformation behaviour of drawn W wires.

P 18.2 Thu 14:25 P-H12

Edge Transport and Fuelling Studies via Gas Puff Modulation in ASDEX Upgrade — •Christian U. Schuster[1,2], Elisabeth Wolfrum[1], Emiliano Fable[1], Rainer Fischer[1], Michael Griener[1], Balazs Tal[1], Clemente Angioni[1], Thomas Eich[1], Peter Manz[3], Ulrich Stroth[1,2], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching — [2]Physikdepartment E28, Technische Universität München, Garching — [3]Institut für Physik Universität Greifswald, Greifswald

In a tokamak the edge profiles of temperature and density are crucial for a multitude of aspects such as the L-H transition, the achievable pedestal top pressure, or the achieved fusion power itself. The processes that determine these profiles are transport on one hand and sources on the other. Especially for the density profile these processes are not sufficiently understood to predict profiles for future devices.

To characterize the edge transport in a quantitative way, we modulate the fuelling gas flow to perturb the plasma. We then use the transport code ASTRA as forward model and several diagnostics in an integrated data approach. This allows us to determine various quantities, depending on the available experimental data and the quality thereof. In particular we find particle transport coefficients, fuelling properties, and correlations of transport to other quantities. The transport coefficients are not constant in time: already slight perturbations of the plasma alter them, especially just inside the separatrix. We present results for various plasma scenarios ranging from L-modes to H-modes with and without large ELMs.

P 18.3 Thu 14:50 P-H12

Studies of propagating ICRF slow waves — •Felix Paulus, Volodymyr Bobkov, Helmut Faugel, Helmut Fünfgelder, Oleksii Girka, Roman Ochoukov, Hartmut Zohm, and ASDEX Upgrade Team — Max-Planck-Institut für Plasmaphysik Garching

Heating a plasma with ion cyclotron range of frequencies (ICRF) waves is an established technique in tokamaks. While the design of ICRF antennas aims to launch one solution of the plasma's dispersion relation (fast wave), the other is an unwanted by-product (slow wave). The slow wave propagates in low-density plasmas only and is usually confined to a small region in the scrape-off layer (SOL) or in the limiter shadow in present-day tokamaks. ICRF systems for future devices as ITER or DEMO will need to cope with a propagating slow wave in front of the antenna since a relatively large clearance is foreseen. Studying the slow wave is important because it modifies the antenna near-field and poses a mechanism for transporting plasma-wall interactions.

An approach to study the ICRF slow wave propagation in the ASDEX Upgrade (AUG) tokamak SOL is demonstrated. RAPLICASOL simulation indicates that in SOL relevant plasmas the slow wave manifests in so-called resonance cones. Experiments on the test stand IShTAR are presented where resonance cones were launched from an RF antenna and detected by probing the oscillation of the plasma potential. Based on these results, experiments on AUG are prepared. Preliminary results from these experiments with the slow wave launched from plasma-facing components of the antenna periphery are shown and compared to simulations.

P 19: Poster II

Time: Thursday 16:00–17:30 Location: P

P 19.1 Thu 16:00 P

Validation of quasilinear transport models in the ASTRA framework — •Michael Bergmann, Rainer Fischer, Pedro Molina Cabrera, Klara Höfler, Frank Jenko, and The ASDEX Upgrade Team — Max-Planck-Institute für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

By combining multiple heating and transport subroutines ASTRA is capable of simulating realistic temperature and density radial profiles of fusion plasmas. While these profiles match experimental data taken from e.g. the Integrated Data Analysis (IDA) code, the simulated gradients often differ from measured ones and are largely dependent on the turbulence subroutine chosen. The interest in correct plasma gradients is particularly high as these give rise to the turbulence which dominates the transport. Using two quasi-linear turbulence solvers (TGLF and Qualikiz) as well as their much faster neural-network versions we shall explore the validity and uncertainty of the models in different discharge scenarios via input-error propagation, as well as comparing the models to high-fidelity codes such as GENE and experimental measurements. This work feeds back into attempts of using ASTRA simulations as a theoretical prior for IDA, where the prior of the simulated profile is needed.

P 19.2 Thu 16:00 P

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-Institut für Plasmaphysik, Garching, Germany

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 19.3 Thu 16:00 P

GPU Offloading of the Gyrokinetic Turbulence Code GENE-X — •Jordy Trilaksono[1], Dominik Michels[1], Andreas Stegmeir[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

Turbulence in magnetic confinement fusion devices is a non-linear phenomenon which involves multi-scale and multi-physics modeling. Simulating turbulence requires a large number of computing resources exploited in parallel which is provided by modern supercomputers. The recently developed gyrokinetic turbulence code `GENE-X` [1] extends the typical coverage of gyrokinetic turbulence simulations from the core to the edge and scrape-off layer of magnetic confinement fusion devices. Currently, `GENE-X` uses a heterogenous parallelization featuring OpenMP for intranode and MPI for internode parallelism respectively. To enable simulations of the edge and scrape-off layer of reactor relevant fusion devices, like ITER, the scalability of `GENE-X` needs to be improved. Therefore, we present progress towards GPU offloading in `GENE-X` in this work. This includes improving the current offloading approach of `GENE-X` by implementing a separate C++ layer to the code using modern Fortran's C interoperability and CUDA.

[1] D. Michels, et. al., Comput. Phys. Commun. 264, 107986 (2021)

P 19.4 Thu 16:00 P

Application of the Gyrokinetic Turbulence Code GENE-X on TCV — •Philipp Ulbl[1], Dominik Michels[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

Turbulence in the edge and scrape-off layer (SOL) of magnetic confinement fusion devices is a complicated phenomenon whose understanding remains a central task on the way to optimized fusion reactors. Recent progress along these lines has been made with the development of the novel gyrokinetic turbulence code `GENE-X` [1]. In this work, we apply `GENE-X` to the validation case "TCV-X21" [2], studying the evolution of plasma profiles such as density, electron- and ion temperature. Further we compare the results to collisional simulations assessing the effect of collisions on edge and SOL turbulence.

[1] D. Michels, et. al., Comput. Phys. Commun. 264, 107986 (2021)
[2] D. S. Oliveira, T. Body, et. al., arXiv:2109.01618 (2021)

P 19.5 Thu 16:00 P

Predictive simulations of Runaway Electron deconfinement by a helical coil — •Nina Schwarz, Javier Artola, Konsta Särkimäki, and Matthias Hölzl — Max Planck Institute for Plasma Physics, Boltzmannstrasse 2, 85748 Garching - Germany

Future tokamak fusion power plants are designed as high plasma current devices which comes with the risk of generating fast electrons during disruptions. Due to an avalanche mechanism a small seed can create so called Runaway Electrons (RE), which can carry more than 50% of the plasma current. The surrounding structures can be damaged seriously when the vertically unstable RE beam comes into contact with the wall. Current avoidance or mitigation concepts are based on active techniques like the injection of deuterium for plasma dilution.

A passive mitigation system has been proposed consisting of a passive coil, in which current is induced during a current quench (CQ), that in turn generates a helical perturbation in the plasma. This triggers magnetic islands that grow and overlap and thus create a region of enhanced radial transport. When a large part of the plasma is stochastic, the complete formation of an RE beam can be mitigated or even be fully prevented. We show here a possible coil geometry based on the SPARC concept [1] in the ASDEX Upgrade configuration. The induction efficiency of the coil is investigated for different CQ times and the vacuum perturbation by different geometries are shown. Finally, 3D non-linear simulations of a disruption with the extended MHD code JOREK are presented with a fully self-consistent inclusion of the passive coil. [1] R.A. Tinguely et al 2021 Nucl. Fusion 61 124003

P 19.6 Thu 16:00 P

Analytical investigation of heat conduction of plasmas in a magnetic field with an island — •Gregor Pechstein and Per Helander — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald

In a hot plasma that is magnetically confined in a fusion device, heat is transported across flux–surfaces towards the plasma vessel. In the W7-X stellarator, the plasma edge consists of a magnetic island chain. The magnetic islands function as Scrape–Off Layer (SOL), directing the plasma to a divertor. Radiative cooling through collisions with impurities such as carbon can play an important role in reducing the heat loads on the plasma-facing components.

We investigate a heat conduction equation with a loss term describing radiation in and around a magnetic island. The full 2D heat conduction problem can be reduced to a 1D description in the limit of large parallel heat conduction. We focus our investigation on understanding heat transport in three regions: the island center (the “O-point”), the seperatrix, and the region far away from the island. Far away from the magnetic island, the heat conduction given by our model reduces to the perpendicular heat conduction across flux surfaces without an island. The effective heat conduction coefficient reaches a maximum at the seperatrix. The influence of this heat conduction coefficient on the position of the radiation front is also discussed.

P 19.7 Thu 16:00 P

Investigation of spontaneous transitions to high core-electron temperatures in W7-X low-iota plasmas — •Juan Fernando Guerrero Arnaiz[1,2], Andreas Dinklage[1,2], Axel Könies[2], Carolin Nührenberg[2], Bernd Pompe[1], Alessandro Zocco[2], Matthias Hirsch[2], Udo Höfel[2], Christian Brandt[2], Joachim Geiger[2], Kian Rahbarnia[2], Jonathan Schilling[2], John Schmitt[3], Henning Thomsen[2], and the W7-X Team[2] — [1]Universität Greifswald, Greifswald Germany — [2]Max-Planck-Institut für Plasmaphysik, Greifswald Germany — [3]Auburn University

Spontaneous transitions to higher core-electron temperatures preserving the electron pressure were detected in the so-called low-iota configuration of W7-X. Data mining employing a large data set at different heating powers and densities was conducted. Permutation Entropy as a fast and robust novelty detection method was used to characterize the conditions for the occurrence of a core-localized spatio-temporal bifurcation. To investigate the transition mechanism in more detail, highly sampled electron cyclotron emission and soft-X ray data reveal low-coherent fluctuations which disappeared when higher electron temperatures were attained. First analysis of the effects due to the evolving bootstrap current indicates a change of the rotational transform (iota) profile temporarily crossing low-order rational values. The same neoclassical analysis indicates that a transition into the stellarator-specific core electron-root confinement regime would be consistent with the observed increase of the central electron temperature. The role of rational iota values is being assessed in MHD stability studies.

P 19.8 Thu 16:00 P

Modeling the beam emission Balmer-α spectrum in neutral beam heated plasmas at Wendelstein 7-X — •Sebastian Bannmann, Oliver Ford, Udo Höfel, and Robert Wolf — Max-Planck-Institut für Plasmaphysik, Greifswald, DE

The optimized stellarator Wendelstein 7-X (W7-X) is equipped with a neutral beam injection (NBI) system. Knowledge about the particle and heat deposition of the beam in NBI shots is essential for further plasma physics analysis. The deposition depends on the beam and plasma parameters and information can be provided by measuring the Balmer-α light emitted by excited beam and halo particles. As the whole spectrum is too complex to be unambiguously fitted, a modular Bayesian inference network called Minerva is used. This requires implementing a detailed forward model with which one can infer beam and plasma parameters from the measured spectra. Existing modeling tools deploy Monte-Carlo techniques which is not feasible to use in combination with a Bayesian inference framework. The presented work describes the implementation of an analytical neutral beam and halo model. The possibility of inferring ion temperature profiles from the halo Balmer-α emission and density profiles from the halo and beam emission is investigated.

P 19.9 Thu 16:00 P

Optimizing quasi-isodynamic stellarators — •Alan Goodman, Rogerio Jorge, Per Helander, and Sophia Henneberg — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald

Stellarators are a class of plasma confinement devices that, if designed properly, may be viable nuclear fusion reactors. The W7-X stellarator’s successes indicate that stellarators designed to be “quasi-isodynamic” (QI) — which, amongst other things, have minimal plasma boostrap currents — may be a viable path forward for future stellarators. QI configurations have contours of constant magnetic field strength wrapping around the device poloidally (the short way around) with a special symmetry.

Experimental measurements from the W7-X and HSX stellarators have shown that optimization methods are powerful tools in finding configurations with desirable properties. W7-X’s optimized QI configuration has proven effective in confining particles trapped in magnetic wells (which is essential for a viable fusion reactor), but further improvements are now possible.

Unfortunately, optimized QI configurations tend to have unintended undesirable properties, such as large elongations and high mirror ratios, so care must be taken to limit these values. We present several objective measures which have shown promise in generating optimized QI stellarators and the results thereof.

P 19.10 Thu 16:00 P

ECRH in early plasma formation — •Albert Johansson and Pavel Aleynikov — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald

Electron Cyclotron Resonant Heating (ECRH) is important for the operation of current and future fusion devices, and is the main plasma heating mechanism in the Wendelstein 7-X (W7-X) stellarator. Although ECRH at high plasma temperatures and densities is routinely used in experiments and understood theoretically, a complete theoretical description of ECRH at the early stages of plasma formation (breakdown) has yet to be derived. Among the critical questions is the possibility of using higher–harmonics during startup in W7-X and effect of the ECRH-assisted startup in ITER.

In current work we seek to determine the minimum microwave beam power necessary to achieve breakdown, i.e., plasma formation, in conditions similar to the W7-X stellarator. We aim to accurately describe the cyclotron–wave interaction in the early stages of plasma formation, including both beam parameters and magnetic field structure.

Here, a fully relativistic integratable Hamiltonian system for an obliquely propagating beam in a much larger homogeneous magnetic field is derived. It is used to find the non–linear particle trajectories, and thus their energy gain, for various beam parameters.

P 19.11 Thu 16:00 P

Model for collisional transport of impurities in tokamaks and the combined impact of rotation and collisionality — •Daniel Fajardo[1], Clemente Angioni[1], Francis Casson[2], Anthony Field[2], Patrick Maget[3], Pierre Manas[3], and JET Contributors[4] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]UKAEA/CCFE, Abingdon, United Kingdom — [3]CEA/IRFM, Saint Paul-lez-Durance, France — [4]See author list of [E. Joffrin et al. 2019 Nucl. Fusion 59 112021]

The collisional transport of impurities in tokamak plasmas can be dominant over the turbulent transport, particularly for heavy impurities like tungsten (W). An analytical model for the Pfirsch-Schlüter (PS) and Banana-Plateau (BP) components of the neoclassical impurity flux has been developed. It is accurate with respect to the drift-kinetic solver NEO across a broad collisional parameter space and reproduces well the profiles of the transport coefficients with experimental ASDEX Upgrade and predicted ITER profiles. The model includes the impact of rotation on the PS transport only. The impact of rotation on the BP transport, relevant at low collisionalities, has received limited consideration so far. The combined effects of rotation, collisionality and trapped particle fraction are analyzed with NEO. It is found that at sufficiently low collisionality and high Mach number an operational window opens where the temperature screening of impurities is enhanced. It is shown that recent experiments at JET have managed to enter this regime. An analytical description of this effect, in particular for the BP flux, is developed for fast integrated modelling applications.

P 19.12 Thu 16:00 P

Analysis of ITER instabilities for a reduced transport model development — •Virgil-Alin Popa, Philipp Lauber, and Thomas Hayward-Schneider — Max Planck Institute for Plasma Physics, Garching, Germany

Previous work has suggested that Alfven Eigenmodes (AEs) such as the Toroidal AEs (TAEs) can be partially unstable in ITER: energetic particles (EPs), such as fusion-born alpha-particles or neutral beam ions are energetic enough to resonantly interact with these weakly damped plasma waves. Due to the sensitivity of the AEs* properties on the background kinetic profiles, an automated analysis method is required to study their stability that does not rely upon prior knowledge of the linear mode spectrum, as is the case for most reduced models for EP transport. In view of this, the first automated time-dependent workflow for energetic particle stability analysis was created. This is used as a main tool for various linear stability analysis. An ITER Deuterium-Tritium scenario given by a transport code (METIS) was investigated. From the analysis, one can determine the dependance of the instabilities on the background profiles and the alpha particle population, as needed for profile optimisation or reduced transport models.

P 19.13 Thu 16:00 P

Experimental impurity transport analysis for tokamak regimes without type-I ELMs — •Tabea Gleiter[1,2], Ralph Dux[1], Marco Cavedon[3], Rachael McDermott[1], Francesco Sciortino[1], Ulrike Plank[1], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Physik-Department E28, Technische Universität München, Garching, Germany — [3]Dipartimento di Fisica "G. Occhialini", Università di Milano-Bicocca, Milano, Italy

A profound knowledge of the transport of impurities is inevitable when it comes to designing tokamak reactor scenarios. In particular, it is necessary to integrate sufficient radiative cooling by impurities near the plasma edge with small impurity concentrations in the core.

High confinement regimes with no or little ELM activity (QCE or EDA H-mode) are promising candidates for future reactor operation. Information about their impurity transport mechanisms is therefore of large interest. In the focus is specifically the pedestal region since an edge transport barrier provokes suppressed turbulence and neoclassical inward transport in the inter-ELM phases of the standard H-mode. However, as no impurity accumulation is observed in the QCE and EDA-H modes despite their negligible ELM activity, a modification of the transport in this area is expected.

In this contribution, first results from transport studies in such ELM-free regimes at ASDEX Upgrade are presented. We show the inverse inference of radially and temporally resolved diffusion and convection from charge exchange recombination spectroscopy (CXRS) data.

P 19.14 Thu 16:00 P

Microstructural evolution of a tungsten heavy alloy during extended heat-treatments — •Philipp Sand and Armin Manhard — Max-Planck-Institute for Plasma Physik, 85748 Garching, Germany

Tungsten heavy alloy (97W-2Ni-1Fe, %wt.) 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 tungsten, whilst showing an improved ductility [1] and hydrogen retention behaviour [2]. These improved properties can be attributed to its heterogenous microstructure, in which, as a consequence of the manufacturer's liquid phase sintering process, tungsten grains are embedded in a perturbating matrix of nickel and iron. In fusion devices as well as in materials testing experiments (e.g. permeation experiments) elevated temperatures for extended times might lead to grain growth or formation of intermetallic phases. Since the grain structure and tungsten-matrix interface constitution can affect the hydrogen transport, the permeation and retention behaviour might change during long-term annealing. A systematic heat treatment study has been performed with a conventional tungsten heavy alloy. Additionally, two-dimensional model systems consisting of Fe-Ni layers on W foils with identical composition where investigated to deepen the understanding of the tungsten-matrix interface. Microstructural changes are tracked with scanning electron microscopy and ion beam analysis. [1] R. Neu, et al., Fusion Eng. Des. 124 (2017) 450-454 [2] H. Maier, et al., J. Nucl. Mater 18 (2019) 245-259

P 19.15 Thu 16:00 P

Off-axis confinement and pulse stacking in a multi-cell Penning-Malmberg trap — •Martin Singer[1,4], James R. Danielson[2], Matthew R. Stoneking[3], Lutz Schweikhard[4], and Thomas Sunn Pedersen[1,4] — [1]Max-Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [2]University of California, San Diego, La Jolla, California 92093, USA — [3]Lawrence University, Appleton, Wisconsin 54911, USA — [4]University of Greifswald, 17489 Greifswald, Germany

For the operation of a multi-cell Penning-Malmberg trap (MCT) the transfer to the storage-cells and consistent stacking of pulses is an essential step. This becomes increasingly complex when many pulses needs to be added in each storage-cell to reach large particle numbers and high plasma space charges, and when the small diameter storage-cells are radially displaced with respect to the large diameter master-cell. If the plasma is displaced off-axis and expanded over both cells, its motion is dominated by competing diocotron drifts. Also, the transfer and pulse stacking into the off-axis cell can lead to halo formation and the loss of particles. Since the APEX collaboration aims to create and study the first magnetically confined, low energy pair plasma, the MCT is a crucial tool on the way to accumulate up to 10^{11} positrons with low heating and particle loss. We will present our new MCT and measurements where we already achieved the transfer and confinement in two off-axis cells simultaneously. This MCT will be used to address open questions such as concerning plasma transfer and stacking as well as off-axis ejection.

P 19.16 Thu 16:00 P

Experimental helium exhaust studies in the full-W ASDEX Upgrade — •Antonello Zito[1,2], Athina Kappatou[1], Marco Wischmeier[1], Volker Rohde[1], Edward Hinson[3], Oliver Schmitz[3], Marco Cavedon[4,1], Rachael McDermott[1], Ralph Dux[1], Michael Griener[1], Arne Kallenbach[1], Ulrich Stroth[1,2], and the ASDEX Upgrade team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Physik-Department E28, Technische Universität München, Garching, Germany — [3]University of Wisconsin-Madison, USA — [4]Dipartimento di Fisica G. Occhialini, Università di Milano-Bicocca, Milano, Italy

An efficient removal of helium ash by active pumping in future fusion devices is mandatory, in order to avoid fuel dilution and not degrade confinement properties. Helium exhaust in reactor-relevant edge and divertor scenarios has been experimentally investigated at the ASDEX Upgrade tokamak. A small amount of helium was injected during otherwise steady-state deuterium plasma discharges, and the time evolution of the resulting helium content was measured in the plasma and in the exhaust gas. The dynamics of the helium decay following the injection was characterized in several different scenarios and interpreted by means of simple analytic models. In attached H-modes plasmas, the helium pumping efficiency was found to greatly improve with increasing divertor neutral pressures. This was shown to be mainly driven by a more efficient divertor retention of helium at higher pressures. On the other hand, an exhaust degradation was qualitatively observed with the divertor entering a detached regime in L-mode.

P 19.17 Thu 16:00 P

Ion mass ratio impact on the collisional closure in the SOLPS-ITER Scrape-off layer simulations — •Sergei Makarov[1], David Coster[1], and Vladimir Rozhansky[2] — [1]Max-Planck-Institut für Plasmaphysik, D-85748 Garching, Germany — [2]Peter the Great St.Petersburg Polytechnic University, 195251, St.Petersburg, Russia

Impurity transport in the Scrape-off layer of a tokamak is an important and challenging problem. For instance, noble gasses are seeded into the tokamak for additional radiation and divertor target protection. When the impurity mass is significantly larger than the mass of the main ions the multispecies extension of the single ion Braginskii approach can be applied. However, usually impurity/main ion mass ratio can not be assumed infinitely large, and the Grad-Zhdanov 21N-moment method should be used for the transport coefficients estimation. This approach takes into account realistic masses of ions are present in the plasma for coefficients calculation. It is the major improvement in comparison to the previous approach applied for the SOLPS-ITER code. New approach is implemented into the SOLPS-ITER code for multiple ion parallel transport description in collisional plasmas. Previously, the sufficient change in the impurity transport is found when the realistic mass ratio between different ion species is taken into account. Here we explore the origin of this impact. The mass ratio between different species is artificially increased in the collisional terms calculation. The improved approach turns into the standard SOLPS-ITER model, for artificially increased mass ratio.

P 19.18 Thu 16:00 P

Analysis of nonlinear dynamics of shear Alfven 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 thermalisation of the plasma core or increase the thermal load on the material's 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 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 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 physics processes regarding both the linear stability properties and the nonlinear saturation mechanisms for a single and multi modes. For this reason, to keep the context of 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 19.19 Thu 16:00 P

Non-local neoclassical PIC simulations for the self-consistent radial electric field in stellarators. — •Michał Kuczyński, Ralf Kleiber, and Håkan Smith — Wendelsteinstraße 1, 17491 Greifswald, Germany

Transport in fusion plasma devices can be classified as either turbulent or neoclassical. Since turbulent transport is predominantly ambipolar, the radial electric field that arises ensures ambipolarity of the neoclassical part of the transport. This fact allows us to perform neoclassical particle-in-cell (PIC) simulations to calculate the electric field self-consistently. We introduce non-linear and non-local terms into the equations of motion in order to investigate ion and electron root transitions.

P 19.20 Thu 16:00 P

Optimal Quasi-isodynamic Stellarator Magnetic Equilibria Using a Direct Construction Approach — •Katia Camacho Mata, Gabriel Plunk, Michael Drevlak, and Per Helander — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Two important requirements for a viable stellarator reactor are easy-to-build-coils and good confinement. Omnigenous configurations, traditionally found through numerical optimization, fulfil the good confinement properties requirement but tend to need complex coils to be realised. However, it is unknown whether such complexity is fundamentally necessary.

To explore this question, we use a method developed for the direct construction of omnigenous MHD (Magnetohydrodynamic) equilibria [1], numerically, at first order from the magnetic axis. It avoids the computational cost of conventional optimization and allows a thorough survey of the space of omnigenous stellarators at large aspect ratio.

Omnigenous magnetic fields are necessarily non-analytical and can only be physically realised by a smooth approximation. In previous works this condition was met by introducing regions where omnigeneity was abandoned. A different approach, employing a smoother approximation, and higher number of field periods is analysed in this work aiming to identify configurations that can be realised with easy-to-build coils.

[1]Plunk, G. G., et. al. (2019). Direct construction of optimized stellarator shapes. Part 3. Omnigenity near the magnetic axis. Journal of Plasma Physics, 85(6).

P 19.21 Thu 16:00 P

Towards Simulations of Deuterium Shattered Pellet injection into an MHD active ITER plasma — •Fabian Wieschollek[1], Matthias Hoelzl[1], Eric Nardon[2], and The JOREK Team[3] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching b. M., Germany — [2]CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France — [3]See the author list of M. Hoelzl et al 2021 NF 61, 065001

The foreseen disruption mitigation strategy for ITER is shattered pellet injection (SPI). In a realistic disruption scenario, the SPI is being triggered, when the plasma has already become MHD active; in particular 2/1 neoclassical tearing modes (NTM) are often present.

Previous theoretical studies on an ASDEX Upgrade equilibrium have shown, that a large pre-existing NTM may influence the thermal quench (TQ) significantly. According to these studies, the injection into the O-point delays TQ, while it occurs considerably earlier with X-point injection. Results indicate that pre-existing islands do not render the mitigation ineffective.

To further verify these findings, the studies are now being extended to an ITER L-mode plasma, into which Deuterium SPI is launched. Scans will be performed of the initial island width, the number of atoms injected, and the relative injection phase with respect to the island O-point and the concentration of background impurities. Also, different shard velocitiy distributions are considered. We are presenting here the detailed research plans, as well as the first preliminary results.

P 19.22 Thu 16:00 P

Validating soft X-ray tomograms via modeling of perturbative events — •Christian Brandt[1], Henning Thomsen[1], Charlotte Büschel[2], Edith V. Hausten[2], Jonathan Schilling[1], René Bussiahn[1], and and the W7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald, Germany — [2]University Greifswald, Germany

The hot core of a fusion plasma is invisible in the visual part of the spectrum but it radiates strongly in the X-ray range. A soft X-ray (SX) tomography system detects the spatiotemporal structure of the core plasma in a poloidal cross-section at the stellarator experiment Wendelstein 7-X. Depending on the presence of localized structures on top of the background X-ray radiation profile, such as injected impurity pellets, injected cryogenic hydrogen pellets or MHD mode structures, the poloidal cross-sectional SX emissivity can be substantially structured. The validity of the tomograms obtained by tomographic inversion with respect to the real topology of the SX emissivity is benchmarked by forward calculations of different modeled perturbation scenarios (e.g. symmetric vs. asymmetric 2-D emissivity, local blobs, mode structures). More parameters sensitively influencing the quality of the tomographic inversion are investigated, i.e. the signal-to-noise ratio and the amplitude calibration.

P 19.23 Thu 16:00 P

Characterization and driving mechanisms of dominant Alfvén eigenmodes at the Wendelstein 7-X Stellarator — •S. Vaz Mendes, K. Rahbarnia, C. Slaby, H. Thomsen, J. Schilling, C. Brandt, M. Borchardt, R. Kleiber, A. Könies, and Wendelstein 7-X Team — Max-Planck-Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

Alfvén waves are often present in different scenarios of the Wendelstein 7-X stellarator plasmas. Magnetic fluctuations were observed during 727 discharges with different magnetic configurations, heating scenarios and variations of further plasma parameters. The measurements were performed using a system of 41 Mirnov coils, located in half-module 11 of W7-X. The correlation of the observed Alfvénic activity with different plasma parameters is investigated. With increasing heating power the fluctuation bands in the frequency spectra (between 100-450kHz) and associated mode spectra become broader with poloidal mode numbers $\|m\| \leq 5$. In addition, the overall amplitudes of the different Alfvénic fluctuations in this range increases with higher plasma energy. To better understand the conditions for enhanced Alfvénic activity at W7-X possible driving mechanisms are discussed. A possible candidate is plasma turbulence. Magnetic fluctuation levels are compared to turbulent activity, observed for e.g. in density fluctuations.

P 19.24 Thu 16:00 P

Assessment of NII line ratio method for analysis of nitrogen enrichment in the W7-X divertor — •F. Henke, M. Krychowiak, R. König, F. Reimold, D. Gradic, and T. Sunn Pedersen — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

Impurities are of great importance in fusion plasmas. At the plasma edge, their radiation provide an advantageous cooling and dissipation, whereas they can negatively impact the energy confinement and dilute

the fusion fuel in the plasma core already at small concentrations. Because the divertor of Wendelstein 7-X consists of graphite, the intrinsic impurity carbon is utilized as the main radiator. As tritium retention rules out carbon for the choice of wall material in a future reactor, seeded gases will be crucial for successful divertor operation.
In order to study the impurity screening capabilities of the divertor of Wendelstein 7-X, we analyse nitrogen seeding experiments via a NII line ratio model in the plasma edge and Charge Exchange Recombination Spectroscopy (CXRS) in the plasma core with the goal of estimating an enrichment coefficient of nitrogen in the divertor $c_{N,divertor}/c_{N,core}$.
Due to the complexity of the W7-X divertor plasmas and geometry, the passive NII line ratio model is subject to considerable uncertainties. The assessment of this method as well as possible model and diagnostics upgrades for its application in future experiment campaigns are discussed in this work.

P 19.25 Thu 16:00 P

Determination of 2D Filament Temperatures and Densities at ASDEX Upgrade with the Thermal Helium Beam Diagnostic — •Daniel Wendler[1,2], Michael Griener[1], Gregor Birkenmeier[1,2], Rainer Fischer[1], Ralph Dux[1], Elisabeth Wolfrum[1], Ulrich Stroth[1,2], and the ASDEX Upgrade team[1] — [1]Max-Planck- Institut für Plasmaphysik, Garching, Germany — [2]Physik Department E28, TUM, Garching, Germany

In all plasma scenarios in magnetic confinement fusion, small filamentary structures appear in the scrape-off layer (SOL), called blobs, with a locally strongly enhanced density which propagate convectively outwards. Blobs contribute to reactor relevant phenomena like the density shoulder formation, large first wall particle and power fluxes close to the density limit and the broadening of the divertor heat flux fall-off length. To calculate the effective power flux which is carried by the filaments, temperature and density as well as the frequency and velocity of filaments have to be determined. While the measurements of mean filament velocities are routinely made with various diagnostics, the simultaneous non-invasive measurement of temperatures and densities of single filaments is now possible with the thermal helium beam diagnostic at ASDEX Upgrade. By means of a grid of 2D distributed lines of sight, the temperature, density and velocities as well as the filament shape can be determined in two dimensions. A dedicated numerical approach based on a collisional-radiative model for the determination of blob temperatures and densities is presented and first measurements of temperatures and densities of blobs in two dimensions are presented.

P 19.26 Thu 16:00 P

Simulations of the O-X mode conversion in MAST-U — •Alf Köhn-Seemann[1], Bengt E. Eliasson[2], Simon J. Freethy[3], Lucy A. Holland[4], Roddy G.L. Vann[4], and David Woodward[2] — [1]IGVP, University of Stuttgart, Germany — [2]SUP, Department of Physics, University of Strathclyde, Glasgow, U.K. — [3]Culham Centre for Fusion Energy, Culham, U.K. — [4]York Plasma Institute, York, U.K.

Coupling microwaves to plasmas where the density exceeds the cut-off density can be achieved by electron Bernstein waves (EBWs). These are electrostatic waves that have no high-density cut-off and are very well absorbed at the electron cyclotron resonance and its harmonics. In addition, EBWs can drive very efficiently toroidal net currents, which is of particular importance in spherical tokamaks like MAST-U.

EBWs can be excited via a two step mode conversion process: an injected O-mode couples to an X-mode at the O-mode cut-off which then propagates outwards again and can couple to EBWs in the vicinity of the upper-hybrid resonance. The overall efficiency is strongly dominated by the O-X conversion. In this work, we present simulations of the O-X coupling process in the MAST-U geometry. Different codes have been used and benchmarked against each other. The dependence on plasma scenarios, beam geometry and plasma density fluctuations were investigated in detail. High conversion efficiencies on the order of 90 % were found making this an attractive heating scheme for MAST-U.

P 19.27 Thu 16:00 P

Causality analysis between turbulent phenomena across the separatrix at the TJ-K stellarator. — •Nicolas Dumérat, Bernhard Schmid, and Mirko Ramisch — IGVP, University of Stuttgart

The use of convergent cross-mapping (CCM) as a causality inference technique has proven its capacity for unveiling causal coupling between two variables measured in the same dynamical system. CCM describes a measure of how well the mapping - from a small region within a multidimensional phase space reconstruction in one variable (from time-delay embedding) - compares to the actual representation of the second variable in its reconstructed phase space.

Thus, CCM allows for the identification of causal links and direction of influence between variables and is extended to the study of plasma turbulence. In this frame, the causal relationship between various turbulent phenomena across the confinement region of the stellarator TJ-K is studied. The causal dependencies between blob generation and the zonal-flow - drift-wave system are investigated through Langmuir probe measurements. Using conditional averaging and bandwidth filtering, different spatial and temporal scales can be isolated and studied individually, allowing for fine causality analysis.

P 19.28 Thu 16:00 P

Investigation of synergistic effects of irradiation damage, hydrogen retention and mechanical loading on tungsten — •Alexander Feichtmayer[1,2], Bailey Curzadd[1,2], Sebastian Estermann[1,2], Maximilian Fuhr[1,2], Till Höschen[1], Robert Lürbke[1,3], Johann Riesch[1], Thomas Schwarz-Selinger[1], Dominik Viebke[1,2], and Rudolf Neu[1,2] — [1]Max-Planck-Institut für Plasmaphysik, 85741 Garching, Germany — [2]Technische Universität München, 85741 Garching, Germany — [3]RWTH Aachen University, 52062 Aachen, Germany

One of the major challenges in the realization of a nuclear fusion power plant such as DEMO is the development of suitable materials for the highly loaded plasma-facing components. The main candidate for the armor inside a future fusion reactor is tungsten. It has a high melting point, low erosion rate and low hydrogen retention, but it is brittle below 500-600 K and irradiation causes further embrittlement.

Since there is no sufficient source for 14.1 MeV fusion neutrons for material tests available, it is proposed to simulate the damage by means of ion irradiation. To investigate the synergistic effects, in-situ experiments such as stress relaxation and tensile tests are performed on thin tungsten wires, during irradiation with high-energy ions and simultaneous loading with low-energy hydrogen. An additional sample heater will allow irradiation and testing under fusion-relevant temperatures up to 1800 K. Due to the fine grain structure of the samples, the experiments will provide results that can be transferred to bulk tungsten and serve also for the development of tungsten fiber-reinforced composites.

P 19.29 Thu 16:00 P

Ortsaufgelöste rovibratorische Besetzungstemperatur von Deuterium im Plasmasimulator PSI-2 — •Nikolas Klose, Stephan Ertmer, Arkardi Kreter, Gennady Sergienko, Bernhard Unterberg und Sebastijan Brezinsek — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Deutschland

Im linearen Plasmasimulator PSI-2 wurden D_2-Moleküle mittels optischer Spektroskopie anhand der Fulcher-Banden ($3p^3\Pi_u \rightarrow 2s^3\Sigma_g^+$) untersucht. Die Hauptdiagonalenübergänge $\Delta v=0$ der ersten 5 Übergänge wurde analysiert und die rovibratorische Besetzungstemperatur als Funktion der Plasmaparameter (n_e: $2\cdot10^{-17}$ m^{-3} - $12\cdot10^{-17}$ m^{-3}; T_e: 2 eV - 12 eV) bestimmt, welche durch den Gasdurchfluss in PSI-2 (50 sccm - 490 sccm) und Strom der Bogenentladung (80 A - 150 A) variiert wurden. Weiterhin wurden die radialen Profile der rovibratorischen Besetzungstemperatur mit Langmuirsondendaten unter ionisierenden und rekombinierenden Plasmabedingungen verglichen. Die Rotationstemperatur des ersten diagonalen Übergangs ist nah an der Raumtemperatur, aber mit höheren Vibrationsquantenzahlen fällt T_{rot} signifikant ab.

P 19.30 Thu 16:00 P

Parallel expansion of a pellet plasmoid in a finite electric potential well — •Alistair Mark Arnold[1], Pavel Aleynikov[1], and Boris Breizman[2] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Deutschland — [2]Institute for Fusion Studies, University of Texas, Austin, USA

We consider the expansion parallel to magnetic field lines of the plasmoid produced by a fuel pellet. In particular, we take into account the finite height of the electric potential well confining the plasmoid electrons. If it is assumed that electron bounce motion occurs much more rapidly than collisions and trapped electron self-collisions occur much more rapidly than other kinds of collisions, a quasi-equilibrium state is reached with a non-Maxwellian electron distribution function. A closed-form expression for the distribution function is obtained for an arbitrary well under the assumption that pitch-angle scattering dominates. Corresponding analytical expressions are found for particle and energy exchange between the passing and trapped electrons. Agreement with literature on mirror machines and even classical thermodynamics is found in appropriate wells. The non-Maxwellian distribution function precludes rigorous modelling of the plasmoid expansion using the Braginskii equations. The trapped distribution function is, however, specified by only two time-dependent quantities – a fluid closure of the system is possible despite the highly non-Maxwellian distribution. We seek to understand the influence of the above effects on the expansion rate and ultimate electron-ion energy balance during fuel pellet injection.

P 19.31 Thu 16:00 P

Global thermal equilibrium of non-neutral plasma in a magnetic quadrupole trap — •Patrick Steinbrunner[1], Matthew Stoneking[2], Thomas O'Neil[3], and Thomas Sunn Pedersen[1] — [1]Max Planck Institute for Plasma Physics, 17489 Greifswald, Germany — [2]Lawrence University, Appleton, Wisconsin 54911, USA — [3]University of California, San Diego, La Jolla, California 92093, USA

Global thermal equilibrium of a non-neutral plasma confined in a cylindrically symmetric trap is obtained by maximizing the entropy for a given number of particles, temperature and rotation frequency around the axis of symmetry [1]. Plasmas in such states are Boltzmann distributed and satisfy Poisson*s equation as it is observed in Penning-Malmberg traps, in which they are in principle confined indefinitely [1]. These traps consists of a homogeneous magnetic field as well as electrostatic potential walls produced by cylindrical electrodes. They can confine one sign of charge, and the amount of confined space charge is limited by the bias on the electrodes. We present an alternative concept using a magnetic quadrupole field, produced by a levitated current-carrying coil surrounded by another coil with opposite current wound around a grounded vacuum chamber. Computational results suggest that global thermal equilibrium states can be confined in this trap without the need of biased electrodes. Turning off the outer coil*s current would yield a dipole trap [2] in which both signs of charge have been confined for a finite time. [1] Dubin, D. H., & O*neil, T. M. (1999). Rev. Mod. Phys., 71(1), 87. [2] Boxer, A. C., et al. Nat. Phys., 6.3 (2010): 207-212.

P 19.32 Thu 16:00 P

Towards implementation of the FAIR prinicples in plasma science — •Markus M. Becker[1], Dirk Uhrlandt[1], Detlef Loffhagen[1], Peter Hill[2], Marina Prenzel[3], and Achim von Keudell[3] — [1]Leibniz Institute for Plasma Science and Technology (INP), Germany — [2]York Plasma Institute, University of York (UoY), UK — [3]Ruhr University Bochum (RUB), Germany

A few years ago, the FAIR data principles were proposed as a guideline for those wishing to enhance the reusability of their data by making them findable (F), accessible (A), interoperable (I) and reusable (R) [Wilkinson *et al.*, *Sci. Data* 3:160018 (2016)]. Since then, various activities aiming at implementation of the FAIR principles in different fields of plasma science have been started. Within the project QPTDat, INP works together with partner institutions on research data management (RDM) solutions for low-temperature plasma physics. This includes a close collaboration with the CRC 1316 at RUB, where the focus lays on the establishment of data stewards to support RDM in daily practise. The international project Fair4Fusion addresses the RDM needs in the field of fusion plasmas, while PlasmaFAIR at UoY strives to improve the quality and sustainability of plasma research software. This contribution presents current activities at INP, RUB and UoY and emphasizes the need for collaborations and community involvement to derive real benefits from the FAIR principles for research in plasma science.

The work was supported by grants 16QK03A (BMBF), EP/V051822/1 (EPSRC), and 327886311 (DFG).

P 19.33 Thu 16:00 P

Ion-induced secondary electron emission of metal surfaces analysed in an ion beam experiment — •Rahel Buschhaus and Achim von Keudell — Experimentalphysik II, Ruhr-Universität Bochum, Deutschland

Electron emission of surfaces upon ion impact is one of the most fundamental plasma-surface-interaction. Many experimental and theoretical approaches address secondary electron emission coefficient determination (SEEC; amount of released electrons per incident ion) in literature. This determination may remain rather indirect though, because the process of ion-induced electron emission occurs often not isolated from all other plasma-surface-interactions. Using beam experiments avoids this complication and allows a precise electron yield determination. Target conditions in plasmas strongly affect electron emission of the target and thus have an impact on the discharge itself. However, data of oxidized and nitrided targets, as they would appear in any reactive plasma discharge, are very sparse and may even contain significant systematic errors, because they were often measured based on global modeling of the complex behavior of plasma discharges. SEECs of different metal foils such as Cu or Ni with various surface conditions are investigated in a beam experiment. Foils are exposed to beams of Ar^+ with E_{ion}=500 eV - 2 keV and electron yields are determined precisely. A model for the electron emission is presented to explain the data.

P 19.34 Thu 16:00 P

Studies on the plasma permeability of porous materials using polymers as marker materials — •Martin Leander Marxen[1], Luka Hansen[1], Armin Reimers[2], Fabian Schütt[2], Lena Marie Saure[2], Erik Greve[2], Rainer Adelung[2], and Holger Kersten[1] — [1]Institute for Experimental and Applied Physics, CAU Kiel — [2]Institute for Material Science, CAU Kiel

Highly porous materials are of large interest due to their broad potential for application, e. g. as sensors or catalysts making use of their extremly high surface areas. The plasma permeability of highly porous framework materials produced from tetrapodal zinc oxide (t-ZnO) in a low pressure capacitively coupled plasma was studied with a new, indirect approach. The t-ZnO materials have a porosity > 90 %. Furthermore, some of the samples have additional nanomaterial surface layers (e. g. graphene) deposited on the t-ZnO arms, resulting in a change of conductivity. A polymer (EPDM) was covered with the material of interest and then exposed to an oxygen plasma. The covering material was removed afterwards and the surface of the EPDM was investigated by water contact angle measurement and XPS. Changes of the surface can be attributed to plasma species that permeated the covering zinc oxide material and reached the surface. This approach offers an easy and affordable opportunity to get insight in how deep plasma can penetrate into highly porous structures with nano- and microscale features.

P 19.35 Thu 16:00 P

Control of Spokes in Magnetron Discharges — •Mathews George, Wolfgang Breilmann, Julian Held, and Achim von Keudell — Experimentalphysik II, Ruhr-University Bochum

Magnetron Sputtering is a Physical Vapour Deposition (PVD) process widely used in industry and scientific communities. Magnetron plasma appears to be homogeneous to the human eye, but shows localized zones of high brightness rotating in the ExB direction when observed with an ICCD camera with exposure times below $1\mu s$. These local ionization zones, also called 'spokes' are assumed to play a role in the transport of particles and energy away from the target. DCMS was chosen for the development of spoke control as an initial test object since the spokes in DC regime are more uniform compared to HiPIMS. Amplified rectangular signals are applied to two pairs of drivers to raise the plasma potential inside a spoke by drawing electron current from the plasma at the highest gradients in the ExB direction. Ion saturation current shows the responses of the spoke frequency and intensity to the applied signal. The metal ion flux from the target surface is measured time and energy resolved with a mass spectrometer. An additional probe is added to study influence of the control signal on the plasma potential inside a spoke.

P 19.36 Thu 16:00 P

Azimuthal particle transport in high power impulse magnetron sputtering plasmas — •Sascha Thiemann-Monjé, Steffen Schüttler, Julian Held, and Achim von Keudell — Experimental Physics II, Ruhr-University Bochum, 44780 Bochum, Germany

In the past years high power impulse magnetron sputtering (HiPIMS) has become a well established method for depositing high quality hard coatings. Nevertheless, knowledge about the processes inside the discharge is still incomplete. This includes the azimuthal rotation of heavy particles which is induced by the electron Hall-current and is believed to be influenced by rotating ionization zones, the so called 'spokes'.

In this work, optical emission spectroscopy (OES) and x-ray photoelectron spectroscopy (XPS) combined with so called marker targets were used to gain further understanding of the above mentioned particle movement. While OES delivers information about the emitting particles inside the plasma, XPS measurements of substrates placed on the side of the plasma show the contribution of particles leaving the discharge. The measurements where done for circular targets with a diameter of 50 mm and 0.5 Pa Argon as working gas.

It could be shown that the maximum rotation velocity is in the range of 0.5 - 1.8 km/s depending on the measured species. This rotation is as well visible as asymmetric deposition distribution on the side of the discharge.

P 19.37 Thu 16:00 P

Analysis of single particle motion confined in the plasma sheath — •Sören Wohlfahrt and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Microparticles are the essential component of a (dusty) complex plasma. Besides particle-plasma interaction and particle-particle interaction, the dynamics of a single particle are worth to be studied. Particles are typically confined in the plasma sheath, where they accumulate a negative charge that causes levitation in the electric field of the sheath. However, even for perfectly spherical particles the charging process is not isotropic. Small differences in the electron- and ion fluxes can create dipole moments on insulating particles. These dipoles should result in a rotation of the particle [1]. In addition, the particles can have an initial angular momentum due to the injection into the plasma. Thus, we investigate motion of single particles in the plasma sheath. We use angular- and polarization resolved light scattering (APRLS)[2] to analyse the precise motion and orientation of the particle relative to the incident laser beam. This allows us to determine even small deviations from the equilibrium position of the particle and track particle rotation with frequencies up to 500 Hz.

[1] I H Hutchonson, New J. Phys. 6, 43 (2004)
[2] S. Wohlfahrt, D. Block, Phys. Plasmas 28, 123701 (2021)

P 19.38 Thu 16:00 P

Molecular dynamics simulations of turbulent complex plasmas — •Eshita Joshi, Prapti Bajaj, Hubertus Thomas, and Mierk Schwabe — Institut für Materialphysik im Weltraum,Deutsches Zentrum für Luft- undRaumfahrt, Weßling, Germany

Turbulence remains one of the oldest unsolved problems in physics. Studying how a flow can transition from laminar to turbulent can deepen our understanding of how and when turbulence emerges. Complex plasmas are ionised gasses with micrometre sized *dust* particles immersed in them, and they are valuable in studying turbulence as the highly charged microparticles are big enough to be imaged directly when their flow becomes turbulent. We investigate the onset of turbulence by studying complex plasmas flowing past a disturbance. We perform molecular dynamics (MD) simulations of the experiment performed using the Plasmakristall-4 (PK-4) laboratory on board the International Space Station at low pressures to study the emergence and decay of turbulence.

P 19.39 Thu 16:00 P

Complex Plasmas in the Einstein Elevator — •Andreas Schmitz[1], Michael Kretschmer[1], Christoph Lotz[2], and Markus Thoma[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität, Gießen, Germany — [2]Instititut für Transport- und Automatisierungstechnik, Gottfried Wilhelm Leibniz Universität Hannover

An experiment with complex plasmas was conducted in a copy of the former International Space Station Plasmakristallexperiment-Nefedov laboratory in the University of Hannover's drop tower, the Einstein Elevator. For the experiment performed, an argon high-frequency plasma was generated in the plasma chamber at low pressures into which melamine-formaldehyde microparticles were injected. When the setup was dropped inside the Einstein elevator, the microparticles underwent an instantaneous transition from 0 g to 1 g and were subsequently lifted from the sheath region into the bulk plasma during the microgravity phase. The first results of the analysis of this experiment are presented here.

P 19.40 Thu 16:00 P

Study of QED effects in collision of near-surface accelerated electrons with high-intensity lasers — •Marko Filipovic, Christoph Baumann, and Alexander Pukhov — Institut für Theoretische Physik I, Heinrich-Heine-Universität, Düsseldorf, Germany

As the development of laser technology progresses, ever higher intensities and better beam qualities in laboratories become available. This advance enables new experimental setups in the study of laser-plasma interaction and quantum electrodynamic (QED) effects like quantum photon emission and pair production in extreme fields and densities.

We present two-dimensional Monte-Carlo particle-in-cell simulations of two high-intensity lasers grazing the surface of a solid-state target. Due to the fields near the target surface electrons are extracted and accelerated. Finally, the extracted electrons collide with the counter-propagating laser, which generates a QED cascade. Here, the processes are studied for various laser intensities, angle of incidence and point of incidence at the surface.

P 19.41 Thu 16:00 P

Ion spectroscopy of ultrashort laser pulse plasmas ignited by pre-pulses — •Lars Schwabe, Jan Riedlinger, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Illuminating solids with a high-intensity sub-10-fs laser creates a short-lived high-temperature plasma. The detailed processes during plasma generation are still not fully predictable today. We examined the emitted ions in terms of reached ionization states, probability and kinetic energy distribution, using a Thomson parabola spectrometer with an increased dynamic range to map ions with energies in the sub-100-keV range. Experiments were done with systematically varied laser parameters and pre-pulses, with peak intensities up to 10^{18} W/cm^2 at pulse durations down to 7 fs. The results allow conclusions on the plasma formation processes and the subsequent ionization dynamics in this ultrashort sub-120-fs domain.

P 19.42 Thu 16:00 P

Reconstructing the plasma temperature by optical probing method in femtosecond laser hydrogen jet interaction — •Long Yang[1,2], Constantin Bernert[1,2], Lingen Huang[1], Stefan Assenbaum[1,2], Martin Rehwald[1,2], Karl Zeil[1], Ulrich Schramm[1,2], Ilja Goethel[1,2], Thomas Kluge[1], Jan Vorberger[1], and Thomas E. Cowan[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Radiation Physics — [2]Technische Universitat Dresden

Plasma temperature is a critical parameter in warm dense matter and unable to be measured directly. In this study, we apply a well-designed experiment to generate an adiabatic expanded, thermalized hydrogen plasma in few ps by 30fs 1.63e18W/cm2 short pulse laser and 5um diameter solid hydrogen jet interaction. With the optical laser probing method at different wave length, the plasma density in expansion process is recorded with optical shadow image. Then plasma temperature is reconstructed by finding the best fit between experiment and hydro with ray tracing simulations. The electron temperature is determined to be around 300eV through this method and compared to the PIC simulations. The results show that both PIConGPU and PICLS overestimate the electron temperature several factors. This is the first time that we design an experiment and benchmark to the PIC codes. The result would help us improve the existed laser plasma interaction model in PIC.

P 19.43 Thu 16:00 P

Temporally and energy resolved actinometry in a micro cavity plasma array — •Henrik van Impel, David Steuer, Volker Schulz-von der Gathen, Marc Böke, and Judith Golda — Ruhr University Bochum, Faculty of Physics and Astronomy, Experimental Physics II, Germany

Dielectric barrier discharges (DBDs) have many applications, such as the generation of ozone or the treatment of volatile organic compounds (VOCs). To understand the underlying processes, fundamental knowledge on the generation of reactive species is necessary. Here we investigate atomic oxygen production as a model system in a micro cavity plasma array, a customized surface DBD confined to geometrically arranged cavities of micrometer size. We studied the behavior and the plasma chemical processes with optical emission spectroscopy methods. The discharge is operated in helium with a molecular oxygen admixture of about 0.1% at atmospheric pressure using a 15 kHz and about 600V excitation voltage. High atomic oxygen densities can already be observed with energy resolved actinometry (ERA). Using a multi-photomultiplier setup and ERA, we measured the temporal evolution of the atomic oxygen density and the effective mean electron energy over the first ignitions, which are affected by the memory effect due to residual charges.

Project is funded within project A6 of the SFB 1316.

P 19.44 Thu 16:00 P

Periodic structures (LIPSS) on metallic coatings (Ti, Cu, Cr) induced by nanosecond laser — •Robin Labenski, Patrick Preissing, Sascha Chur, Marc Böke, Volker Schulz-von der Gathen, and Judith Golda — Ruhr University Bochum, Faculty of Physics and Astronomy, Experimental Physics II, Germany

Catalysts show an increased efficiency in dependence of their morphology and chemical composition. In our research we investigate the formation of Laser-induced Periodic Surface Structures (LIPSS) on metallic coatings (Ti, Cu, Cr, 20nm-100nm) on Si-wafer induced by pulsed laser irradiation (ns-Nd:YAG, 532nm/1064nm, 20Hz). We found that LIPSS usually appear right above the melting threshold of the respective surface material. Under normal incidence they develop a periodicity roughly equal to the used wavelength and are being oriented perpendicular to the polarization direction. For an increasing angle of incidence the periodicity changes in a for the applied polarization (s or p) characteristic manner. All results match prognosis of the Efficacy-Factor-Theory by Sipe [1]. In upcoming measurements we test the chemical composition of LIPSS when induced in different atmospheres and/or simultaneously being treated by the COST reference microplasma jet. Supported by DFG within SFB1316.

[1] JE Sipe "Laser-induced periodic surface structure. I. Theory", Phys. Rev. B 27.4 (1983)

P 19.45 Thu 16:00 P

RF-atmospheric pressure plasma jet as a source of vacuum-UV photons for photoionisation — •Natascha Blosczyk[1], Tristan Winzer[1], Judith Golda[1,2], and Jan Benedikt[1] — [1]Kiel University — [2]current address: Ruhr-Universität Bochum

Vacuum-UV(VUV) radiation has great use, not only as a means of analysing gas mixtures by their emission and absorption spectra, but also as a way to induce chemical reactions in a target gas. Therefore, the aim of this work is to study VUV-radiation of different atmospheric plasma sources and develop a way to efficiently use it for photoionisation at atmospheric pressure. The VUV-radiation of helium and helium/argon plasmas with excimer continua and line-radiation is measured by VUV-spectroscopy in the 60 to 200 nm range as function of the input power.

Acetylene is used as a model precursor to investigate the use of VUV-photons for photoionisation and follow-up chemistry, where the generated primary ions and ions formed in the polymerization reactions are detected by positive ion mass spectrometry. The VUV-generation in the plasma is separated from the diluted acetylene gas via a controlled gas flow. To further study the effects of the photons on the chemistry, the FTIR-spectrometry will be used to study the properties of deposited thin films from the VUV-photon activated gas mixture, as well as SMPS measurements to ensure a dust-free process.

P 19.46 Thu 16:00 P

Cold Atmospheric Plasma Decontamination of FFP3 Face Masks and Long-Term Material Effects — •Alisa Schmidt[1], Chen-Yon Tobias Tschang[1], Joachim Sann[2], and Markus H. Thoma[1] — [1]I. Physical Institute, Justus Liebig University, Giessen, Germany — [2]Institute of Physical Chemistry, Justus Liebig University, Giessen, Germany

Motivated by the shortages of face masks and safety clothing in the beginning of the corona pandemic, we conducted studies on decontamination of FFP3 face masks with cold atmospheric plasma (CAP) and resulting material effects. Therefore, the bactericidal (Escherichia coli) and sporicidal (Bacillus atrophaeus) efficacy of CAP afterglow decontamination of FFP3 mask material was investigated by decontamination experiments in a surface micro discharge (SMD) plasma chamber. In addition, a detailed analysis of changes in long-term plasma treated (15h) mask material and its individual components - ethylene vinyl acetate (EVA) and polypropylene (PP) - was carried out using surface analysis methods such as laser microscopy, contact angle measurements, X-ray photoelectron spectroscopy (XPS) as well as fabric permeability and resistance measurements. The microbiological experiments showed that plasma treatment of FFP3 face masks with CAP afterglow of an SMD device effectively inactivates E. coli and B. atrophaeus on the fabric. Furthermore, long-term material effects indicate that FFP3 masks can be plasma decontaminated and reused multiple times (up to 5h) but only to a limited extent, as otherwise permeability levels no longer meet DIN EN 149 specifications.

P 19.47 Thu 16:00 P

Comparison of mass spectrometry and optical measurements of plasma catalysis conversion of n-butane — •Laura Chauvet, Christoph Stewig, Theresa Urbanietz, Marc Böke, and Achim von Keudell — Ruhr-Universität Bochum Institute of Experimental Physics II Faculty for Physics and Astronomy Universitätsstraße 150 Building NB 5/174 D-44780 Bochum

With the progress in the production of renewable energy, the use of plasmas to convert molecules into value added species present a novel research field of interest. The coupling of plasma with a surface catalyst might exhibit synergetic effects enhancing the conversion or the selectivity of reactions.

In this framework, a plasma chamber has been designed to study the mechanisms involved in the conversion of carbon-based molecules by plasma catalysis. The chamber is fed by a helium flow with small admixtures of n-butane. A capacitively coupled atmospheric pressure RF discharge is used to dissociate n-butane. Different kinds of catalysts can be spray coated on the electrodes and brought into contact with the plasma. In this work, a sampling system has been designed to sample the gas directly from the edge of the discharge to perform in situ measurements by mass spectrometry. The measurements are compared to the ones performed by Fourier Transform Infrared Spectroscopy (FTIR) measurements. As mass spectrometry is not limited by infrared active species, it is a complementary method to benchmark the optical measurements.

P 19.48 Thu 16:00 P

CO2 utilization in 3D-printed barrier discharge reactors — •Dimas Adrianto[1], Milko Schiorlin[1], Volker Brüser[1], Ronny Brandenburg[1,2], and Sven Grundmann[2] — [1]Leibniz Institute for plasma science and technology, Greifswald, Germany — [2]University of Rostock, Rostock, Germany

Plasma technology and rapid prototyping are two emerging technologies, each with its own set of benefits. However, the benefits of these technologies are rarely combined. The discharge chamber of Dielectric Barrier Discharge (DBD) reactors for investigating CO2 utilization were created using a 3D printer in this study. Because of rapid prototyping's high adaptability and modification potential, the results of fluid dynamics simulations can be directly introduced in the plasma reactor manufacturing process. DBD reactors are made of methacrylic acid polymer and have an overall dimension of 120 x 120 mm, with a powered electrode size of 55 x 55 mm in the center. 3D-printed reactors were initially tested with three different feed-gases: synthetic air, nitrogen, and carbon dioxide to ensure that stable plasma could be generated. Based on electrical characterization, in particular voltage-charge plots, operation parameters such as applied voltage, plasma power, and effective capacitance were studied in detail. Three DBD reactors with different gas flow distribution and velocity profiles were then investigated for carbon monoxide formation in pure CO2. In future experiments, the production of value-added chemicals such as CO and methanol will be further studied.

P 20: Invited talks V

Time: Friday 11:00–12:30 Location: P-H11

Invited Talk P 20.1 Fri 11:00 P-H11

On the hunt for a reactor-relevant scenario for W7-X — •Golo Fuchert for the W7-X team-Collaboration — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

The optimized stellarator Wendelstein 7-X (W7-X) aims to demonstrate a steady-state reactor-relevant scenario. Already the first divertor experiments at W7-X gave initial insights in how such a scenario could potentially look like, which key questions need to be answered in order to improve the performance of W7-X, and if the scenarios that will be developed can also teach us something about a potential reactor. A starting point of scenario development is the understanding of operational limits. Obviously it has to be physically possible to run a particular scenario. Here, mainly limitations arising from the ECR heating physics and the power balance (radiative density limit) have been identified in the first experimental campaigns of W7-X and essentially follow theoretical expectations. Furthermore, a reactor-relevant scenario should combine good energy confinement, steady-state conditions and divertor detachment. All three criteria have been achieved individually. Good confinement seems to depend on reduced turbulent transport in plasmas with steep density gradients. Steady-state plasmas have been achieved at moderate densities and heating powers. And detachment was demonstrated at high densities. But combining all three into an integrated scenario is a challenge that will guide the experimental exploration of W7-X for the foreseeable future. On this path, the flexibility of the magnetic configuration offers unique opportunities, but increases the complexity of the task at hand.

Invited Talk P 20.2 Fri 11:30 P-H11

Plasma für die Gaskonversion: Power-to-X — •Andreas Schulz, Katharina Wiegers, Matthias Walker und Günter Tovar — Universität Stuttgart, IGVP, Pfaffenwaldring 31, 70569 Stuttgart, Germany

Im Koalitionsvertrag 2021 - 2025 zwischen der Sozialdemokratischen Partei Deutschlands (SPD), BÜNDNIS 90 / DIE GRÜNEN und den Freien Demokraten (FDP) „Mehr Fortschritt wagen“ steht als eines der großen Ziele, die Klimaneutralität spätestens 2045 zu erreichen. Das Umweltbundesamt beziffert den deutschen Primärenergiebedarf für 2018 auf 3.942.341 TJ (1,1 EWh); davon liegt alleine der Anteil für die chemische Industrie bei rund 42 %. Für das Erreichen der angestrebten Klimaneutralität müssen Technologien erforscht werden, die Energie aus erneuerbaren Ressourcen für die chemische Industrie nutzbar machen. Eine Möglichkeit ist, elektrische Energie über Plasmaverfahren in die chemische Synthese zu integrieren. Dabei muss sich das Plasma gegenüber etablierten und sehr gut erforschten Verfahren, wie die Elektrolyse oder elektrische Widerstandserwärmung (Power-to-Heat), behaupten. Grundsätzlich wird ein Plasma dazu genutzt, um ein energetisch tief liegendes Molekül durch Energiezufuhr in einen aktivierten Zustand überzuführen. Aktuell sind am IGVP die Moleküle CO_2, N_2, und H_2O im Fokus der Forschung. CO_2 wird durch Dissoziation in CO und O· zerlegt, N_2 mit O_2 zu NO reagiert und aus H_2O wird für die Radikalchemie die beiden Radikale ·OH und H· erzeugt.

Invited Talk P 20.3 Fri 12:00 P-H11

Combined Phase Contrast Imaging and Small-Angle X-Ray Scattering Diagnostic of Relativistic Plasmas at the High Energy Density Instrument at European XFEL — •Alejandro Laso Garcia[1], Toma Toncian[1], Hauke Hoeppner[1], Alexander Pelka[1], Carsten Baehtz[1], Erik Brambrink[2], Jan-Patrick Schwinkendorf[2], Motoaki Nakatsutsumi[2], Johannes Hagemann[3], and Thomas Preston[2] — [1]Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany — [2]European XFEL GmbH, Schenefeld, Germany — [3]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

The bright ultra-short X-ray pulses of the EuXFEL provide an invaluable tool to spatially and temporally investigate the laser-plasma interactions at solid density. At the HED instrument, the high-power laser ReLaX currently delivers pulses of 3 J of energy with 25 fs duration on target, reaching intensities up to 10^{20} W/cm^2.

In April and May 2021, Small Angle X-Ray Scattering and Phase Contrast Imaging were simultaneously demonstrated in pump-probe experiments at HED in a community experiment involving 15 institutions from all over the world. In this talk we will present the preliminary results of this community experiment probing ultrafast phenomena in a wide array of target configurations: hole boring in wires, shockwave generation in CH blocks, buried heating of a wire inside a CH medium, foam ionization and collective effects in heated foils.

P 21: Atmospheric Pressure Plasmas II

Time: Friday 14:00–15:45 Location: P-H11

P 21.1 Fri 14:00 P-H11

Production of crystalline silicon nanoparticles in an atmospheric plasma jet — •Maren Dworschak[1], Filip Matějka[2], Niklas Kohlmann[3], Pavel Galář[2], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Institute of Physics, Czech Academy of Sciences, Czech Republic — [3]Faculty of Engineering, Kiel University, Germany

Due to their opto-electrical properties semiconductor nanoparticles can be used in a wide range of applications including photovoltaic cells. Cold atmospheric plasmas are highly reactive systems that can be used for the generation of such nanoparticles. Compared to low pressure systems the production of crystalline particles is more challenging, but also provides economical benefits. We report on an RF-driven capacitively coupled atmospheric plasma jet with a dielectric on the electrodes. The so-called HelixJet [1] can be operated at large powers and elevated gas temperature, where its operation is not compromised by depositions inside the jet. Its original setup has been modified with an additional electrode to work reliable even at high admixtures of reactive gases. Using silane, silicon nanoparticles with precise size control can be generated over a broad range of sizes. Different reactive gas admixtures are used to modify the surface passivation of the generated nanoparticles. Under the right conditions it is possible for the particles to become crystalline. Their crystallinity is observed through measurements of (time-resolved) photoluminescence, Raman spectroscopy and TEM measurements.

[1] J. Schäfer et al., Plasma Process. Polym. 17 (2020)

P 21.2 Fri 14:15 P-H11

Vibrational excitation in a CO_2/N_2 ns-discharge — Yanjun Du[1,2], •Tsanko V. Tsankov[1], Dirk Luggenhölscher[1], and Uwe Czarnetzki[1] — [1]Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany — [2]North China Electric Power University, Beijing, China

Repetitively pulsed ns-discharges exhibit large departure from equilibrium. This is especially well suited for studying the excitation of molecules due to the separation of the time scales for population and relaxation. Of particular interest in recent years is the study of discharges in CO_2 in relation to efficient molecule dissociation through ladder climbing excitation of the vibrational states [1]. A tunable quantum cascade laser system for absorption measurements has been set up to measure this excitation with ns resolution [1,2].

Here the system is employed to obtain the excitation dynamics of the CO_2 states in a ns pulsed discharge in a near-atmospheric pressure CO_2/N_2 mixture. The mechanisms for CO_2 molecular excitation during the discharge pulse and in the subsequent afterglow are discussed and compared to the ones in discharges in CO_2/He mixtures.

[1] Y. Du, Ts. V. Tsankov, D. Luggenhölscher, U. Czarnetzki, *J. Phys. D: Appl. Phys.* **54** (2021) 365201.

[2] Y. Du, Ts. V. Tsankov, D. Luggenhölscher, U. Czarnetzki, *J. Phys. D: Appl. Phys.* **54** (2021) 34LT02.

P 21.3 Fri 14:30 P-H11

Plasma catalytic synergies of a non-equilibrium atmospheric pressure plasma jet with MnO_2 surface catalyst — •Christoph Stewig, Theresa Urbanietz, Laura Chauvet, Marc Böke, and Achim von Keudell — Ruhr-Universität Bochum Institute of Experimental Physics II Faculty for Physics and Astronomy Universitätsstraße 150 Building NB 5/174 D-44780 Bochum

Plasma catalysis seeks to exploit potential synergies between surface catalytic reactions and plasma reactions. An excess of renewable energies could be used to produce value-added molecules and thus provide the chemical industry with important reactants or allow for alternative methods of energy storage.

Potential synergetic effects are: (i) a reduction or prevention of catalyst poisoning due to a cleaning of the catalyst surface, hence (ii) a lowering of the catalyst activation temperature, and (iii) an increase in the catalyst activity due to the creation of additional reactive sites by the plasma. (iv) finally, specific molecular excitations could promote specific surface reactions.

We investigate these mechanisms in a RF driven temperature-controlled capacity coupled plasma jet at atmospheric pressure. Fourier Transformed Infrared Spectroscopy (FTIR) measurements are conducted in the plasma and yield information on the excitation and density of noble gas diluted molecules like CO_2 or n-butane.

The effect of a MnO_2 surface catalyst for temperatures of 20°C and

200°C on the dissociation of n-butan are presented.

P 21.4 Fri 14:45 P-H11

VUV-photoionization chamber for the selective study of ion-substrate interactions — •Kerstin Sgonina, Alexander Quack, Christian Schulze, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Germany

The high reactivity of cold atmospheric pressure plasmas, for example with biological substrates, is in addition to the reactive neutral oxygen and nitrogen species, also based on additive or synergistic effects of these reactive species with charged species, photons, and electric fields. In contrast to photons or electric fields, the study of the isolated effect of ions with biological substrates or ion-based deposition of thin films is more challenging as their isolated production under atmospheric pressure conditions is not trivial. To prove the expected enhanced effect of ions due to their charge and internal energy, knowledge about the ion composition and absolute ion fluxes to the substrate is needed.

To study the isolated effect of ions on substrates and ion-based thin film deposition, an experimental setup has been developed in which photoionized ions are directed towards the substrate. The ions are generated in a helium atmosphere with a small admixture of O_2, C_2H_2 or other gaseous species by VUV-radiation of the helium excimer emission (60-100 nm) generated by a helium driven atmospheric pressure plasma. Mass spectra and relative ion fluxes along the substrate position are measured by ion mass spectrometry. Combined with spatial resolved current measurements, the absolute ion flux can be determined. The deposition of thin films with ions generated from C_2H_2 will be discussed.

P 21.5 Fri 15:00 P-H11

Vibrational excitation in a nanosecond discharge — •Jan Kuhfeld[1], Zoltan Donko[2], Nikita Lepikhin[1], Dirk Luggenhölscher[1], and Uwe Czarnetzki[1] — [1]Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany — [2]Wigner Research Centre for Physics, Budapest, Hungary

Vibrational distribution functions of nitrogen are measured in a nanosecond discharge (200-250 ns, conducting electrodes) by coherent anti-Stokes Raman scattering (CARS). It is found, that for vibrational states with $v < 8$ a two temperature distribution function is a very good approximation to the vibrational distribution. The excitation conditions for vibrational states are constant during most of the discharge pulse and agree very well with the excitation rates from the literature for the given electric field, which is measured by E-FISH (electric field induced second harmonic generation). The development of the vibrational states during the afterglow is compared to a state-to-state kinetic model, which is dominated by VV transfer and transport losses. Here too, good agreement was found for rates available in the literature. Additionally, Particle-in-Cell/Monte Carlo Collisions (PIC/MCC) simulations are performed for the same conditions as in the experiments. The results of these simulations are used to derive analytical models for the discharge. The models can explain the value of the reduced electric field in the plasma bulk (about 80% of the discharge volume), which favors vibrational excitation.

P 21.6 Fri 15:15 P-H11

CO2 dissociation by a nanosecond pulsed dielectric barrier discharge — •Sepideh Mousazadeh Borghei, Volker Brüser, and Juergen F. Kolb — Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany

Reduction of CO2 into value-added chemicals and fuels by means of plasma technology has gain significant interest in recent years. In this project, a coaxial dielectric barrier discharge generated with high voltage pulses of 15-20 kV and a pulse duration of 500 ns at ambient temperature and atmospheric pressure was used to investigate the process of CO2 splitting for CO2 and an admixture of Ar in the ratio of 1:2 (CO2:Ar). The influence of gas flow rate and more importantly the effects of positive and negative polarity on the process of dissociation were investigated. The gaseous product after plasma treatment was analyzed by Fourier transform infrared spectroscopy. The results indicated that gas flow rate plays an important role in the process of dissociation, which the highest CO2 conversion of 5.6% detected for the lowest flow. In addition, positive polarity shows an up to 1.3 fold higher CO concentration compared to negative polarity. Indeed, the obtained results from the inception voltage approved that less voltage was required to start the plasma in positive polarity, and therefore, at the same condition, there are more filamentary channels in positive polarity than negative polarity.

P 21.7 Fri 15:30 P-H11

CO2 conversion in a barrier corona discharge at elevated pressures — •Hamed Mahdikia, Volker Brüser, and Ronny Brandenburg — Leibniz Institute for Plasma Science and Technology, 17489, Greifswald, Germany

A barrier corona discharge in CO2 with admixture of Argon is studied. The aim is to investigate the operation at elevated pressures up to 5 bar for industrial scale CO2 conversion. Therefore, the coaxial asymmetric dielectric barrier discharge contains an inner brush electrode to intensify the electric field strength and to minimize the amplitude of the applied high voltage driving the discharge. Charge-voltage plots are used to characterize the discharge. Depending on the conditions (sinusoidal voltage amplitude, gas composition and pressure), full or partial coverage of the electrodes is obtained. This so-called partial discharging is monitored by the variation of the effective dielectric capacitance. Optical emission spectroscopy was done at full coverage condition for each gas composition and pressure. The line intensity ratio of atomic oxygen at 777 nm to Argon excited species at 772 nm increase significantly by increasing the pressure. On the other hand, absolute CO2 conversion decreases by increasing the CO2 content in the gas mixture and pressure at constant specific energy input (SEI=1.5 kJ/L) while effective conversion increases as well as the energy efficiency, and CO production. A correlation of the mean reduced electric field strength (E/N) and the CO2 dissociation is found. The E/N decreased by increasing the pressure and sustaining voltage to ~ 40 Td for 5 bar which leads to a higher dissociation degree.

P 22: Helmholtz Graduate School HEPP V

Time: Friday 14:00–15:15 Location: P-H12

P 22.1 Fri 14:00 P-H12

Experimental validation of gyrokinetic simulation with scale-resolved multi-field turbulence measurements — •Klara Höfler[1,2], Tobias Görler[2], Tim Happel[2], Pascale Hennequin[3], Pedro Molina Cabrera[2,4], Michael Bergmann[2], Rachel Bielajew[4], Carsten Lechte[5], Anne White[4], Ulrich Stroth[2,1], and the ASDEX Upgrade Team[2] — [1]Physik Department E28, TUM, Garching, Germany — [2]MPI für Plasmaphysik, Garching, Germany — [3]LPP, Ecole Polytechnique, Palaiseau, France — [4]MIT PSFC, Cambridge, Massachusets, USA — [5]IGVP, Stuttgart, Germany

Turbulence is the main driver of heat transport which deteriorates the performance of fusion reactors. To design turbulence optimised devices, simulation codes need to be validated by experiments. Validation work has already been done for single or a reduced number of parameters.

The comprehensive set of turbulence data presented in this contribution is measured on ASDEX Upgrade in different plasma scenarios but at the same radius. It includes wavenumber spectra, density and temperature fluctuation amplitudes and radial correlation lengths, the poloidal dependence of the velocity perpendicular to the magnetic field and the cross phase between density and temperature fluctuations.

These quantities are measured for extensive code validation by Doppler reflectometers and a CECE radiometer. They are compared to non-linear simulations of the gyrokinetic code GENE because of its mature capabilities to assess and reproduce core turbulence. In addition synthetic diagnostic modeling accounts for diagnostic effects.

P 22.2 Fri 14:25 P-H12

The importance of the tertiary instability in the collisionless Dimits regime — •Axel Hallenbert and Gabriel Plunk — Max-Planck-Institut für Plasmaphysik, D-17491 Greifswald, Germany

The upshift from the linear instability threshold until turbulent transport commences, caused by self-generated zonal flows, is known as the Dimits shift. Though this phenomenon could facilitate enhanced magnetic confinement device performance, it has proved difficult to understand and quantitatively predict except in simple cases. These have generally been of the simple fluid model kind, so to proceed towards more realistic scenarios, fully gyrokinetic simulations have been used to investigate the Dimits shift in simple geometries. Here the tertiary instabilty, which describes how zonal flows give way to increasing drift waves, was both the main tool and focus. Many features and dynamics previously linked to this instability in fluid models were indeed confirmed to remain in the presence of kinetic effects. Of greatest importance, in the collisionless regime this facilitates an efficient and here accurate Dimits shift prediction, while also hinting at its further validity in more varied geometries.

P 22.3 Fri 14:50 P-H12

Excitation of High Frequency Waves in Full-6D Kinetic Simulations of Magnetically Confined Plasmas — •Mario Raeth, Klaus Hallatschek, and Katharina Kormann — Max Planck Institute für Plasmaphysik, Garching, Deutschland

Although current gyrokinetic computer simulations are in fair agreement with experimental results in core physics, the assumptions in the derivation make them unreliable in regimes of higher fluctuation amplitudes and stronger gradients, such as the tokamak edge. To correctly describe all phenomena in such regimes, more involved simulations might be necessary. We have developed a novel optimised and scalable semi-Lagrangian solver to simulate ion-temperature gradient modes with the full 6D kinetic equations. It has been verified extensively in the regime of gyrokinetics, including the growth of linear modes and the turbulent saturation. Furthermore, the excitation of high-frequency Bernstein waves (IBWs) has been shown in the nonlinear saturation phase. To increase the understanding of the relevance of such high-frequency waves in turbulence, we investigated various excitation mechanisms. Investigations range from non-linear transfer of energy up the frequency scale, to the presence of secondary linear instabilities. The latter lead to a model which allows us to predict a threshold, in the amplitude of a primary gyrokinetic mode, for the excitation and the resulting growth rate of the secondary instability. This helps us to predict the presence and amplitude of IBWs in nonlinear ITG simulations, which we could confirm by simulations in our full-6D kinetic code.