Plasma Physics Division
Fachverband Plasmaphysik (P)

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Overview of Invited Talks and Sessions

(Lecture halls H2, H4, H5, and H6; Poster P)

Plenary Talks of the Plasma Physics Division

PV III	Tue	9:00– 9:45	Audimax	**ASDEX Upgrade tokamak: 30 years of science and technology development for a fusion power plant** — •Arne Kallenbach
PV VI	Wed	9:00– 9:45	Audimax	**Low pressure dusty plasmas for the synthesis of nanocrystals and quantum dots** — •Uwe Kortshagen

Invited Talks

P 1.1	Mon	11:00–11:30	H5	**Diagnostics of magnetized high frequency technological plasmas** — •Julian Schulze, Moritz Oberberg, Birk Berger, Julian Roggendorf, Dennis Engel, Christian Wölfel, Jan Lunze, Ralf Peter Brinkmann, Peter Awakowicz
P 2.1	Mon	11:00–11:30	H6	**Predictive modelling of beryllium erosion, transport and deposition during H, He and DT plasmas in ITER** — •Juri Romazanov, Sebastijan Brezinsek, Andreas Kirschner, Richard A. Pitts, Vladislav S. Neverov, Christian Linsmeier
P 3.1	Mon	16:30–17:00	H6	**An overview of the theoretical description and modelling of low-current arcs at small gap distances** — •Margarita Baeva
P 4.1	Tue	11:00–11:30	H5	**Overview on turbulence in the shear- and scrape-off layer at W7-X** — •Andreas Krämer-Flecken, Olaf Grulke, Xiang Han, Carsten Killer, Elisee Trier, Thomas Windisch, Haoming Xiang
P 6.1	Tue	16:30–17:00	H5	**The Wendelstein 7-X Scrape-Off Layer** — •Carsten Killer, W7-X Team
P 8.1	Wed	14:00–14:30	H5	**Visualizing the Dynamics of a Plasma-Based Particle Accelerator** — •Malte Kaluza
P 11.1	Thu	11:00–11:30	H4	**Microfluidic flow in single-layer dusty plasmas** — •Peter Hartmann, Truell W. Hyde
P 12.1	Thu	11:00–11:30	H5	**Planetary and astrophysical high Mach-number shocks: kinetic simulations vs in-situ measurements** — •Artem Bohdan, Martin Pohl, Paul Morris
P 13.1	Thu	14:00–14:30	H4	**How turbulence sets boundaries for fusion plasma operation** — •Peter Manz, Thomas Eich, the ASDEX Upgrade Team
P 14.1	Thu	14:00–14:30	H5	**Streamer inception and imaging in various atmospheres** — •Sander Nijdam, Siebe Dijcks, Shahriar Mirpour
P 15.1	Thu	16:30–17:00	H5	**Physics studies with high-power electron cyclotron heating (ECRH) on ASDEX Upgrade** — •Jörg Stober, ASDEX Upgrade Team
P 16.1	Fri	11:00–11:30	H2	**Configurational temperature of multi species complex (dusty) plasmas** — •Dietmar Block, Frank Wieben, Michael Himpel, Andre Melzer

Sessions

P 1.1–1.5	Mon	11:00–12:30	H5	**Low Pressure Plasma Sources I**
P 2.1–2.4	Mon	11:00–12:25	H6	**Magnetic Confinement, Plasma-Wall Interaction & Helmholtz Graduate School I**

P 3.1–3.6	Mon	16:30–18:15	H6	**Atmospheric Pressure Plasmas and their Applications I**
P 4.1–4.3	Tue	11:00–12:00	H5	**Magnetic Confinement II**
P 5.1–5.46	Tue	14:00–16:00	P	**Poster I**
P 6.1–6.3	Tue	16:30–17:50	H5	**Magnetic Confinement III & Helmholtz Graduate School II**
P 7.1–7.3	Wed	14:00–15:15	H4	**Helmholtz Graduate School III**
P 8.1–8.4	Wed	14:00–15:15	H5	**Laser Plasmas I**
P 9.1–9.4	Wed	16:30–17:30	H5	**Codes and Modelling (Methods)**
P 10	Wed	17:45–18:45	MVP	**Mitgliederversammlung Plasmaphysik**
P 11.1–11.5	Thu	11:00–12:30	H4	**Complex Plasmas and Dusty Plasmas I**
P 12.1–12.4	Thu	11:00–12:15	H5	**Astrophysical Plasmas & Laser Plasmas II**
P 13.1–13.4	Thu	14:00–15:45	H4	**Magnetic Confinement IV & Helmholtz Graduate School IV**
P 14.1–14.7	Thu	14:00–16:00	H5	**Atmospheric Pressure Plasmas and their Applications II**
P 15.1–15.4	Thu	16:30–18:15	H5	**Magnetic Confinement V & Helmholtz Graduate School V**
P 16.1–16.5	Fri	11:00–12:30	H2	**Low Pressure Plasmas II & Dusty Plasmas II**
P 17.1–17.44	Fri	14:00–16:00	P	**Poster II**

Annual General Meeting of the Plasma Physics Division

Wednesday 17:45–18:45 MVP

P 1: Low Pressure Plasma Sources I

Time: Monday 11:00–12:30 Location: H5

Invited Talk P 1.1 Mon 11:00 H5

Diagnostics of magnetized high frequency technological plasmas — •Julian Schulze[1], Moritz Oberberg[1], Birk Berger[1], Julian Roggendorf[1], Dennis Engel[2], Christian Wölfel[3], Jan Lunze[3], Ralf Peter Brinkmann[2], and Peter Awakowicz[1] — [1]Institute of Electrical Engineering and Plasma Technology, Ruhr-University Bochum — [2]Institute of Theoretical Electrical Engineering, Ruhr-University Bochum — [3]Institute of Automation and Computer Control, Ruhr-University

Capacitively coupled radio frequency magnetrons are frequently used for sputter deposition of ceramic layers. Many fundamentals of their operation are not understood. We characterize such a discharge operated in argon with oxygen admixture at low pressure by a synergistic combination of different diagnostics and find that the magnetron magnetic field induces a discharge asymmetry. This Magnetic Asymmetry Effect affects the DC self bias and ion flux-energy distributions functions at boundary surfaces, which can be controlled by adjusting the magnetic field. Tuning the magnetic field allows to magnetically control the self-excitation of plasma series resonance oscillations of the RF current and, thus, Non-Linear Electron Resonance Heating. PROES reveals space and time resolved insights into the dynamics of the electron power absorption in the presence of the magnetic field. Measurements are also performed as a function of the oxygen admixture to understand the plasma behavior during sputter applications that are affected by hysteresis effects. In parallel the deposition rate and composition of the deposited thin films are determined.

P 1.2 Mon 11:30 H5

Spectroscopic determination of rotational and vibrational temperatures in nitrogen microwave discharges from low to atmospheric pressure — •David Rauner[1], Alistair Brydon[2], Ante Hecimovic[2], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Microwave (MW) discharges allow to cover a large pressure range: from the low-pressure, non-equilibrium regime of several Pa up to atmospheric conditions where heavy particle collisions play a dominant role and (partial) thermal equilibrium can typically be observed.

To demonstrate the transition between these low- and high-pressure regimes in MW plasmas, nitrogen discharges are excellently suited: via high-resolution optical emission spectroscopy and molecular spectra simulation, rotational and vibrational temperatures of different excited molecular species (N_2(B, C), $N_2{}^+$(B)) can be assessed. To cover the required large pressure range experimentally, two laboratory microwave plasmas driven at 2.45 GHz are utilized: a surface wave discharge (surfaguide) for the pressure range between 3 Pa and 2000 Pa and a microwave plasma torch, capable to operate at higher pressures up to atmospheric conditions. By assessing almost six orders of magnitude in pressure, a gradual equilibration of rotational and vibrational distributions is clearly seen and discussed in this contribution.

P 1.3 Mon 11:45 H5

Plasma enhanced chemical vapour deposition of ZrO_2 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 — [2]Inorganic Chemistry II, Ruhr-University Bochum

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.

An evaporated metalorganic precursor is transported into the reaction chamber by a nitrogen-flow of 25-50 sccm at pressures of about 100 Pa. A ZrO_2 layer is deposited onto a heated substrate in the centre of the chamber. The desired layer growth rate lies at > 500 nm/h and the layer thickness at < 30 μm. To influence and improve the reaction chemistry, a microwave plasma source is mounted opposite the substrate surface. The discharge interacts with the incoming precursor molecules, with the aim to reduce the reaction temperature.

During this process, the growth rate and substrate temperature are monitored by in-situ ellipsometry to obtain insights into chemical kinetics and mass transport phenomena. 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 1.4 Mon 12:00 H5

Infrared-spectrometric monitoring of the growth and surface treatment of a-C:H nanoparticles in a low-pressure plasma — •Oguz Han Asnaz[1], Niklas Kohlmann[2], Hauke Folger[1], Franko Greiner[1], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Faculty of Engineering, Kiel University, Germany

Due to their unique physical, mechanical, electrical, and optical properties, nanoparticles have found a wide range of applications ranging from drug carriers in biomedicine 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 a-C:H nanoparticles generated in a capacitively coupled low-pressure plasma and monitored by means of in situ time-resolved FTIR spectroscopy during operation with a multipass cell with 24 passes. The particles reach a size of about 500 nm after 90 seconds of growth and can be confined easily for multiple hours for treatment with hydrogen and deuterium as a first reactive test treatment to investigate in situ the surface treatment or particle etching and reveal the potentials and sensitivity of these diagnostics for other reactive plasma treatments. Additionally, using an electrostatic particle extractor system (EPEX) developed in our group, particle samples are extracted at multiple moments during the treatment for further SEM analysis with negligible disturbance of the plasma.

P 1.5 Mon 12:15 H5

Ion energy and collisions in high power impulse magnetron sputtering discharges — •Julian Held, Sascha Thiemann-Monjé, Achim von Keudell, and Volker Schulz-von der Gathen — Experimentalphysik II, Ruhr-Universität Bochum

High power impulse magnetron sputtering (HiPIMS) discharges are important tools for the deposition of thin, hard coatings. In such discharges, the transport of sputtered and then ionized cathode material towards the substrate determines the deposition rate and, therefore, the usefulness of the discharge for application. To understand how this transport is affected by collisions, we measured the velocity distribution function (VDF) of titanium and chromium ions using high-resolution optical emission spectroscopy. The VDF was found to be mostly Maxwellian, with high temperatures of 9 eV and 4.5 eV for titanium and chromium ions, respectively. Such a Maxwellian distribution implies a surprisingly high frequency of heavy particle collisions. Different types of heavy-particle collisions are discussed and Coulomb collisions are identified as the most frequent process. A simple model is created, following the self-relaxation process of the VDF from the initial Thompson distribution, created by the sputtering, towards the observed Maxwellian distribution. This model shows good agreement to the measured distribution, indicating that the high ion energy is caused by a redistribution of energy from the energetic Thompson distribution into the partly thermalized Maxwell-like distribution, observed in the experiment.

P 2: Magnetic Confinement, Plasma-Wall Interaction & Helmholtz Graduate School I

Time: Monday 11:00–12:25 Location: H6

Invited Talk P 2.1 Mon 11:00 H6

Predictive modelling of beryllium erosion, transport and deposition during H, He and DT plasmas in ITER — •Juri Romazanov[1], Sebastijan Brezinsek[1], Andreas Kirschner[1], Richard A. Pitts[2], Vladislav S. Neverov[3], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung * Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]ITER Organization, Route de Vinon-sur-Verdon, CS 90 046, 13067 St.-Paul-lez-Durance Cedex, France — [3]National Research Centre Kurchatov Institute, Moscow, Russia

Beryllium (Be) will be the main chamber armor material for the international thermonuclear fusion reactor ITER, which is currently under construction in France. We present a comparison of the Be erosion for different plasma conditions, including the baseline DT burning plasma scenario with power gain Q=10, as well as the low-power hydrogen (H) and helium (He) plasmas foreseen in the ITER pre-fusion power operation (PFPO) phase. It is shown that in the latter ones, the gross erosion is two orders of magnitude smaller. Another important finding is the difference in Be migration: in the DT baseline scenario 90% of the eroded Be is redeposited in the main chamber, while in the H and He cases the redeposition is reduced to 44 and 56%, respectively. The remaining Be is deposited in the divertor. Finally, it is shown that in DT the erosion is dominated by Be self-impact, while in H and He the sputtering by energetic charge-exchange neutrals (CXN) dominates.

P 2.2 Mon 11:30 H6

In situ mechanical characterization of ion-irradiated tungsten — •Bailey Curzadd[1,2], Max Boleininger[3], Maximilian Fuhr[1,2], Till Höschen[1], Robert Lürbke[1,4], Johann Riesch[1], and Rudolf Neu[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Technical University Munich, Garching, Germany — [3]CCFE, UKAEA, Abingdon, UK — [4]RWTH Aachen, Aachen, Germany

Although its low erosion and low retention of tritium make tungsten (W) the preferred plasma-facing material for future fusion reactors, its low-temperature brittleness is a critical vulnerability that could lead to the premature failure of plasma-facing components. Additionally, the degradation of essential material properties in the reactor environment – especially by neutron radiation and H/He trapped in the microstructure – greatly increases the likelihood of component failure, yet the degradation of W in a fusion environment is poorly characterized. For this reason, a novel in situ accelerator experiment was developed to characterize the mechanisms by which the mechanical properties of W are altered by radiation damage and trapped impurities, with a principle focus on the investigation of synergistic interactions between the factors that lead to material deterioration. This experiment uses thin drawn W wires prepared to a diameter of 5 *m to enable complete irradiation of the sample cross-section and allows simultaneous damaging and implantation of impurity atoms. The capabilities of the system and the results of the first experimental campaign examining radiation-induced relaxation of tensile stress in W will be presented.

P 2.3 Mon 11:55 H6

Conventional and non-conventional diagnostics on an atmospheric pressure DC glow microplasma discharge for in situ TEM studies — •Luka Hansen[1], Niklas Kohlmann[2], Ulrich Schürmann[2], Lorenz Kienle[2], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics, Kiel University, 24098 Kiel, Germany — [2]Institute of Materials Science, Kiel University, 24143 Kiel, Germany

Plasma surface interaction is one of the most discussed topics in plasma technology due to its relevance for the production or modification of micro- or even nano-structured surfaces. Still, state of the art analysis is mostly limited to the separation of plasma processing and surface analysis, since observing plasma induced surface changes in real time and nanoscale resolution is challenging. Based on the proof of principle experiments by Tai *et al.* [1] a DC microplasma discharge cell for in situ TEM integration is developed to overcome this limitation. Prior to introducing the cell close to the sensitive TEM optics extensive testing and diagnostics of the plasma discharge have to be done to ensure stability and reproducibility. Results of the conventional (electrical measurements, optical imaging, and emission spectroscopy) as well as non-conventional (calorimetry) diagnostics will be presented and a report on the current progress of the in situ measurements will be given.

[1] K Tai *et al* 2013 *Scientific Reports* **3** 1325

P 2.4 Mon 12:10 H6

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

Electron emission from surfaces during ion impact is one of the most fundamental plasma-surface-interaction. The surface conditions in plasmas strongly affect this electron emission and thus have an impact on the discharge itself. However, data of oxidized targets for instance, as they would appear in any reactive plasma discharge, are very spare and may even contain significant systematic errors, because they were often measured by modeling the complex behavior of plasma discharges. Many experimental and theoretical approaches address secondary electron emission coefficient determination (SEEC; amount of released electrons per incident ion) in literature [1,2]. However, this determination may remain rather indirect, because the process of ion-induced electron emission overlaps with other plasma-surface-interactions. Using beam experiments avoids this complication and allows a precise electron yield determination. SEECs of clean, untreated (air-exposed) and intentionally oxidized Cu and Ni foils are investigated in a beam experiment. Here, metal foils and oxidized foils are exposed to beams of Ar^+ with E_{ion}=200 eV - 10 keV and electron yields are determined precisely. A model for the electron emission is presented to explain the data. Surface conditions were analyzed by ex-situ XPS measurements. [1] D. Depla et al. J.Phys.D:Appl.Phys.,2008 [2] M. Daksha et al. J.Phys.D:Appl.Phys., 2016

P 3: Atmospheric Pressure Plasmas and their Applications I

Time: Monday 16:30–18:15 Location: H6

Invited Talk P 3.1 Mon 16:30 H6

An overview of the theoretical description and modelling of low-current arcs at small gap distances — •Margarita Baeva — Leibniz Institute for Plasma Science and Technology, Greifswald, Germany

This contribution will present the achievements of a three-year research project that was concerned with the development of a unified non-equilibrium modelling of direct current electric arcs of short lengths at low currents. Such arcs are currently considered as promising tools in material processing. They are also encountered in switching devices among others.

A thorough analysis of the physical processes and arc plasma properties were carried out in order to provide knowledge about the spatial structure of the arc when the arc length was reduced to only a few millimeters and below one millimeter, and the electric current amounted a few Amperes. Results will be presented that demonstrate the arc-electrode interaction over different arc lengths, the spatial extension of the regions of space charge, and how these regions change when the arc length becomes minuscule. The challenges in modelling of short arcs between melting electrodes will be discussed.

The potentials and limitations of the modelling approach will be considered with respect to further developments.

The project on modelling of microarcs is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - project number 390828847.

P 3.2 Mon 17:00 H6

Kalorimetrische Messungen an Plasmaspritzanlagen unter Atmosphärendruck mit passiven Thermosonden — •Kristian Amand Reck[1], Maximilian Stummer[2], Thorben Kewitz[3], Rüdiger Foest[3] und Holger Kersten[1] — [1]Christian-Albrechts-Universität zu Kiel, Kiel, Deutschland — [2]INOCON Technologie GmbH, Attnang-Puchheim, Österreich — [3]Leibniz-Institut für Plasmaforschung und Technologie e. V.

Das Plasmaspritzen ist ein etabliertes Beschichtungsverfahren für metallische und keramische Schichten als auch für Polymere und Komposite auf verschiedenen Substraten. In der Industrie und Forschung besteht ein großes Interessen an der Kontrolle und der Optimierung des gesamten Prozesses. Aufgrund der höheren Energiedichte als bei anderen Plasmaquellen und der Zuführung von Beschichtungsmaterialien ist die Auswahl an Diagnostiken allerdings begrenzt.

Der Energiestrom bei Plasma-Oberflächen-Wechselwirkungen ist ein wichtiger Parameter für das Schichtwachstum. Zur Messung des Energiestroms wurden passive Thermosonden verwendet, die für die anspruchsvollen Bedingungen adaptiert wurden. Eine Anpassung und Erweiterung der Auswertung ist ebenfalls notwendig gewesen. Es wurden an zwei unterschiedlichen Plasmaquellen die räumliche Verteilung des Energiestroms und die Abhängigkeiten von der Leistung, Gasflüssen und Beschichtungsmaterialien untersucht. Die vorgestellten Messungen zeigen die vielseitigen Einsatzmöglichkeiten von passiven Thermosonden, auch um Plasmaspritzanlagen zu charakterisieren.

P 3.3 Mon 17:15 H6

Influence of the fluid flow description on the characteristics of a plasma spray torch — •Tao Zhu, Margarita Baeva, Thorben Kewitz, Holger Testrich, Detlef Loffhagen, and Rüdiger Foest — Leibniz Institute for Plasma Science and Technology, 17489 Greifswald, Germany

In direct current plasma spray torches operated at current values of several hundred Amperes, the velocity of the generated plasma jet can approach the speed of sound, i.e. Mach numbers (Ma) close to one are reached. Then, the description of the fluid flow can affect the models' predictions. We present a two-dimensional and stationary magneto-hydrodynamic model of a plasma in local thermodynamic equilibrium for the steady operating mode of a plasma spray torch. Approaches related to both low- and high-Ma (bounded by Ma=0.3) are considered on the computational platform COMSOL Multiphysics for a laminar and compressible flow with flow rates from 40 to 80 normal litre per minute (NLPM). The predicted pressure, plasma temperature, velocity, and electric potential differ depending on the approach employed. The thermal efficiency of the torch computed by the high-Ma model is between 50% and 60% and agrees well with experimental values. In contrast, a thermal efficiency of about 50% is predicted by the low-Ma model. It agrees with the measurements at a flow rate of 40 NLPM, but gradually decreases to about 40% for a flow rate of 80 NLPM.

This work is funded by the European Union and the Federal State of Germany Mecklenburg-Western Pomerania (Project number TBI-V-1-321-VBW-112).

P 3.4 Mon 17:30 H6

Spectroscopical analysis of an atmospheric pressure argon methane microwave plasma for methane pyrolysis — •Simon Kreuznacht, Marc Böke, and Achim von Keudell — Experimental Physics II, Ruhr University Bochum, Germany

Recently, the climate friendly and energy efficient production of hydrogen has gained a lot of interest. Today, hydrogen is used as an important precursor in the chemical industry, but hydrogen may also serve as energy carrier, for energy storage, or as climate friendly fuel in the future. Usually, hydrogen is produced by steam reforming of methane. However, this process produces a lot of CO_2 (9 t per ton of hydrogen). Methane pyrolysis in a microwave plasma, as an oxygen free technology, is a promising production method of hydrogen without the emission of greenhouse gases.

Here, we present a detailed spectroscopic analysis of an argon methane microwave plasma based on the evaluation of high resolution dicarbon emission spectra. The dicarbon rotational temperature deduced from these spectra can be used to estimate the space resolved gas temperature. The product gas stream was monitored using an online gas analyser at the same time. Since the gas temperature heavily influences the chemistry in the plasma, the space resolved determination of the gas temperature can be used to tune the microwave plasma methane pyrolysis for optimal conversion and energy efficiency.

P 3.5 Mon 17:45 H6

Photo-chemistry of organosilicon and hydrocarbon precursors initiated by VUV/UV-radiation from an atmospheric pressure RF plasma jet in argon and helium — •Tristan Winzer, Natascha Blosczyk, and Jan Benedikt — Institute for Experimental and Applied Physics, Kiel University, Kiel, Germany

Deposition of thin films using atmospheric pressure plasmas (APPs) has received increased interest in recent years. This is because APPs do not require expensive vacuum chambers and continuous material treatment is possible. However, hot electrons in the plasma lead to formation of negative ions and subsequently to particle formation, which can be incorporated as defects in the film.

APPs ignited in argon or helium emit intense VUV/UV-radiation from noble gas excimer species. In this study, this radiation is utilized to create ions and free radicals from a gas mixture of helium/argon and organosilicon or hydrocarbon precursors. A plasma source for separation of plasma generated species and photo-chemistry products will be presented. The electrons created by photo-ionization of the precursor gas remain cold and the production of negative ions via electron attachment is omitted. The photo-ionization products in dependence of plasma parameters and reactive gas admixture will be analysed using positive ion mass spectrometry. Deposited films are characterized using Fourier-transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM).

P 3.6 Mon 18:00 H6

Electric field strengths within a micro cavity plasma array measured by Stark shift and splitting of helium — •Sebastian Dzikowski[1], Syvain Iseni[2], Judith Golda[3], Marc Böke[1], and Volker Schulz-von der Gathen[1] — [1]Experimentalphysik II, Ruhr-Universität Bochum — [2]GREMI, Universität Orlèans — [3]Plasma Interface Physics, Ruhr-Universität Bochum

Over the last years micro-structured plasma devices have received increased attention for decomposition and reformation of volatile organic compounds (VOC) [1]. Here, we present a metal-based microcavity reactor which is a demountable alternative to silicon-based devices. This layer-structured reactor consists of a nickel foil operating as an electrode and an electrically grounded magnet. Both electrodes are separated from each other by a 40 microns thick dielectric foil. The nickel foil consists of four sub-arrays where hundreds to thousands of cavities in the 100 microns range are arranged equally. To obtain more control over charged particles, the electric field is of high importance. Here, the Stark effect of the allowed 492.19 nm Helium line and its forbidden 492.06 nm counterpart is exploited. By using a combination of a plane grating spectrometer and an attached ICCD camera the typical displacement of about 0.2 nm between both transitions can be resolved. With that technique spatial integrated and phase-resolved electric field strengths with a time resolution up to one microsecond can be measured for this reactor depending on operation and geometric parameters. Depending on the polarity of the applied voltage, the electric field increases with smaller cavity diameters up to 60 kV cm-1.

P 4: Magnetic Confinement II

Time: Tuesday 11:00–12:00 Location: H5

Invited Talk P 4.1 Tue 11:00 H5

Overview on turbulence in the shear- and scrape-off layer at W7-X — •Andreas Krämer-Flecken[1], Olaf Grulke[2], Xiang Han[1], Carsten Killer[2], Elisee Trier[3], Thomas Windisch[2], and Haoming Xiang[1] — [1]Institut für Energie- und Klimaforschung, Forschungszentrum Jülich, 52425 Jülich — [2]MPI für Plasmaphysik, Teilinstitut Greifswald, 17491 Greifswald — [3]MPI für Plasmaphysik, Teilinstitut Garching, 85748 Garching

The presentation intends to give an overview on mode and turbulence phenomena observed in the plasma edge, island divertor and scrape-off layer (SOL) at the stellarator W7-X. This region is investigated by a suit of probe heads measuring profile properties as well as characterizing turbulence in the SOL and island region. In the shear layer those measurements are continued by poloidal correlation reflectometry. Measurements of quasi coherent modes are reported in the shear layer located in the plasma edge. Furthermore a low frequency mode in plasmas with an edge iota of $\iota = 1$ are observed which show a modulation of the plasma flow as well.

During scans of the edge iota, plasmas with an increased diamagnetic energy due to variations in the positioning of the 5/5 island chain gained large interest. In these plasmas a low frequency modulation of the plasma rotation is observed, interrupted by fast events in the plasma current. Transient high frequency events in the range of $800\ kHz - 1000\ kHz$ precede the observation of spikes in the plasma current signal.

P 4.2 Tue 11:30 H5

Analytical model for collisional impurity transport covering all collisionality regimes — •Daniel Fajardo[1,2], Clemente Angioni[1], Patrick Maget[3], Pierre Manas[3], and the ASDEX Upgrade Team[1] — [1]Max-Plack-Institut für Plasmaphysik, Garching, Germany — [2]Technische Universität München, Munich, Germany — [3]CEA/IRFM, Saint Paul-lez-Durance, France

In tokamak plasmas, collisional transport of impurities can be dominant over turbulent transport, particularly for heavy impurities. A recent analytical model for the Pfirsch-Schlüter (PS) flux, including the self-consistent coupling to the poloidal density distribution [P. Maget et al, Plasma Phys. Control. Fusion 62 (2020) 105001], is extended to cover all collisionality regimes, relaxing the condition of main ions in the deep banana regime. Additionally, a fully analytical model for the Banana-Plateau (BP) flux was developed, completing the neoclassical flux. This new model is compared to the drift-kinetic code NEO and the fluid code NCLASS, showing agreement with NEO on broad scans in collisionality, trapped particle fraction, charge and mass. A change in magnitude and even in sign in the temperature screening effect at the transition between the BP and PS regimes is identified and well reproduced. Radial profiles of transport coefficients are calculated for ASDEX Upgrade experimental profiles and ITER and DEMO predicted profiles, and successfully compared to NEO and NCLASS. This model is suited for fast integrated modelling applications due to its low computational cost.

P 4.3 Tue 11:45 H5

Impurity transport studies on Wendelstein 7-X by Tracer-Encapsulated Solid Pellets (TESPEL) — •René Bussiahn[1], Naoki Tamura[2], Kieran McCarthy[3], and the W7-X team[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald, Germany — [2]National Institute for Fusion Science(NIFS), Toki, Japan — [3]Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas

During OP1.2b operation phase of the stellarator Wendelstein 7-X, the TESPEL injections have proven successfully as a complementary tool to Laser-Blow-Off (LBO) for impurity transport studies. Contrary to LBO - depositing tracers close to the plasma edge which are subsequently transported and spread out into the plasma, TESPEL can release the embedded impurity tracers instantly after the ablation of the protecting polystyrene shell in the core of the plasma within a well defined spatial region of a few cm^3. The deposited tracers are localized within the plasma from time-of-flight measurements. The temporal dynamics of the shell ablation is well reproduced by neutral gas shielding models. This confirms the applicability of the tracer localisation method. The spectral line emission time-traces of various tracer ion charge states show distinct differences between LBO and TESPEL, especially in their initial phase. Later, the curves are similar and the related impurity decay times are inversely proportional to the heating power. First impurity transport studies by means of the code STRAHL resulted in a good reproduction of the line emission time-traces and confirm the important role of anomalous transport in W7-X, as reported for LBO injections before.

P 5: Poster I

Time: Tuesday 14:00–16:00 Location: P

P 5.1 Tue 14:00 P

Introduction of quasilinear transport models to the Integrated Data Analysis framework — •Michael Bergmann, Rainer Fischer, and Frank Jenko — Max-Planck-Institute für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Combining the analysis of multiple diagnostics, well-chosen priors and Bayesian probability theory the Integrated Data Analysis (IDA, see [Fischer 2010]) is capable of providing density and temperature radial profiles of fusion plasmas. These profiles are then used for further analysis such as the simulation of discharges. Since IDA considers uncertain measurement data from a heterogeneous set of diagnostics but no transport physics, the estimated profiles and their gradients can be in contradiction to the profiles from transport solvers. Using transport solvers such as QLK and their much faster neural network models e.g. QLKNN we have created a loop in which simulated profiles are fed back into IDA as another prior thus providing constraints about the physically reasonable parameter space. This work feeds into a broader effort to make IDA more robust against measurement uncertainties by combining multiple transport solvers with different accuracies and computing costs in a multi-fidelity approach.

P 5.2 Tue 14:00 P

Dynamic structure factor of the magnetized one-component plasma — •Hanno Kählert — Christian-Albrechts-Universität zu Kiel, ITAP, Leibnizstr. 15, 24098 Kiel

Magnetized plasmas are known for a multitude of different wave modes. In this contribution, the focus is on the effect of strong particle interactions on waves in the magnetized one-component plasma. In particular, the dynamic structure factor is computed from molecular dynamics simulations. Collective modes that occur in a weakly coupled state are traced as the system enters the strong coupling regime. The resulting modification of the mode spectrum is studied for a variety of different magnetization parameters. The simulation results are complemented by analytical results for the dynamic structure factor of a magnetized plasma.

P 5.3 Tue 14:00 P

Ab Initio Plasmon Dispersion of the Warm Dense Electron Gas — •Paul Hamann[1], Tobias Dornheim[2], Jan Vorberger[3], Zhandos Moldabekov[2], and Michael Bonitz[1] — [1]Christian-Albrechts-Universität zu Kiel, Germany — [2]Center for Advanced Systems Understanding, Görlitz, Germany — [3]Helmholtz-Zentrum Dresden Rossendorf, Germany

The plasmon dispersion ω(q) and damping γ(q) contain important information on the state of warm dense matter. On the other hand, x-ray Thomson scattering (XRTS) experiments provide accurate data for the dynamic structure factor S(q, ω) that is directly linked to the plasmon spectrum [1]. However, details of this link depend on the quality of the theoretical model for the dielectric function. Here we present the first ab initio data for the dielectric function that is obtained by quantum Monte Carlo simulations [2]. This allows us to obtain high quality results for ω(q) and γ(q) of the electron component at warm dense matter conditions that differ significantly from previous models. Second, we critically analyze the commonly used weak damping approximation for the dispersion and improve it by performing the analytic continuation of the retarded dielectric function. This yields results that apply at strong damping and large wave numbers as well, which is the basis for a more accurate comparison with XRTS experiments [3].

[1] Glenzer et al., Phys. Rev. Lett.98, 065002 (2007) [2] Dornheim et al., Phys. Rev. Lett.121, 255001 (2018) [3] Hamann et al., Contrib. Plasma Phys.60, e202000147 (2020)

P 5.4 Tue 14:00 P

Full-6D Kinetic Simulations of Magnetically Confined Plasmas — •Mario Räth, Klaus Hallatschek und Katharina Kormann — Max Planck Institute for Plasmaphysics, Garching bei München, Germany

With the increase in computational capabilities over the past years it is possible to simulate more and more complex and accurate physical models. Gyrokinetic theory was introduced in the 1960s and 1970s to describe a plasma more accurately than with fluid equations, but still eliminate the complexity of the fast gyration about the magnetic field lines. 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 has been shown in the non-linear saturation phase. The presence of such waves provide a first insight into physics beyond gyrokinetic theory.

P 5.5 Tue 14:00 P

A research data management workflow for applied plasma science — •Markus M. Becker[1], Ihda Chaerony Siffa[1], Hans Höft[1], Fabian Hoppe[2], Detlef Loffhagen[1], Nick Plathe[1], Harald Sack[2], Volker Skwarek[3], Tabea Tietz[2], Simon Tschirner[3], and Laura Vilardell Scholten[1] — [1]Leibniz Institute for Plasma Science and Technology (INP) — [2]FIZ Karlsruhe – Leibniz-Institut für Informationsinfrastruktur — [3]Hamburg University of Applied Sciences

The necessity and potential of systematic archiving and publication of digital research data is currently a hot topic in the scientific landscape, due to various benefits such as ensuring reproducibility of research results and providing the basis for data-driven science. This requires measures to ensure data quality and particularly a documentation of stored data by means of metadata, which is understandable to both humans and machines. Machine-actionable metadata is not only important for findability and interoperability of the data but also enables automated data processing. This contribution introduces a workflow for data and metadata, which uses programmatic data aggregation, electronic lab notebooks, ontology-based metadata, and blockchain protocols for partly automated processing and documentation of raw data as well as quality assured data publication, respectively. The practical relevance of the suggested (meta)data workflow is demonstrated at the example of highly resolved current measurements for pulsed dielectric barrier discharges in a nitrogen-oxygen gas mixture.

This work was supported by the BMBF under grants 16QK03A, 16QK03B, 16QK03C and the DFG under grant 408777255.

P 5.6 Tue 14:00 P

Optische Manipulation von Mikropartikeln in einer kapazitiv gekoppelten Zwei-Frequenz-Entladung — •Jessica Schleitzer, Viktor Schneider und Holger Kersten — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität Kiel, Leibnizstr. 19, 24108 Kiel, Deutschland

Innerhalb der letzten Jahrzehnte wurde die Idee umgesetzt, extern injizierte, kleine Mikropartikel als nicht-invasive Sonden zu verwenden, die durch verschiedene Kräfte und Energieflüsse im Plasma beeinflusst werden. In dieser Arbeit werden optisch eingefangene Mikropartikel in einer optischen Pinzette verwendet, um die Randschicht einer Zwei-Frequenz-CCRF-Entladung zu untersuchen. Diese Entladung ist vornehmlich für ihre Besonderheit bekannt, den Ionenfluss und die Ionenenergie getrennt und unabhängig voneinander unter Ausnutzung elektrischer Asymmetrien im Plasma zu beeinflussen. Die Messgröße, welche bei der Verwendung optischer Pinzetten von besonderer Bedeutung ist, ist die äußere Kraft, die auf die Mikrosonde einwirkt. Diese erhält man, indem die Verschiebung des Partikels in der optischen Falle gemessen wird, während die eingefangene Mikrosonde durch das Plasma und die Randschicht und damit relativ zur Entladung bewegt wird. Anhand der erhaltenen Kraftprofile wird die Stärke der elektrischen Feldkraft in der Randschicht in Abhängigkeit vom Druck, sowie die Abhängigkeit vom Abstand der Mikrosonde zur HF-Elektrode und die Ausdehnung der Randschicht bestimmt. Dies wird sowohl für eine Ein- als auch für eine Zwei-Frequenz-Entladung geprüft.

P 5.7 Tue 14:00 P

Ion flux measurements in an expanding H_2 plasma utilizing a Mach probe — •Vinzenz Wolf[1], David Rauner[1], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Density gradients and electromagnetic fields in a low pressure plasma lead to a particle flux. In order to determine the orientation and the magnitude of the ion flux, a mach probe can be used, which typically consists of a specifically arranged set of differently orientated contacts with a limited collection angle. Using the ratio of currents measured with two opposed contacts, the ion flux direction and ion velocity (i.e. the Mach number) can be calculated, the latter relying on models for calibration factors. These are used to describe the influence of the plasma parameters on the ion flow towards the probe and are thus valid for a certain set of plasma parameters.

For characterization purposes a four pin mach probe is used in a cylindrical ICP discharge (1 MHz, 2 - 8 Pa, 200 - 800 W), consisting of a quartz glass tube (Ø 9 cm) where a hydrogen plasma is generated and expands into a stainless steel chamber (Ø 32 cm). The ion flux is determined in a two-dimensional section perpendicular to the cylinder axis of the plasma vessel. The influence of a variation of gas pressure and RF power on the ion flux is investigated, as well as plasma drifts induced by applying an external magnetic field in the expansion region.

P 5.8 Tue 14:00 P

Nitrogen-doped $NiCo_2O_4$ on carbon paper as a self-supported air cathode for Rechargeable Zn-air batteries — •He Li, Jan Benedikt, and Sadegh Askari — Institute of Experimental and Applied Physics, Kiel University, Germany

A noble-metal-free bifunctional oxygen evolution/reduction catalyst with outstanding activity and stability is of great importance for the development of rechargeable Zn-air batteries. $NiCo_2O_4$, a typical spinel oxide, is considered as one of the most promising bifunctional catalyst, but the electrocatalytic performance of this material is still unsatisfactory due to its poor conductivity and low surface area. Herein, we report an effective way to fabricate nitrogen-doped $NiCo_2O_4$ on carbon paper as a binder-free air cathode for rechargeable Zn-air batteries. After nitrogen plasma treatment, this modified material exhibits higher electrocatalytic performance than pristine $NiCo_2O_4$ because of the enhanced conductivity and more active sites. Both the liquid-state and the flexible all-solid-state Zn-air batteries with engineered nitrogen-doped $NiCo_2O_4$ show high operating potentials and excellent stability. This work provides an efficient and reliable approach for the modification of self-supported catalysts, thereby contributing to the development of rechargeable Zn-air batteries.

P 5.9 Tue 14:00 P

ZrO2 based layers investigated by the 3ω method — •Vitali Bedarev, Philipp A. Maass, Marina Prenzel, Marc Böke, and Achim von Keudell — Experimental Physics II, 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 and can be used for galvanic isolation. 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 a 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 thermal conductivity of the sample. 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 5.10 Tue 14:00 P

Terahertz time-domain spectroscopy as a novel plasma diagnostic — •Jente Wubs, Klaus-Dieter Weltmann, and Jean-Pierre van Helden — Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany

In non-thermal plasmas, electrons determine, to a large extent, the plasma chemical behaviour, meaning that electron density measurements are crucial for understanding plasma chemical phenomena. In the case of low-pressure plasmas, Langmuir probes are commonly used for determining electron-related plasma parameters. However, at atmospheric pressure, these probes can no longer be reliably used due to their perturbative characteristics. Terahertz time-domain spectroscopy (THz-TDS) is a novel diagnostic technique for spectroscopic investigations of plasma densities, independent of the pressure. This technique requires ultrafast femtosecond laser pulses for the generation and detection of a broadband electromagnetic signal in the THz range. The signal is sampled in the time-domain using the principle of asynchronous optical sampling (ASOPS) and is subsequently Fourier transformed to obtain spectral information, with a resolution of 1 GHz. This approach allows for electron density measurements with high temporal resolution, whilst simultaneously yielding information on molecular densities within the plasma. This contribution explains the working principle of ASOPS-based THz-TDS. In addition, an exploratory characterisation of the experimental setup will be presented, including an overview of the possibilities and limitations for measuring with spatial resolution.

P 5.11 Tue 14:00 P

Quenching microwave plasmas via gas injection into the effluent: Effects on the conversion of CO_2 — •Christian Karl Kiefer[1], Ante Hecimovic[1], Federico Antonio D'Isa[1], and Ursel Fantz[1,2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]University of Augsburg, 86159 Augsburg, Germany

Negative-emissions technologies are required to reach the goal of the Paris Agreement that limits the global mean temperature increase to a maximum of 1.5°C. A plasma torch powered by 2.45 GHz microwaves offers a unique possibility to be used as a power-to-gas technology and thermally dissociate CO_2 into carbon monoxide and oxygen at high energy efficiencies. Very fast cooling of the plasma is essential to prevent recombination reactions towards CO_2, thereby maintaining the degree of conversion. For this purpose, an extension for the microwave plasma torch was developed that allows one to inject colder (room temperature) gases into the effluent of the plasma via four radial gas inlets. Experiments with atomic (He or Ar) as well as molecular (N_2 or CO_2) gas admixture were performed in the pressure range of 100 mbar up to atmospheric pressure, covering regimes of diffuse plasma as well as regimes of contracted plasma. The conversion of CO_2 was measured by the application of a mass spectrometer. To further characterize the setup, optical emission spectroscopy was used to determine the rotational and vibrational temperatures of the plasma.

P 5.12 Tue 14:00 P

Electrical characteristics of a coaxial dielectric barrier discharge for CO2 splitting at elevated pressure — •Rezvan Hosseini Rad, Milko Schiorlin, Michael Schmidt, Volker Brüser, and Ronny Brandenburg — Leibniz Institute for plasma science and technology, Greifswald, Germany

CO2 splitting using nonthermal plasmas is investigated for CO2 utilisation into valuable chemical compounds like methanol. In this work, an asymmetric, coaxial dielectric barrier discharge reactor for CO2 decomposition into CO is investigated. Beside the operation at atmospheric pressure, the effect of an increase up to 1.6 bar is studied. At first, the operation parameters for a full discharging in the reactor has to be carried out to keep the operating voltage amplitude moderate (below 10 kV) at elevated pressures. So, the electrical characteristics of the plasma reactor with three different inner electrode materials (stainless steel, copper, and aluminium) and with the addition of argon as an inert, electropositive gas with lower breakdown voltage than CO2 are studied in detail, and correlated with the CO formation. The discharge power, effective capacity, burning voltage, and area fraction covered by plasma in the reactor are determined by voltage-charge plots. The addition of Ar to CO2 (ratio Ar:CO2 =4:1) reduces the sustaining voltage and enables full plasma coverage in the reactor with voltage amplitudes below 10 kV even at the highest pressure. Increasing pressure or decreasing the argon admixture decreases the current peaks intensity as well as the discharge power. Stainless steel shows higher CO2 conversion, but copper shows higher CO generation.

P 5.13 Tue 14:00 P

Cold Atmospheric Plasma Sterilization for Planetary Protection — •Alisa Schmidt[1], Meike Müller[2], Markus H. Thoma[1], and Hubertus Thomas[2] — [1]I. Physikalisches Institut, Justus-Liebig-Universität, Gießen, Germany — [2]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt e.V., Oberpfaffenhofen, Germany

In the search for extraterrestrial life, decontamination of the surface of spacecraft and lander is of great importance. Since currently used methods - dry heat and hydrogen peroxide - are effective but material damaging for sensitive surfaces, in this contribution the application of cold atmospheric surface micro-discharge (SMD) afterglow plasma sterilization for spacecraft decontamination was investigated. Inactivation tests were performed with Bacillus atrophaeus spores on stainless steel carriers placed at the bottom of stainless steel tubes with varying heigths and diameters. It could be shown, that spore inactivation was achieved inside the tubes but much slower than outside at a treatment time of 60 min. Furthermore, the height of the diffusion barriers did not result in significant differences in inactivation rates but with increasing diameter the sporicidal effect increased respectively. By operating a fan to circulate the gas in the treatment chamber, higher inactivation rates could be achieved at unchanged treatment times. Moreover, it could be demonstrated, that the method of applying spores to the sample carrier influences the inactivation rate of the plasma treatment.

P 5.14 Tue 14:00 P

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

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 and admixture of different reactive gases.

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.

P 5.15 Tue 14:00 P

Self-similar expansion of a plasmoid supplied by pellet ablation — •Alistair Arnold, Pavel Aleynikov, and Per Helander — Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald

Cryogenic pellet injection is an important means of refuelling and terminating fusion plasmas, with fuel pellets exhibiting a range of phenomena beneficial to confinement and the energy balance between ions and electrons. We consider the self-similar expansion along magnetic field lines of the plasmoid produced by a small pellet. In particular, we consider the case when the expansion timescale is comparable to the time taken for the pellet gas cloud to cross a field line. It is shown that plasmoid ions acquire a significant fraction of the energy that is transferred to plasmoid electrons via collisions with the ambient plasma. This expansion is insensitive to the details of the profile of the gas cloud and details of ionisation - the plasma flux emerging from the gas cloud is the only quantity that affects the expansion.

P 5.16 Tue 14:00 P

Linear MHD stability analysis of pedestals in magnetically perturbed tokamak equilibria — •Jonas Puchmayr[1,2], Mike Dunne[2], Erika Strumberger[2], and Hartmut Zohm[2] — [1]Department of Physics, Ludwig-Maximilians-Universität, Schellingstr. 4, 80799 München, Germany — [2]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

In the regime of high confinement (H-mode), a region of self-organized suppression of turbulent transport at the plasma edge forms resulting in steep gradients of pressure, temperature and density evolve. The edge gradients provide free energy for a new type of instability, Edge Localized Modes (ELMs). These instabilities are well-described by linear MHD and can be identified as coupled peeling-ballooning modes. Experimentally, ELMs cause large quasi-periodic bursts of particle and energy loss, that will lead to severe damage in future fusion devices. For this reason, control of ELMs is inevitable for H-mode operation in future machines. Resonant magnetic perturbation (RMP) fields are observed to mitigate or suppress ELMs. These perturbation fields break the axisymmetry of tokamak equilibria, resulting in weakly 3D configurations.

In this work, the code CASTOR3D is used to study (non-)ideal MHD stability of weakly 3D tokamak equilibria. Toroidal mode coupling is observed and the ideal MHD energy functional, which is newly implemented in CASTOR3D, is used to analyze the eigenfunctions and understand the change that the 3D structure has on stability.

P 5.17 Tue 14:00 P

Challenges and expectations for the magnetic diagnostics during high-performance experiments at Wendelstein 7-X — •K Rahbarnia[1], S Vaz Mendes[1], J Schilling[1], H Thomsen[1], J Schmitt[2], M Khokhlov[1], T Bluhm[1], B B Carvalho[3], M Zilker[1], and Wendelstein 7-X Team[1] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Auburn University, Auburn, AL, USA — [3]Instituto de Plasmas e Fusao Nuclear Instituto Superior Tecnico, Lisbon, Portugal

During the last experimental campaign at the Wendelstein 7-X stellarator the magnetic diagnostics were successfully operated. That involves equilibrium sensors, such as Rogowski coils, diamagnetic and saddle loops as well as Mirnov coils. The latter were used to study magnetohydrodynamic activity, which was mainly found within the frequency range up to 400 kHz and is of Alfvénic nature. Identifying their driving mechanism is crucial to understand the influence on plasma confinement properties. The measured data of the equilibrium sensors are suitable for equilibrium reconstructions, which are also relevant for the previously mentioned studies. In addition plasma energy and current measurements are directly embedded in machine safety systems, like the plasma heating interlock, and will in future campaigns also be integrated in the quench detection system. Fast and potentially critical plasma collapses are tracked and the impact on the main magnetic field coil system can be analysed. For future high-performance experiments electrical and mechanical improvements were implemented including an upgrade of the DAQ systems.

P 5.18 Tue 14:00 P

Characterization and driving mechanisms of dominant Alfvén eigenmodes at the W7-X Stellarator — •Sara Vaz Mendes, Kian Rahbarnia, Christoph Slaby, Thomsen Henning, Jonathan Schilling, Christian Brandt, Matthias Borchardt, Ralf Kleiber, and Axel Könies — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

Electromagnetic Alfvén waves are often present in different scenarios of the W7-X stellarator plasmas. Induced magnetic fluctuations (between 100-450 kHz) were observed for 727 discharges during different magnetic configurations, heating scenarios and general plasma parameters. The measurements were performed using a system of 125 Mirnov coils, located in four out of five modules of W7-X.
The Alfvénic nature is proven through the scaling of dominant magnetic fluctuation frequencies with the plasma density. In addition, the correlation of the observed Alfvénic activity with different plasma parameters is being analyzed.
In the future operation of W7-X a bigger population of energetic particles (EPs) is expected and the possible resonant wave-particle transport of EPs must be avoided since it can result in degradation of plasma confinement or even damaging of plasma facing components. To better understand these risks the conditions for enhanced Alfvénic activity at W7-X are studied and possible driving mechanisms are discussed.

P 5.19 Tue 14:00 P

Development of a model based early heating advanced scenario for ASDEX-Upgrade — •Raphael Schramm, Alexander Bock, Maximilian Reisner, Jörg Stober, Hartmut Zohm, and The ASDEX Upgrade Team — Max-Planck Institut für Plasmaphysik, Garching, Germany

Advanced Tokamak scenarios offer improved stability, confinement and pulse length compared to standard scenarios due to an increase of the plasma's bootstrap current ($j_{bs} \propto q\nabla p$). They are accessed by manipulating the safety factor profile q through external actuators, which can be applied during the current ramp-up (early heating), or after an equilibrium is reached (late heating). The former allows for a longer discharge and more varied current distributions, but due to the volatility of the early plasma, creating such a scenario experimentally, with feed-forward control usually takes a lot of trial and error.

To combat this, a model, capable of predicting the plasma response to actuator changes with reasonable accuracy and a run-time of only a few minutes, has been developed in the transport code ASTRA. It includes Gyro-Bohm based core transport, edge transport according to a recently developed scaling law as well as the L/H-transition based on the heating power at the separatrix. Multiple fitting factors have been scaled according to a set of reference discharges and a good agreement between simulation and experiment has been achieved.

Using this model, an advanced scenario with early heating and an elevated q-profile has been developed and successfully tested at ASDEX-Upgrade.

P 5.20 Tue 14:00 P

Statistical analysis of confinement data from pellet fueled high-density plasmas in ASDEX Upgrade — •Tobias Engelhardt[1], Peter Lang[2], Martin Prechtl[1], and ASDEX Upgrade Team[2] — [1]Hochschule Coburg — [2]Max-Planck-Institut für Plasmaphysik

A dataset of pellet-fueled discharges in the high density regime of ASDEX Upgrade (AUG) has been collected, covering 8 years of operation. It comprises scenarios with moderate performance, as well as attempts to achieve high performance by applying either N-seeding or high shaping. This data show that the H06 scaling [1] is more appropriate to describe plasma confinement in this regime, than the H98(y,2) scaling [2]. Additionally, the enhanced confinement gained by the different methods cannot be maintained when the density n_e exceeds the Greenwald density n_{Gw}.
According to observations at JET (with carbon wall), see e.g. [3], higher H-factors (H98(y,2)) at constant n_e/n_{Gw} were observed when the triangularity δ was increased. Whether this trend is also present at AUG (with tungsten wall and- divertor) will be investigated. The reduction of confinement when exceeding n_{Gw} can possibly be attributed to a rising separatrix density $n_{e,sep}$. The assumption that primarily the divertor density n_0^{Div} influences $n_{e,sep}$, may turn out to be too shallow. Therefore, potential other correlations between $n_{e,sep}$ and several other plasmaphysical parameters are planned to be analysed.
[1] Johner, FST **59** (2011), 308; [2] IPB, NF **39** (1999), 2175;
[3] Mukhovatov, PPCF **45** (2003), A235

P 5.21 Tue 14:00 P

Effects of thin surface oxide films on deuterium uptake in self-damaged tungsten - Evidence for permeation barrier effect — •Kristof Kremer[1,2], Thomas Schwarz-Selinger[1], and Wolfgang Jacob[1] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Deutschland — [2]Physik-Department E28, Technische Universität München, 85747 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 in W through 33 and 55 nm thick oxide films. To trace the D, a 2 μm thick layer of self-ion-damaged W was created underneath the oxide. It acts as a getter layer and traps any D that permeates the oxide film. The sample was then exposed to a "gentle" D plasma (<5eV/D ion) at 370 K to a fluence of 10^{24} D/m^2. We measured the depth-resolved concentration of D and oxygen with nuclear reaction analysis and Rutherford backscattering spectroscopy and the surface modifications of the oxide film with scanning electron microscopy.

We observed a strong influence of surface oxide films on D uptake, i.e., the oxide films completely block D uptake into metallic W, although high D concentrations were found in the oxide film itself. We explain this by the difference in the heat of solution between W oxide and metallic W.

P 5.22 Tue 14:00 P

Comparing ion energy distributions of a symmetric capacitively coupled plasma with 1D-PIC/MCC simulations: an alternative approach to estimate γ coefficients? — •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 Center for Physics, Hungary

Secondary electron emission (SEE) is an important effect since it directly influences not only the plasma ignition but also the plasma properties. Changes in plasma properties can be utilized to estimate SEE coefficients under realistic conditions for example from the I-V-characteristics of magnetron discharges [D Depla et al 2008 J. Phys. D: Appl. Phys. **41** 202003]. But plasma density, plasma potential and sheath thickness also have an impact on the ion transport through the sheath and on the ion energy distribution function (IEDF). Here, we critically discuss potentials and challenges of using energy resolved ion mass spectrometry measurements of IEDFs and their comparison to 1D-PIC/MCC simulations for the estimation of SEE coefficients.
Two identical symmetric capacitively coupled plasma (CCP) electrodes

are coated with Al and Al_2O_3, respectively, to investigate the impact of changed surface properties on the IEDF of Ar^+ ions. Since pressure, electrode distance and neutral gas temperature can have a similar impact on the IEDF as the SEE coefficient, their impact on the IEDFs need to be analyzed and they need to be determined with sufficient precision to avoid systematic errors.

P 5.23 Tue 14:00 P

Optimisation and characterisation of an ion-beam-driven permeation experimental setup — •Philipp Sand[1,2], Armin Manhard[1], Rodrigo Arrendondo Parra[1], and Udo von Toussaint[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Technical University Munich, 85748 Garching, Germany

Hydrogen permeability is an important property for many materials in future technologies such as, e.g., nuclear fusion. One method to determine permeation properties is to implant deuterium ions from a mass-filtered ion beam with a well-defined flux and energy into a sample foil. At the rear side of the foil, the effusion flux of the permeating species is then measured by a quadrupole mass spectrometer. The ion optics of such a setup is characterised for a 4.7 keV D_3^+ ion beam. The ions are decelerated by the sample bias voltage to implantation energies of 500 eV per D. The settings are optimised in order to obtain a high ion current to reach reasonable signal intensities and affordable experiment times. Another goal for the optimisation is to minimise the flux of charge exchange neutrals, which are created in the beamline. They will not be decelerated by but impinge on the sample with their full energy. They lead to degradation of the sample material due to displacement damage and sputtering and can also affect the permeation signal. The neutral fraction can potentially be minimised by electrostatically deflecting the beam after passing the volume of highest neutral generation rate. Photographs of the beam footprint are obtained using ion-induced fluorescence on a quartz plate.

P 5.24 Tue 14:00 P

Spectroscopic investigation of W7-X detachment induced via nitrogen seeding — •Frederik Henke, Maciej Krychowiak, Ralf König, Felix Reimold, Dorothea Gradic, and Thomas Sunn Pedersen — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

As power exhaust is one crucial aspect of a future fusion power plant, dissipation of the localized heat fluxes striking the divertor is needed. The regime, in which a large fraction of the input power is radiated isotropically into full solid angle while the peak heat- and particle-fluxes to the target are strongly reduced, is called detachment.
Stable detachment is accessible via two different paths in the island divertor of W7-X. First, increasing the density via hydrogen fueling can lead to the transition into the detachment regime with carbon as the intrinsic impurity being the main radiator. Because in a future power plant carbon will not be used at any first wall components due to strong tritium retention, extrinsically seeded low-Z impurities are investigated as the second way to reach detachment.
In this work nitrogen seeding experiments are analyzed applying a spectroscopic line-ratio model of singly ionized nitrogen to measure the local plasma parameters electron density n_e, electron temperature T_e and impurity concentration c_Z. From the analysis of data acquired in the previous operation campaign possible upgrades of the diagnostic, as well as extensions of the physics model to i.e. analyse carbon radiation are explored.

P 5.25 Tue 14:00 P

Determination of (quasi) coherent mode properties at the edge of improved confinement plasmas — •Joey Kalis[1,2], Gregor Birkenmeier[1,2], Michael Griener[2], Peter Manz[3], Takashi Nishizawa[2], Luiš Gil[4], and Ulrich Stroth[1,2] — [1]Physik-Department E28, TUM, Garching — [2]Max-Planck-Institut für Plasmaphysik, 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 the high confinement modes without type-I ELMs. In the past years, several natural ELM-free operation scenarios, such as the EDA H-mode, the I-mode and the QH-mode, have been achieved in ASDEX Upgrade. Each scenario is characterized by the appearance of quasi coherent fluctuations at the plasma edge, which may be responsible for the stabilization of the ELMs. For the comparison with theory, it is important to analyze the properties of all edge modes in more detail to identify their underlying driving forces and outline possible similarities and differences. The first focus is on the quasi-coherent mode (QCM), being present in the EDA H-mode. Due to its high spatial and temporal resolution, the He-beam diagnostic is used to outline different QCM properties. First, a time series analysis is performed to investigate the interaction of the QCM with other modes and general plasma parameters. Second, the propagation velocity and the wavenumber of the QCM is determined by means of spectral methods and compared with theoretical predictions.

P 5.26 Tue 14:00 P

Characterization of lanthanum-hexaboride electron emitters as cathodes in pressure gauges for strong magnetic fields — •Bartholomaeus Jagielski, Uwe Wenzel, Mirko Marquardt, Jiawu Zhu, and Thomas Sunn Pedersen — Max Planck Institute for Plasma Physics, Greifswald, Germany

In order to evaluate the particle exhaust rate at the sub-divertor, the neutral gas pressure can be measured. In the last operation phase (OP 1.2) of the Wendelstein7-X (W7-X) nine newly developed Crystal Cathode Pressure Gauges (CCPG) were tested during pressure recordings. While cathodes from thoriated tungsten regularly bent under the influence of the j x B forces (2,1T), the CCPGs, equipped with emitters made of lanthanum hexaboride, functioned satisfactorily[1]. The LaB_6 cathodes of the CCPGs have a simple geometry and due to the low work function of 2.5eV, the heating current was reduced to 2-3 A in W7-X in hydrogen atmosphere, whereby the stress under Lorentz forces was further reduced[2]. This makes the LaB_6-emitter a promising candidate for precise manometers in a range between 10^{-6} and 1mbar and an application in future fusion plants (ITER, DEMO).

Recently three different cathode designs have been tested in different environmental conditions and compared: a 8mm and a 6mm long cathode, and a new 2-emitter design. Results of the investigations within an external magnetic field of 3T, latest optimization and future plans for the CCPGs are presented.

[1] U. Wenzel et al, J. Instrum.12(09), C09008 (2017).
[2] U. Wenzel et al, Rev. Sci. Instrum., 90, 123507 (2019).

P 5.27 Tue 14:00 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. Most of 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. For the confined region a first experimental case has been matched by using both core and edge models. Fully integrated simulations during ramp-up, flat-top and ramp-down are planned for the future.

P 5.28 Tue 14:00 P

Structure-property relations for thin drawn tungsten wires — •Maximilian Fuhr[1,2], Bailey Curzadd[1,2], Batuhan Sancak[1,2], Till Höschen[1,2], Martin Balden[1], Wolfgang Pantleon[3], Jürgen Almanstötter[4], Johann Riesch[1], and Rudolf Neu[1,2] — [1]Max-Planck-Insitut für Plasmaphysik, Garching, Deutschland — [2]Technische Universität München, Garching, Deutschland — [3]Technical University of Denmark, Lyngby, Dänemark — [4]OSRAM GmbH, Schwabmünchen, Deutschland

Tungsten (W) shows a ductile-to-brittle transition and fractures brittle below, but ductile above a certain transition temperature. This transition temperature, which is far above room temperature for coarse-grained W, can be shifted towards lower temperatures by wire drawing or other working processes. Wires drawn to very small diameters can deform ductilely at room temperature. The correlation between plastic deformation and the shift of the transition temperature is not fully understood, but the microstructure is thought to play a crucial role. In order to gain further insight into the open question of the enhanced ductility of worked tungsten, we investigated the mechanical properties (via uniaxial tensile testing) and microstructure (by EBSD) of four chemically identical wires drawn to diameters between 16 μm and 490 μm. Thorough quantitative analysis reveals the strong influence of the particular microstructure of the wires consisting of highly elongated grains with strong {110} fiber texture on their mechanical behavior and allow for formulating structure-property relations.

P 5.29 Tue 14:00 P

Heat conduction simulation in plasmas with magnetic field lines of mixed topology — •Gregor Pechstein, Brendan Shanahan, and Per Helander — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald

Fusion devices must dissipate heat before it reaches the plasma-facing components. For this purpose the W7-X stellarator relies on a chain of magnetic islands close to the plasma edge channelling the plasma to a divertor. Detachment, a scenario in which energy is radiated due to collisions with neutrals, is a promising method for reducing heat flux onto the divertor. First divertor experiments on W7-X exhibit stable detachment, whose main features are reproduced by the EMC3-Eirene edge transport code. With an increase in the radiated power fraction the position of the radiation front approaches the X-point and the separatrix of the magnetic islands. Here we seek to understand the stability and position of the detached radiation front using a heat conduction model. In contrast to 1-d analytical heat conduction models used in Tokamak divertors, perpendicular transport cannot be ignored in the islands of W7-X. The importance of transport perpendicular to the magnetic field is due to the long connection lengths in the islands. Accordingly, we perform 2-d heat conduction simulations in slab geometry with an island. These simulations employ a simplified radiation function as a heat sink. Depending on the parameter varied the radiation front exhibits different patterns and stability. Concomitant to the simulations, analytical limits of the parameter space are investigated. The implications for stable detachment in W7-X will be discussed.

P 5.30 Tue 14:00 P

PIC-Simulations of Perpendicular Collisionless Shocks in Multiple-Ion GRB Plasmas — •Jonas Graw, Martin Weidl, and Frank Jenko — Max Planck Institute for Plasma Physics

Ultra-high-energy cosmic rays (UHECRs) are electrically charged particles, which move throughout the universe with energies greater than about 1 EeV. Understanding where and how these particles are created, i.e., unravelling the nature of cosmic accelerators, is one of the biggest challenges in present-day astrophysics. One likely source of UHECRs are gamma-ray burst (GRBs). 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. Presently, we examine both real and phase space and we explore how the highest energetic particles behave in such a plasma. We analyze different modes that both come from analytical considerations and simulations. Particularly interesting are the modes that do not exist in an electron-proton plasma. The acceleration of UHECRs is thereby strongly connected to particle-wave interactions inside the plasma. In our analysis, we deepen the understanding of the nature of possible acceleration mechanisms.

P 5.31 Tue 14:00 P

Current Filamentation Instabilities of Proton Beams in Proton Driven Wakefield Accelerators — •Erwin Walter[1], Martin S. Weidl[1], John P. 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. However, for alternative beam parameters, the electromagnetic Weibel-like beam filamentation instability could result in magnetic field amplification, perpendicular scattering, emittance growth and possibly even the formation of a collisionless shock.

Our research investigates which beam parameters are required for filamentation to dominate and whether this parameter regime is accessible to the AWAKE experiment. We present and compare results of linear theory, quasi-static simulations and full-PIC simulations.

P 5.32 Tue 14:00 P

Generalized Fluid Models for Edge Turbulence Simulations — •Christoph Pitzal, Andreas Stegmeir, and Frank Jenko — Max Planck Institute for Plasma Physics, Garching, Germany

Fluid models are a useful tool for simulations in the field of Plasma Physics. On the one hand, fluid models are less computationally intense than kinetic models. On the other hand, the models have limited predictive capabilities, since not all effects are captured, that 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. Every fluid model introduces a hierarchy of moments, which connects a fluid moment with the next higher one and needs to be closed for the model to become applicable. Models with a collisional closure, as the Braginskii model [1], significantly overestimate for example the parallel heat conductivity due to the absence of Landau damping. By using particular closure approximations instead of the commonly used collisional closure the model can mimic certain kinetic effects, as first shown with Landau damping in [2]. The scope of this project is to study different kinetic effects and their applicability for current plasma fluid codes, such as GRILLIX [3]. Further steps will be the implementation of such a model and to compare the increase of fidelity and computational effort. [1] S. Braginskii and M. Leontovich Reviews of plasma physics, 1965. [2] G. W. Hammett and F. W. Perkins Phys. Rev. Lett., vol. 64, pp. 3019-3022, Jun 1990. [3] A. Stegmeir, A. Ross, T. Body, et al. Phys. Plasmas, vol. 26, p. 052517, 2019.

P 5.33 Tue 14:00 P

TALIF on H_2 Plasmas in Preparation of its Usage for 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) offers the possibility to measure both the velocity distribution function and the density of ground state H atoms in H_2 plasmas. Here, the atoms are excited via the simultaneous absorption of two photons followed by the emission of fluorescence which is used for diagnostic purposes. In order to generate the necessary 205.08 nm photons, a pulsed, frequency tripled dye laser is employed. In addition to the complexity of such an instrument, the diagnostic as a whole needs to be characterized thoroughly and calibration is necessary. This was done at a planar ICP where a 600 W, 13.56 MHz RF generator is used to drive H_2 plasmas. Here, TALIF is supplemented by optical emission spectroscopy on the Balmer lines and the molecular Fulcher-α transition in order to determine basic plasma parameters. The measurement results of scanning gas pressure and RF power coupled to the plasma are presented in this contribution. They are used to gain insight into the particle reactions taking place in the plasma. In addition, the implementation of TALIF at the H^-/D^- ion source BATMAN Upgrade is prepared from the knowledge that was gained at the ICP.

P 5.34 Tue 14:00 P

Performance of neutral pressure gauges using LaB6-emitters in deuterium plasmas — •Victoria Haak[1], Uwe Wenzel[1], and Gen Motojima[2] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]National Institute for Fusion Science, Toki, Japan

Neutral pressure gauges using a LaB6-crystal as an emitter, an advanced type of neutral pressure gauge optimized for the use in high magnetic fields are used to measure the neutral gas pressure in fusion experiments. They were successfully operated in hydrogen plasmas in Wendelstein 7-X (W7-X) during OP1.2b [1]. Due to the low heating current of 2-2.5 A, LaB6 neutral pressure gauges present a promising concept for measurements of the neutral gas pressure in future fusion devices. Two LaB6-neutral pressure gauges were installed and tested in the Large Helical Device for the last two campaigns in order to study the effect of neutrons on the electron emission properties of LaB6.

Both crystals showed stable electron emission during operation in hydrogen and helium atmosphere and were operated at a low heating current of 1.7 A. One of the emitters experienced an increase of the heating current from 1.7 to 4 A during deuterium operation. Apart from damage to the crystal, the neutral pressure gauge cannot be reliably used for measurements once the heating current reaches a given limit. As stability of the emission properties is essential for the use of LaB6 in neutral pressure gauges, degradation of the emission properties is studied in this contribution, in particular the role of neutron damage.

[1] U. Wenzel et al, Rev. Sci. Instrum., 90, 123507 (2019).

P 5.35 Tue 14:00 P

Generic Determination of Rotating and Locked MHD Mode Amplitudes on ASDEX Upgrade — •Felix Klossek, Marc Maraschek, Anja Gude, Hartmut Zohm, Louis Giannone, and the ASDEX Upgrade Team — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

When approaching a disruption in tokamaks, the plasma typically becomes unstable regarding a tearing mode which locks to the vessel. For the disruption to occur, multiple phase-locked tearing modes with different poloidal mode numbers m are considered necessary for producing a thermal shortcut by stochastisation. For rotating modes it has been possible for a long time to differentiate between different poloidal mode numbers at ASDEX Upgrade. Similar observations for locked modes could not be made until now, as the pick-up coils used for rotating modes rely on induction. The saddle coils used for locked mode detection are located at only one poloidal position on the high field side and therefore cannot resolve the poloidal mode numbers m.

A new method for evaluating magnetic mode signals, in particular the mode amplitude and phase, by projecting the signals on appropriate sine and cosine base vectors with the desired mode number is introduced. With this method, no compute intensive FFT algorithms are needed. For detecting the poloidal mode structure of locked modes for the first time the inactive RMP coils at ASDEX Upgrade are used in addition to the locked mode detector. It is shown that the mode structure is changed during the locking phase prior to the disruption.

P 5.36 Tue 14:00 P

Fast characterization of plasma states in W7-X with permutation entropy — •Juan Fernando Guerrero Arnaiz[1,2], Andreas Dinklage[1,2], Bernd Pompe[1], Matthias Hirsch[2], Udo Höfel[2], Christian Brandt[2], Henning Thomsen[2], Jonathan Schilling[2], Kian Rahbarnia[2], Tamara Andreeva[2], Ulrich Neuner[2], and the W7-X Team[2] — [1]Universität Greifswald, Greifswald Germany — [2]Max-Planck-Institut für Plasmaphysik, Greifswald Germany

Permutation entropy (PE) is applied on time series of plasma measurements. PE is a single number that represents the information rate to derive the ordinal properties of a time series. Here, we systematically characterize, by means of the PE, highly sampled multi-variate signals from a 32-channel electron cyclotron emission radiometer. Being capable to detect changes in bulk data, core localized spatio-temporal bifurcations of the plasma states were revealed from changes of the PE. Hereby, spontaneous transitions to high core-electron temperatures (Te) were detected at different heating powers and densities in the so-called low-iota configuration of W7-X. The transitions have been seen to go along with the occurrence of low frequency MHD activity, which ceases when Te increases. It is this MHD activity which PE is sensitive to. While visual a-posteriori inspection of the (noisy) data results in similar findings, the time to identify changes is much reduced. Therefore, PE is suggested to be employed for machine learning techniques to identify plasma state changes.

P 5.37 Tue 14:00 P

Tackling turbulence in the plasma edge pedestal with a revised version of the GENE code — •L. A. Leppin, P. Crandall, 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 a new modification of the well-established gyrokinetic, Eulerian, delta-f code GENE (genecode.org), which enables numerically stable global, electromagnetic simulations at high beta values. This new "f-version" utilizes a slightly different definition of the underlying distribution function. The new f-version is fully integrated into the GENE code and can e.g. make use of block-structured grids in velocity space, which lower the resolution requirements dramatically. We demonstrate the successful implementation and give an outlook with first applications of the new GENE f-version to the plasma edge. By simulating turbulence at different timepoints within an edge localized mode (ELM) of an ASDEX Upgrade discharge we contribute to the characterization of turbulence in the pedestal within an ELM cycle.

P 5.38 Tue 14:00 P

Collisional Relaxation of an Anisotropic Two-Species System as a Verification of a Simplified Fokker-Planck-Type Collision Operator — •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

Collisions have significant effects on the properties of edge and scrape-off-layer turbulence in magnetic confinement fusion devices. State of the art simulations of plasma turbulence are built on the gyrokinetic equations and require the addition of a so-called collision operator. The typical choice in a plasma, a Fokker-Planck collision operator does yield physically accurate results but also heavily impacts the computational performance of numerical codes. Therefore, it can be beneficial to use simplified Fokker-Planck-type collision operators that capture most of the physics and are faster to calculate. In this work, we present the Lenard-Bernstein/Dougherty (LBD) collision operator [1, 2] that has been implemented in the gyrokinetic turbulence code GENE-X [3]. We show a verification of the physics based on the collisional relaxation of an anisotropic electron-deuterium system. Further, we compare the results with analytical estimations and with results from a Bhatnagar-Gross-Krook (BGK) collision operator [4].

[1] A. Lenard, and I. B. Bernstein, Phys. Rev. 112, 1456 (1958)
[2] J. P. Dougherty, Phys. Fluids 7, 1788 (1964)
[3] D. Michels, et. al., Comput. Phys. Commun. 264, 107986 (2021)
[4] P. L. Bhatnagar, et. al., Phys. Rev. 94, 511 (1954)

P 5.39 Tue 14:00 P

Disruption simulations in ASDEX Upgrade with JOREK-STARWALL — •Nina Schwarz, Matthias Hoelzl, Javier Artola, Gabriella Pautasso, and Mike Dunne — Max Planck Institute for Plasma Physics, 85748 Garching, Germnay

During major disruptions or due to a loss of the control system in tokamaks, the plasma becomes vertically unstable and eddy currents are induced in the conducting structures and halo currents appear in the SOL. The magnitude of the resulting vertical forces have not been successfully extrapolated to reactor sized tokamaks yet [Hender2007]. Also, horizontal forces can appear, when the plasma shows asymmetric features that may rotate. To estimate the magnitude and the distribution of halo currents as well as the forces during disruptions the extended non-linear MHD code JOREK is used together with the electromagnetic code STARWALL to study the evolution of halo currents and forces during disruptions and hot VDEs in ASDEX Upgrade.

In particular, the discharge #25000 the vertical control system was intentionally shut off to produce a hot VDE and has been analyzed in detail [Pautasso2011]. This shot has been modelled before in the two dimensional codes DINA [Lukash2010] and TSC [Nakamura2010] to study the halo current magnitude during disruption following the vertical displacement. The aim of this contribution is to show first 2D calculations in JOREK to validate the magnitude of the halo currents at a given halo width and temperature. This will later be used as a basis to extend the simulation to 3D and observe non-axissymmetric effects of the plasma and halo current evolution.

P 5.40 Tue 14:00 P

Transport Studies in ASDEX Upgrad via Gaspuff Modulation Experiments — •Christian Schuster[1,2], Elisabeth Wolfrum[1], Emiliano Fable[1], Rainer Fischer[1], Michael Griener[1], Clemente Angioni[1], Ulrich Stroth[1,2], and ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching — [2]Physik-Department E28, Technische Universität München, Garching

To obtain sufficient fusion power in a future reactor, the core plasma has to be hot and dense. A large part of the radial density increase occurs at the edge of the plasma. Apart from the impact on fusion power the density profile also influences many different phenomena such as the L-H transition [Shao, PPCF 2016] or the achievable pedestal top pressure. The processes that determine the edge density profile are however still not understood sufficiently to be able to extrapolate to future devices.

Apart from particle transport, which we model by diffusion and a convection called pinch, fueling of the plasma by neutral atoms contributes to the density profile. The individual contributions cannot be distinguished by analyzing stationary profiles. We therefore modulate the gas flow and analyze the plasma response measured with various diagnostics in an integrated data approach. We find that the modulation, among other effects, causes a cold pulse whose propagation into the core can only be explained by time dependent transport models.

P 5.41 Tue 14:00 P

Impurity parallel transport in ITER using improved collisional closure in the SOLPS-ITER code — •Sergei Makarov[1], D Coster[1], V Rozhansky[2], E Kaveeva[2], I Veselova[2], S Voskoboynikov[2], I Senichenkov[2], A Stepanenko[3], V Zhdanov[3], and X Bonnin[4] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]SPbPU, St.Petersburg, Russia — [3]MEPhI, Moscow, Russia — [4]TER, St-Paul-Lez-Durance Cedex, France

Impurity transport in the Scrape-off layer of a tokamak is a challenging problem. Impurities occur in fusion plasmas naturally, for instance helium ash as a product of the D-T reaction, and artificially, 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's 21N-moment method should be used for the transport coefficients estimation. This approach takes into account 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. This approach is implemented into the SOLPS-ITER code for multiple ion parallel transport description in collisional plasmas. The change in the impurity transport behavior in ITER is studied using improved method and taking into accout masses of ions. Significant differences are found in the ion transport, where the masses of ions are not sufficiently different.

P 5.42 Tue 14:00 P

Positron accumulation in a multi-cell Penning-Malmberg trap — •Martin Singer[1], Patrick Steinbrunner[1], Stephan König[2], Matthew R. Stoneking[1], James R. Danielson[3], Lutz Schweikhard[2], and Thomas Sunn Pedersen[1,2] — [1]Max Planck Institute for Plasma Physics, Germany — [2]Institute for Physics, University of Greifswald, Germany — [3]hysics Department, University of California, San Diego, USA

Positron-electron plasmas, which are examples of pair plasmas, are just beginning to be studied experimentally. Due to their equal mass constituents, many features that are found in electron-ion plasmas will not occur in pair plasmas, and they are expected to be extraordinarily stable when magnetically confined. The APEX collaboration aims to create the first magnetically confined, low energy pair plasma with a spatial dimension of several Debye lengths so that collective behavior can be observed. To create such a plasma numerous obstacles must be overcome, since positrons are rare. One crucial challenge is the accumulation of large numbers of moderated positrons. Therefore, a device is needed which is capable of storing up to 10^{11} positrons without heating and particle loss. One solution is the multi-cell Penning-Malmberg trap (MCT) concept, which separates the space charge of the positrons into an array of small Penning-Malmberg traps. We present first measurements with electrons stored in a single Penning trap that serves as the master-cell as well as in a prototype MCT. This MCT will be used to confine plasmas simultaneously in multiple cells, to investigate the confinement and different injection and ejection schemes.

P 5.43 Tue 14:00 P

Modeling the beam emission Balmer-α spectrum in neutral beam heated plasmas at Wendelstein 7-X — •Sebastian Bannmann[1], Oliver Ford[1], Udo Höfel[1], Peter Poloskei[1], Jakob Svensson[1], Benedikt Geiger[2], and Robert Wolf[1] — [1]IPP Greifswald — [2]University of Wisconsin, Madison, US

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 focuses on the modeling of the neutral beam halo including collisional radiative processes to determine the fraction of neutrals in excited states. It is shown that the ballistic transport of halo particles can be described by a steady-state charge exchange diffusion equation. The possibility of inferring ion temperature profiles from the halo Balmer-α emission is investigated.

P 5.44 Tue 14:00 P

Proof of concept of a fast surrogate model of the VMEC code via neural networks in Wendelstein 7-X scenarios — •Andrea Merlo, Daniel Böckenhoff, Jonathan Schilling, Udo Höfel, Sehyun Kwak, Jakob Svensson, Andrea Pavone, 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 magnetohydrodynamic (MHD) model is used to self-consistently calculate the effects the plasma pressure induces on the magnetic field used to confine the plasma. The VMEC is the most widely used to evaluate 3D ideal-MHD equilibria, however, considering the computational cost, it is rarely used in large-scale or online applications. Access to fast MHD equilbria is a challenging problem in fusion research, one which machine learning could effectively address. In this work, we present artificial neural network (NN) models able to quickly compute the equilibrium magnetic field of Wendelstein 7-X. Magnetic configurations that extensively cover the device operational space, and plasma profiles with volume-averaged normalized plasma pressure $\langle\beta\rangle$ ($\beta = \frac{2\mu_0 p}{B}$) up to 5% and non-zero net toroidal current are included in the data set. The achieved normalized root-mean-squared error ranges from 1% to 20% across the different scenarios. The model inference time for a single equilibrium is on the order of milliseconds. Finally, this work shows the feasibility of a fast NN drop-in surrogate model for VMEC, and it opens up new operational scenarios where target applications could make use of magnetic equilibria at unprecedented scales.

P 5.45 Tue 14:00 P

Modifications of the fusion reactor systems code PROCESS to general stellarators — •Jorrit Lion, Felix Warmer, and Robert C. Wolf — Max Planck Institute for Plasma Physics, D-17491, Greifswald, Germany

Stellarators are attractive candidates for a fusion power plant, owing to their inherent steady-state capability and absence of plasma-current driven instabilities. A convenient way to study different power plant designs is by applying systems codes, which aspire to model an entire fusion power plant within a single framework by using simplified 0D or 1D models to capture relevant reactor constraints. In this work, we report on modifications of the fusion reactor power plant systems code PROCESS to a general class of stellarator configurations. This is achieved by introducing a set of new models in PROCESS, which reflect the stellarator specific constraints of a fusion reactor, like inhomogeneous neutron wall loads, coil-force magnitudes, wall loads by fusion born alpha particle wall loads or stellarator specifics operational boundaries by an electron cyclotron resonance heating scheme. Previous models, as introduced in [1], were adapted and generalized to generic stellarators. 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.

[1] F. Warmer, et al., "Implementation and verification of a HELIAS module for the systems code PROCESS", Fusion Eng. Design, vols. 98 99 (2015)

P 5.46 Tue 14:00 P

A novel MMC-like topology for ASDEX Upgrade Toroidal Field Coils Power Supply — •Antonio Magnanimo[1], Markus Teschke[1], and Gerd Griepentrog[2] — [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 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 the toroidal field (TF) coils of ASDEX Upgrade (AUG). Due to the pulsed DC operation of these coils and their high power needs for each experiment, a small-scale adapted version of the MMC is under development with some differences compared to conventional ones: SM capacitors have been replaced with supercapacitor (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 poster shows first an overview of the conceptual full-scale converter that could replace in future one of the FGs of AUG and then the development and the operation of a single IGBT full-bridge (FB) SM highlighting advantages and challenges of this configuration.

P 6: Magnetic Confinement III & Helmholtz Graduate School II

Time: Tuesday 16:30–17:50 Location: H5

Invited Talk P 6.1 Tue 16:30 H5

The Wendelstein 7-X Scrape-Off Layer — •Carsten Killer and W7-X Team — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

The stellarator Wendelstein 7-X employs the island divertor concept, where the intersection of out-flowing plasma by the divertor takes places in a chain of large, intrinsic magnetic islands. The Scrape-Off Layer (SOL) formed by the magnetic islands is inherently three-dimensional and features rather long parallel connection lengths of typically several 100 m, adding additional transport channels and complexity compared to a typical tokamak SOL. Understanding the transport processes in the SOL is essential for controlled high performance plasma operation since the SOL profiles formed by the relation of parallel and perpendicular transport ultimately govern the heat flux distribution on the targets.
Using a multi-diagnostic approach with a focus on reciprocating probes, we show that the magnetic islands significantly affect the SOL plasma. Most notably, the islands result in a very wide SOL (∼5 cm) with flat or even locally hollow/peaked profiles of T_e and n_e across the islands. In addition, the islands affect parallel and poloidal plasma flows. Finally, the role of turbulent radial particle transport is found to be smaller in the W7-X SOL compared to tokamaks.

P 6.2 Tue 17:00 H5

GENE-X: A Gyrokinetic Turbulence Code for the Edge and Scrape-Off Layer — •Dominik Michels[1], Andreas Stegmeir[1], Philipp Ulbl[1], Frank Jenko[1,2], and the ASDEX Upgrade Team[3] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]University of Texas at Austin, Austin, TX 78712, USA — [3]See author list of Meyer H et al 2019 Nucl. Fusion 59 112014

Plasma turbulence in the edge and scrape-off layer is characterized by steep gradients and large fluctuation amplitudes. As such, nonlinear effects caused by the coupling between the plasma background and fluctuations are important and a so called full-f treatment of the underlying equations is necessary. Furthermore, the poloidal magnetic field vanishes at the X-Point of a tokamak – which introduces a coordinate singularity in the commonly used flux coordinates.

To tackle these problems we have created the gyrokinetic turbulence code GENE-X [1], a new version of the established GENE [2] code. GENE-X implements a full-f gyrokinetic model and is able to perform simulations in single-null, double-null as well as other advanced divertor geometries by using the flux coordinate independent approach [3]. We present a careful verification of the GENE-X code and demonstrate its ability to simulate gyrokinetic turbulence in single null geometry at the example of ASDEX Upgrade.

[1] F. Jenko et al., Phys. Plasmas 7 (2000) 1904
[2] D. Michels et al., Comput. Phys. Commun. 264 (2021) 107986
[3] F. Hariri et al., Comput. Phys. Commun. 184 (2013) 2419

P 6.3 Tue 17:25 H5

Core plasma density fluctuations in Wendelstein 7-X ECRH plasmas — •Jan-Peter Bähner[1], Jorge A. Alcusón[1], Søren K. Hansen[2], Håkan M. Smith[1], Adrian von Stechow[1], Zhouji Huang[2], Eric M. Edlund[3], Miklos Porkolab[2], Olaf Grulke[1,4], and The W7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald, Germany — [2]MIT Plasma Science and Fusion Center, Cambridge, MA, USA — [3]SUNY Cortland, Cortland, NY, USA — [4]Technical University of Denmark, Kongens Lyngby, Denmark

Ion-scale turbulence is thought to be the main driver for anomalous transport in the optimised stellarator Wendelstein 7-X (W7-X). The most important instabilities on this scale are the ion-temperature-gradient (ITG) mode and the trapped-electron mode (TEM). The Phase Contrast Imaging (PCI) diagnostic measures line-integrated density fluctuations throughout the plasma core with temporal and wavenumber resolution spanning the ITG and TEM scales. In edge-fuelled, electron cyclotron heated discharges, a localisation of density fluctuations to approximately 75% of the plasma minor radius is shown experimentally via a match of the dominant measured phase velocity of fluctuations to the profile of the $E \times B$ rotation velocity and via gyrokinetic simulations with GENE. The localisation and characteristics of the measured fluctuations and gyrokinetic simulations match the expectation of ITG dominated turbulence in W7-X. The dynamic evolution of multiple phase velocities connected to a qualitative change of turbulence during improved confinement after pellet injection as well as low frequency oscillations reminiscent of ZFOs are presented.

P 7: Helmholtz Graduate School III

Time: Wednesday 14:00–15:15 Location: H4

P 7.1 Wed 14:00 H4

Simplified nonlinear MHD models of external kink modes in stellarators — •Rohan Ramasamy[1,2], Matthias Hoelzl[1], Erika Strumberger[1], Guillermo Suárez López[1], Sophia Henneberg[3], Karl Lackner[1], and Sibylle Günter[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Max Planck Princeton Center for Plasma Physics, New Jersey, USA — [3]Max Planck Institute for Plasma Physics, Greifswald, Germany

Non-linear magnetohydrodynamic (MHD) codes are an important tool in improving the understanding of disruptions in tokamaks. Recently, there has been renewed interest in advancing state-of-the-art MHD codes to model stellarators. Herein, two simplified models are explored, using the nonlinear code, JOREK, and the equilibrium code, VMEC.

VMEC is used to calculate the nonlinear saturated state of ideal external kink modes in simplified $l = 2$ stellarators. These saturated states are then compared against a simpified axisymmetric approximation of the stellarator, implemented in JOREK. The axisymmetric approach includes the external rotational transform by means of a *virtual current* model.

This approach is then applied to an unstable quasi-axisymmetric configuration to assess the stabilising influence of increasing external rotational transform on the MHD activity. The results show that while the external modes are stabilised significantly, nonlinearly triggered internal modes degrade confinement further. A relatively large external rotational transform is necessary to avoid a significant loss of confinement.

P 7.2 Wed 14:25 H4

First results for stellarator simulations with JOREK —

•Nikita Nikulsin[1], Rohan Ramasamy[1], Matthias Hoelzl[1], Alessandro Zocco[2], Karl Lackner[1], and Sibylle Guenter[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany

The JOREK code has recently been extended to allow nonlinear fully 3D stellarator simulations. This is made possible by generalizing the JOREK reduced MHD model to support stellarator geometries, and by allowing the grid to be non-axisymmetric, so that it can be aligned to the flux surfaces in a stellarator.

The models differ mainly in that the magnetic field can be represented as any curl-free field plus a perturbation in the stellarator model, whereas in the tokamak model it is a toroidal field plus a perturbation. We implement the curl-free field as a gradient of a Dommaschk potential, which in turn is calculated from the vacuum magnetic field as given by the EXTENDER code. In order to run a stellarator simulation, we must initialize the reduced MHD variables using the data from the GVEC equilibrium code.

Finally, we present the very first stellarator simulation results. While force balance is not satisfied exactly in stellarator reduced MHD, we show the error to be small. For stable plasmas, a barely noticeable shift is seen, after which equilibrium is restored and persists for thousands of Alfvén times. We also simulate unstable plasmas and benchmark the growth rates against the linear MHD code CASTOR3D.

P 7.3 Wed 14:50 H4

MHD-kinetic hybrid code based on structure-preserving finite elements with particles-in-cell — •Florian Holderied[1,2], Stefan Possanner[1], and Xin Wang[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]Technical University of Munich, Arcisstraße 21, 80333 München, Germany

This talk presents a STRUcture-Preserving HYbrid code - STRUPHY - for the simulation of magneto-hydrodynamic (MHD) waves interacting with a small population of energetic particles (EPs) far from thermal equilibrium (kinetic species). Such configurations can appear e.g. in fusion reactors, where hot α-particles can resonantly interact with MHD waves and compromise confinement time. The implemented model features linear, ideal MHD equations in curved, 3d space, coupled nonlinearly to the full-orbit Vlasov equations via a current coupling scheme. The implemented algorithm is based on finite element exterior calculus for MHD and particle-in-cell methods for the kinetic part; it provably conserves mass, energy, and the divergence-free constraint for the magnetic field, irrespective of metric, mesh parameters and chosen order. The motivation for this work stems from the need for reliable long-time simulations of EP-physics in complex geometries. In STRUPHY, the finite element spaces are built from tensor products of univariate B-splines on the logical cuboid. Time-stepping is based on operator splitting with implicit sub-steps. After presenting the scheme, numerical results in different geometries including toroidal domains with a singularity at the magnetic axis are shown and discussed.

P 8: Laser Plasmas I

Time: Wednesday 14:00–15:15 Location: H5

Invited Talk P 8.1 Wed 14:00 H5

Visualizing the Dynamics of a Plasma-Based Particle Accelerator — •Malte Kaluza — Institut für Optik und Quantenelektronik, Max-Wien-Platz 1, 07743 Jena — Helmholtz-Institut Jena, Fröbelstieg 3, 07743 Jena

Relativistic plasmas generated by high-power laser pulses are a potential candidate for future compact electron accelerators. In a plasma-electron accelerator, the driving laser pulse generates a high-amplitude plasma wave forming the electric field structure (the "wakefield"), which can trap and accelerate electrons to several GeV energies over distances of a few centimeters only. The properties of the generated electron pulses (spectrum, pulse duration, lateral dimensions) strongly depend on the parameters and the evolution of this accelerating structure. Therefore, a complete understanding of the physical phenomena underlying the acceleration process is mandatory to improve the controllability of the electron pulses, which will determine their potential applicability in the future. This presentation will give a short introduction to laser wakefield accelerators, discuss transverse optical probing as a diagnostic tool [1, 2] and present experimental results on the characterization and evolution of the electron pulses [3] and of the plasma wave [4,5].

[1] M. B. Schwab et al., Applied Physics Letters 103, 191118 (2013) [2] M. C. Downer et al., Reviews of Modern Physics 90, 035002 (2018) [3] A. Buck et al., Nature Physics 7, 543 (2011) [4] A. Sävert et al., Physical Review Letters 115, 055002 (2015) [5] E. Siminos et al., Plasma Physics and Controlled Fusion 58, 065004 (2016)

P 8.2 Wed 14:30 H5

Spin-polarized particle beams from laser-plasma based accelerators — •Lars Reichwein[1], Anna Hützen[2,3], Markus Büscher[2,3], and Alexander Pukhov[1] — [1]Institut für Theoretische Physik I, Heinrich Heine Universität Düsseldorf, Germany — [2]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich, Germany — [3]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf, Germany

Spin-polarized particles with high energies are needed for various experiments, i.a. to examine the structure of protons and neutrons for further insight of QCD or to probe the nuclear spin structure. A promising option is the acceleration of pre-polarized particles from a plasma using a high-intensity laser [1]. We give a brief overview of the state-of-the-art for this subject, for which proof-of-principle experiments are currently being prepared. Further, we will present the acceleration of protons via magnetic vortex acceleration (MVA) in more detail and discuss the effects of density down-ramps on the proton yield studied by means of particle-in-cell simulations [2]. We show that the beam's average spin polarization remains robust against moderate changes of the down-ramp length and is only affected by changes in the collimation process for a significant increase in length.

[1] M. Büscher et al., doi:10.1017/hpl.2020.35, High Power Laser Sci (2020)

[2] L. Reichwein et al., doi:10.1088/1361-6587/ac0614, Plasma Phys. Control. Fusion (2021)

P 8.3 Wed 14:45 H5

Multiparameter-controlled laser ionization of gases in the tunnel ionization regime — •Michael Stumpf and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Within the scope of developing a Plasma Photocathode for Wakefield Acceleration of electrons we present a novel optical setup to ionize gases with controlled and modifiable ionization volume, number of electrons and initial energy. The reflection-based setup, called AMBER (Axicon Mirror Beam ExpandeR), allows the implementation into a fs-laser beamline without disturbing the spectral phase of the laser pulse. By changing the beam profile, pulse duration and pulse energy of the laser a desired ionization volume and state can be achieved. The dedicated ionization simulations are in good agreement with the gained experimental results which allows a precise prediction of laser-gas interactions.

P 8.4 Wed 15:00 H5

Monoenergetic High-Energy Ion Source via Femtosecond Laser Interacting With a Microtape — •Xiaofei Shen and Alexander Pukhov — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

Intense laser-based ion sources are characterized by unsurpassed acceleration gradient and exceptional beam emittance. They are promising candidates for next-generation accelerator towards a broad range of potential applications. However, the ion beams achieved currently have limitations in energy spread and peak ion energy. In this talk, I will present our recent work on achieving monoenergetic proton beams with energy spread at 1% level and peak energy of hundred MeV. Using fully three-dimensional particle-in-cell simulations, we show that such proton beams can be stably generated by using a readily available femtosecond laser interacting with a microtape. As the laser pulse sweeps along the tape, it drags out a huge charge (~100 nC) of collimated energetic electrons and accelerates them along the tape surface to superponderomotve energies. When this dense electron current arrives at the rear edge of the tape, it induces a strong electrostatic field. Due to the excessive space charge of electrons, the longitudinal field becomes bunching while the transverse field is focusing for protons. Together, this leads to a highly monoenergetic energy spectrum and much higher proton energy as compared to simulation results from typical target normal sheath acceleration and radiation pressure acceleration at the same laser parameters.

P 9: Codes and Modelling (Methods)

Time: Wednesday 16:30–17:30 Location: H5

P 9.1 Wed 16:30 H5

Determination of 2D Plasma Parameters with Filtered Cameras - An Application to the X-Point Radiator — •Emanuel Huett[1,2], Matthias Bernert[1], Alexander Bock[1], Marco Cavedon[1,2], Pierre David[1], Tilmann Lunt[1], Korbinian Moser[1], Takashi Nishizawa[1], Ou Pan[1], Ulrich Stroth[1,2], and The ASDEX Upgrade Team[1] — [1]Max-Plack-Institut für Plasmaphysik, Garching, Germany — [2]Technische Universität München, Munich, Germany

A method for the determination of 2D plasma parameters with filtered cameras has been developed. Major advantages are a high spatial resolution, 2D electron temperature, electron density and neutral density. The camera system at the ASDEX Upgrade Tokamak was upgraded to measure the deuterium balmer alpha, beta, gamma spectral lines and a nitrogen II multiplett simultaneously. Reflections are taken into account and can make a substantial contribution. The method's application is of interest in divertor physics, but also for more exotic studies like plasma production for wall conditioning. The method has been successfully applied to discharges with a well developed X-point radiator, one of the most promising scenarios for power exhaust control in a fusion reactor. First results show that the X-point radiator successfully cools the plasma to a point where recombination dominates. This is supported by simulations. A first verification with the new divertor Thomson scattering and divertor spectroscopy shows a reasonable agreement.

P 9.2 Wed 16:45 H5

Full-wave simulations of measurements of the perpendicular velocity of density fluctuations with Doppler reflectometry at ASDEX Upgrade — •Antonia Frank[1,2], Klara Höfler[1,2], Tim Happel[2], Carsten Lechte[3], Tobias Görler[2], Ulrich Stroth[2,1], and the ASDEX Upgrade Team[2] — [1]Technische Universität München, Munich, Germany — [2]Max-Planck-Institut für Plasma Physik, Garching, Germany — [3]Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie IGVP, Stuttgart, Germany

The perpendicular propagation velocity of turbulent density fluctuations $v_\perp$ is an important quantity in fusion plasmas since sheared plasma flows are crucial for the reduction of turbulence and thus a relevant input parameter for simulations of turbulent transport. In the recent past, poloidal asymmetries have been observed in various fusion devices using Doppler reflectometry and correlation reflectometry. An explanation of these asymmetries may lie in the diagnostic response. Hence, numerical investigation using synthetic diagnostics is of great interest. The IPF-FD3D full-wave code is used as a synthetic Doppler reflectometry diagnostic, simulating microwave propagation and scattering. Turbulence flows are studied in several geometries with different synthetic turbulence spectra. The influence of the measurement's poloidal location on the diagnostic response is investigated. Full-wave simulations are also applied to turbulence from the gyro-kinetic code GENE in ASDEX Upgrade geometry on basis of selected experimental data for direct comparison with measurements.

P 9.3 Wed 17:00 H5

Two-part simulation approach of the source plasma of the KATRIN experiment — •Jonas Kellerer[1] and Felix Spanier[2] — [1]Institut für Astroteilchenphysik, KIT, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany — [2]Institut für Theoretische Astrophysik, Universität Heidelberg, Albert-Überle-Str. 2 und Philosophenweg 12, 69120 Heidelberg, Germany

The **Ka**rlsruhe **Tri**tium **N**eutrino (KATRIN) experiment aims to determine the effective neutrino mass through spectroscopy of gaseous Tritium β-decay. Those high energy β-decay electrons ionize the surrounding gas in the source and thus create a partly ionized plasma. The exterior experimental conditions generate unconventional plasma conditions resulting in a highly magnetized, partly collisional, multi-species, non-thermal (with thermal components), bound plasma. The combination of these properties make a self-contained analytical description impossible. Thus, we decided on a two-part iterative simulation approach: the slow ion physics will be covered by the newly developed Monte Carlo code KARL, which produces electron energy distributions and ion currents. The results of KARL will be used by a modified version of the well tested ACRONYM Particle in Cell code to resolve the fast electron-field interactions. The modifications include cylindrical boundaries and position dependent background currents and fields. The derived fields will in turn be used as input for the KARL code. In this presentation, key concepts and challenges of the iterative approach and the underlying codes will be presented.

P 9.4 Wed 17:15 H5

Effects of laterally shifted bunch collisions on QED processes — •Marko Filipovic[1], Christoph Baumann[1], Alexander Pukhov[1], Alexander Samsonov[2], and Igor Kostyukov[2] — [1]Heinrich-Heine-Universität, Düsseldorf, Germany — [2]Institute of Applied RAS, Nizhny Novgorod, Russia

The collision of ultrarelativsitic electron bunches is a promising opportunity to study quantum electrodynamic effects in extreme fields and densities, this includes quantum photon emission and pair production. It was even conjectured that the interaction of light and matter can become fully non-perturbative. In this talk, the results of three-dimensional particle-in-simulations will be presented. First, the basic idea of the fully non-perturbative particle collider [1] will be recalled. Subsequently the configuration will be modified by considering the collision of two laterally shifted bunches. In detail, the impact on photon and pair yields through the modification will be compared and assessed by previous Beam-Beam collision estimates. Finally, the influence of longer bunches in the collider configurations will be considered.

[1] V. Yakimenko et al., Phys. Rev. Lett. **122**, 190404 (2019)

P 10: Mitgliederversammlung Plasmaphysik

Time: Wednesday 17:45–18:45 Location: MVP

Mitgliederversammlung P

P 11: Complex Plasmas and Dusty Plasmas I

Time: Thursday 11:00–12:30 Location: H4

Invited Talk P 11.1 Thu 11:00 H4

Microfluidic flow in single-layer dusty plasmas — •Peter Hartmann[1] and Truell W. Hyde[2] — [1]Wigner Research Centre for Physics, Budapest, Hungary — [2]CASPER, Baylor University, Waco, TX, USA

Experiments on strongly coupled dusty plasmas provide unique access to the microscopic details of macroscopic processes in condensed matter. Since the early years of this field, the application to hydrodynamic processes was one of the main motivations. In most cases, however, the complexities of the experiments prevented the drawing of universal conclusions. In our experiment, utilizing the control provided by a plane-parallel radio frequency (RF) discharge, two metallic disks are used to form an electrostatic potential channel. Dust particle flow through the channel was induced by indirect laser manipulation, which is essential in order to keep the external effects acting on the particles under control. By adjusting the argon gas pressure and RF power, the channel was tuned to allow the formation of single or multiple lanes of transiting dust particles. We use this system to address fundamental details of microfluidic flows like the acceleration and stopping of particles, lane formation and ordering in the channel, etc.

P 11.2 Thu 11:30 H4

String Formation and Recrystallisation — •E Joshi[1], M Pustylnik[1], M Schwabe[1], H Thomas[1], M Thoma[2], A Lipaev[3], A Zobnin[3], A Usachev[3], and A Ivanishin[4] — [1]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt, Weßling, Germany — [2]I. Physikalisches Institut, Justus-Liebig Universität Giessen, Giessen, Germany — [3]Joint Institute for High Temperatures, Russian Academy of Sciences — [4]Gagarin Cosmonaut Training Center, Russia

Plasmas with micrometre sized particles embedded in them where the particles gain high negative charges and become strongly coupled are known as complex plasmas. These complex plasmas can be studied in microgravity conditions using the Plasmakristall-4 (PK-4) facility onboard the International Space Station. Recrystallisation was studied in a complex plasma with string-like structure using the PK-4 lab by turning the plasma off for a fraction of a second to destroy the stringy order, then turning the plasma on again to see how the structure reforms. We characterised the ‘stringiness’ of the system by the average number of string neighbours at a given time and noted how it changed during the experiment. We then performed molecular dynamics (MD) simulations using Large-scale Atomic/Molecular Massively Parallel Simulator (LAMMPS) to compare with the experiment, and used a Yukawa + wake potential for the interparticle interactions. This lets us mimic the effect of ions in our simulation which led to string formation. We found that the simulations had a good agreement with experimental findings.

P 11.3 Thu 11:45 H4

Video aided 1D Extinction – a novel technique for nanodust density measurements — •Andreas Petersen, Alexander Schmitz, and Franko Greiner — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel

Extinction measurements are the basis of dust density diagnostics in nanodusty plasmas. Standard techniques are computed tomography (CT) for arbitrarily shaped clouds and Abel inversion (AIN) for cylindrically symmetric dust clouds. For density measurements in a plasma chamber, where no full optical access is possible, we developed a new technique, which utilizes a laser stripe, two CMOS line cameras and one 2D camera. The VaEM method can be used to measure the dust density along a slice through the dust cloud and does not require cylindrical symmetry.

P 11.4 Thu 12:00 H4

High precision in-situ particle size measurement — •Sören Wohlfahrt, Niklas Kohlmann, and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Microparticles are the essential component of a (dusty) complex plasma. The forces affect-ing these particles, as well as their accumulated charge, depend prominently on their size. In addition, the (complex) refractive index of the particles is of importance when optical tech-niques are used for particle manipulation or in-situ diagnostic purposes. Thus, a precise knowledge of these particle parameters is a key input for a quantitative description and modelling. However, in interaction with the plasma the particle properties can change. The size and refractive index of particles can be determined simultaneously with very high preci-sion by means of angle- and polarisation-resolved light scattering (APRLS), which is based on a comparison of experimental data with Lorentz-Mie theory [1]. We will present the time resolved evolution of the size and refractive index of silica (SiO2)- and melamine-formaldehyde (MF) microparticles. Especially the consistency and absolute precision of the measurements as well as the time resolved changes in the refractive index for MF-particles are discussed. [1] N. Kohlmann, F. Wieben, O. H. Asnaz, D. Block, F. Greiner, Phys. Plasmas 26, 053701 (2019)

P 11.5 Thu 12:15 H4

Charge measurement of SiO_2 nanoparticles in an RF-plasma by IR absorption — •Harald Krüger and André Melzer — Institute of Physics, University Greifswald

Dusty plasmas with nanoparticles have drawn increased attention in the last few years. We have performed measurements of the IR absorption of SiO_2 nanoparticles confined in an argon radio-frequency plasma discharge using an FTIR spectrometer. By varying the gas pressure of the discharge and duty cycle of the applied radio-frequency voltage we observed a shift of the absorption peak of SiO_2. We attributed this shift to charge-dependent absorption features of SiO_2. The charge-dependent shift has been calculated for SiO2 particles and from comparisons with the experiment the particle charge has been retrieved. With the two different approaches of changing the gas pressure and altering the duty cycle we are able to deduce a relative change of the particle charge with pressure variations and an absolute estimate of the charge with the duty cycle.

P 12: Astrophysical Plasmas & Laser Plasmas II

Time: Thursday 11:00–12:15 Location: H5

Invited Talk P 12.1 Thu 11:00 H5

Planetary and astrophysical high Mach-number shocks: kinetic simulations vs in-situ measurements — •Artem Bohdan[1], Martin Pohl[1,2], and Paul Morris[1] — [1]DESY, DE-15738 Zeuthen, Germany — [2]Institute of Physics and Astronomy, University of Potsdam, DE-14476 Potsdam, Germany

High-Mach-number collisionless shocks are found in planetary systems and supernova remnants (SNRs). Electrons are heated at these shocks to temperatures well above the Rankine-Hugoniot prediction. However, the processes responsible for causing the electron heating are still not well understood. We use a set of large-scale particle-in-cell simulations of nonrelativistic shocks in the high-Mach-number regime to clarify the electron heating processes. The physical behavior of these shocks is defined by ion reflection at the shock ramp. Further interactions between the reflected ions and the upstream plasma excites electrostatic Buneman and two-stream ion-ion Weibel instabilities. Electrons are heated via shock surfing acceleration, the shock potential, magnetic reconnection, stochastic Fermi scattering, and shock compression. The main contributor is the shock potential. The magnetic field lines become tangled due to the Weibel instability, which allows for parallel electron heating by the shock potential. The constrained model of electron heating predicts an ion-to-electron temperature ratio within observed values at SNR shocks and in Saturn’s bow shock. We also present evidence for field amplification by the Weibel instability. The normalized magnetic field strength strongly correlates with the Alfvenic Mach number, as is in-situ observed at Saturn’s bow shock.

P 12.2 Thu 11:30 H5

Detector characterisation for grating-based X-ray phase-contrast imaging — •Constantin Rauch, Bernhard Akstaller, Lisa Dietrich, Dennis Haag, Veronika Ludwig, Stephan Schreiner, Max Schuster, Andreas Wolf, Thilo Michel, Gisela Anton, and Stefan Funk — Ecap - Erlangen Centre for Astroparticle Physics, University Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen

Imaging at X-ray backlighter allow to capture fast dynamic processes due to extremely short exposure times. Grating-based X-ray phase-contrast imaging is expected to observe plasma shocks with higher contrast than absorption-based imaging due to its sensitivity to the differential phase-shift caused by local electron density variation present in plasma shocks. These rapid processes place special demands on the imaging system consisting of two gratings and a detector. Optimising the setup promises improvements in photon noise and sensitivity. This can be achieved by optimising the gratings, their positions and the detector. In this contribution, a methodology for characterising X-ray detectors according to their resolution, sensitivity and noise in phase-contrast imaging is introduced.

P 12.3 Thu 11:45 H5

X-ray phase contrast imaging as a plasma diagnostics technique — •Lisa Dietrich, Bernhard Akstaller, Stephan Schreiner, Veronika Ludwig, Max Schuster, Gisela Anton, and Stefan Funk — ECAP - Erlanger Centre for Astroparticle Physics, Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen, Germany

A single-shot x-ray phase-contrast imaging technique with short exposure time allows to capture sharp images of fast dynamic processes, like laser-produced plasma shock-waves in high-energy density pump-prope experiments. Using grating-based x-ray phase-contrast imaging as a measurement technique, allows to determine the projected electron density distribution of a sample with a single acquisition. In this talk the methodology of grating-based phase-contrast imaging and its ability to retrieve electron density distribution is introduced. Further, the concept of a portable grating-based phase-contrast imaging setup is explained, which allows to adjust the interferometer at low repetion rate backlighter sources within a reasonable time using a fast-alignment method.

P 12.4 Thu 12:00 H5

Noise reduction for single-shot grating-based phase-contrast imaging at an x-ray backlighter — •Stephan Schreiner[1], Bernhard Akstaller[1], Lisa Dietrich[1], Paul Neumayer[2], Max Schuster[1], Andreas Wolf[1], Veronika Ludwig[1], Thilo Michel[1], Gisela Anton[1], and Stefan Funk[1] — [1]Friedrich-Alexander Universität Erlangen-Nürnberg, Erwin-Rommel-Straße 1, 91058 Erlangen, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

X-ray backlighters allow to capture sharp images of fast dynamic processes , like laser-produced plasma shock-waves in high-energy density experiments, due to extremely short exposure times. Moiré imaging using a two-grating imaging setup enables to measure the absorption and differential phase-contrast (DPC) of these processes simultaneously, allowing to retrieve the electron-density distributions of the imaged object. However, acquiring images with one single-shot limits the x-ray photon flux, which can result in noisy images. In this contribution an implementation of a laser-driven x-ray backlighter experiment is presented and two noise reduction methods for single-shot images are evaluated.

P 13: Magnetic Confinement IV & Helmholtz Graduate School IV

Time: Thursday 14:00–15:45 Location: H4

Invited Talk P 13.1 Thu 14:00 H4

How turbulence sets boundaries for fusion plasma operation — •Peter Manz[1], Thomas Eich[2], and the ASDEX Upgrade Team[2] — [1]Institut für Physik, Universität Greifswald — [2]Max-Planck-Institut für Plasmaphysik, Garching

The operational space for safe and efficient operation of a tokamak is limited by several constraints. Well known examples are the Greenwald density limit and the accessibility of high confinement. Their extrapolation to reactor machine size is based on empirical scalings. Both phenomena are related to turbulent transport. Large turbulent transport can lead to a transition to low confinement or trigger events finally leading to a disruption (the L-mode density limit). The strength of turbulent transport in the plasma edge depends on the competition between rather gentle drift-wave and the rather violent resistive ballooning turbulence. The operation boundaries are derived in terms of a combination of dimensionless parameters describing interchange-drift-Alfven turbulence without any free adjustable parameter. This way, the disruptive density limit is related to a transition from the electrostatic to the electromagnetic resistive ballooning regime. At the L-H transition, drift-wave dominated turbulence is suppressed by a combination of flow shear, diamagnetic and beta stabilization. The derived boundaries are compared to about 300 discharges and agreement within experimental error bars.

P 13.2 Thu 14:30 H4

Multi-class disruption prediction at JET using a shapelet based neural-network. — •Victor Artigues[1], Frank Jenko[1], and JET Contributors[2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]See the author list of 'Overview of JET results for optimising ITER operation' by J. Mailloux et al. to be published in Nuclear Fusion Special issue: Overview and Summary Papers from the 28th Fusion Energy Conference (Nice, France, 10-15 May 2021)

Disruptions, the very fast, uncontrolled, termination of plasma experiments in tokamaks, remain to this day an unsolved issue on the path towards fusion-based power plants. Due to the their complex nature, disruptions have been very hard to investigate with physics-based approaches. In recent years, progress has been made with data-driven methods to build disruption detection systems, but many questions remain open such as disruption type identification, or transfer between tokamaks.

We propose a Shapelet based neural-network for the task of multi-class disruption prediction, and compare it to two approaches from the literature, trained on our data: stacked Support-Vector Machines (SVM), and a Long Short-Term Memory (LSTM) neural-network. Two datasets of discharges from the Joint European Torus (JET) tokamak, have been compiled. One containing stable discharges and 7 different disruption types, before the installation of the ITER-Like Wall (ILW). The second, with fewer shots and binary classification, from the more recent C36 campaign with ILW. Using the binary and multi-class classification results on the different datasets, we report on the performance of the three models and discuss the advantages of our method.

P 13.3 Thu 14:55 H4

Alpha particle dynamics and Alfvenic instabilities in ITER post-disruption plasmas — •Andrej Lier[1], Gergely Papp[1], Philipp Lauber[1], Stefanie Braun[2], George Wilkie[3], and Ola Embreus[4] — [1]Max Planck Institute for Plasma Physics, D-85748 Garching, Germany — [2]Department of Physics, Chalmers University of Technology, SE-41296 Gothenburg, Sweden — [3]Princeton Plasma Physics Laboratory, Princeton NJ 08540, USA — [4]Department of Physics, Chalmers University of Technology, SE-41296 Gothenburg, Sweden

Fusion-born alpha particles in ITER disruption simulations are investigated as a possible drive of Alfvenic instabilities. The ability of these waves to expel RE seed particles is explored in the pursuit of a passive, inherent RE mitigation scenario in synergy with built-in RE mitigation systems. An analytical model is introduced that is able to compute the spatiotemporal evolution of the alpha particle distribution in a mitigated thermal quench. We use a linear gyrokinetic stability code to calculate the Alfven spectrum and find that the equilibrium is capable of sustaining a wide range of modes. The natural radial anisotropy of the alpha population provides free energy to drive Alfvenic modes during the quench phase of the disruption. The self-consistent evolution of the mode amplitudes and the alpha distribution is calculated utilizing wave-particle interaction methods. Intermediate mode number Toroidal Alfven Eigenmodes (TAEs) are shown to saturate at an amplitude of up to dB/B ~ 0.1% in the spatial regimes crucial for RE seed formation.

P 13.4 Thu 15:20 H4

2.5 MeV and 14 MeV neutron rate measurements on ASDEX Upgrade and predictions for Wendelstein 7-X — •Jan Paul Koschinsky[1], Christoph Biedermann[1], Sergey A. Bozhenkov[1], Joona Kontula[2], Simppa Äkäslompolo[1,2], Monika Koleva[3], Giovanni Tardini[3], C. F. B. Zimmermann[3], Ralf Nolte[4], Elisa Pirovano[4], Andreas Zimbal[4], G. A. Wurden[5], Robert C. Wolf[1], the W7-X Team[1], and the ASDEX Upgrade Team[3] — [1]Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, D-17491, Greifswald, Germany — [2]Aalto University, Espoo, Finland — [3]IPP, Garching — [4]PTB, Braunschweig — [5]LANL, US

Fast-ion confinement is crucial for realizing burning fusion plasmas, both in tokamaks and stellarators, as fast fusion-born alpha particles are meant to provide the self-heating of the plasma. Therefore, the possible application of a scintillating fiber neutron detector, SciFi, for studying fast ions in future deuterium plasmas of the Wendelstein 7-X stellarator, is investigated here.

In deuterium plasmas, 2.5 MeV neutrons and 1 MeV tritons are generated via two equally probable fusion channels, respectively. Depending on confinement and slowing-down processes, produced tritons will fuse with surrounding deuterons and give birth to 14 MeV neutrons. A time-resolved study of this triton burn-up process is attainable with SciFi, which can discriminate between 14 MeV and 2.5 MeV neutrons.

Triton burn-up studies with SciFi on the ASDEX Upgrade tokamak are presented. Moreover, predictions of neutron rates in W7-X and the resulting performance of SciFi are discussed.

P 14: Atmospheric Pressure Plasmas and their Applications II

Time: Thursday 14:00–16:00 Location: H5

Invited Talk P 14.1 Thu 14:00 H5

Streamer inception and imaging in various atmospheres — •Sander Nijdam, Siebe Dijcks, and Shahriar Mirpour — Eindhoven University of Technology, The Netherlands

Streamers are the first stage of many discharges involving high voltages. They consist of a propagating ionization front leaving behind a trail of conductive, quasi-neutral plasma. In this contribution we will show experiments on streamers revealing some of their most important properties: their inception and their propagation and branching behaviour.

We study streamer inception by applying repetitive high voltage pulses and studying the statistics of inception delay. By means of small bias pulses between the high voltage pulses, we are able to manipulate these statistics, which reveals a lot on the processes governing the inception.

Secondly, we study the propagation and branching of streamers by a combination of stereoscopic and stroboscopic measurements of 'low complexity' streamer discharges. We have developed automated routines which can determine propagation velocities, branching angles and much more from these.

Finally, we study single streamers in great detail, using optical imagining, optical emission spectroscopy, Raman scattering and E-FISH together to get a complete picture of the properties of these discharges and compare this to numerical simulations.

P 14.2 Thu 14:30 H5

From single- to multi-filament arrangements for pulsed dielectric barrier discharges — •Hans Höft, Manfred Kettlitz, and Ronny Brandenburg — Leibniz Institute for Plasma Science and Technology (INP), Felix-Hausdorff-Straße 2, 17489 Greifswald, Germany

It has been demonstrated that the discharge characteristics in pulsed-operated single-filament dielectric barrier discharges (DBDs) can be controlled by varying the pulse width of the applied high voltage (HV). The transfer of this knowledge to multi-filament DBDs is crucial for the further understanding and design of plasma reactors. Therefore, a direct comparison between a single-filament and a multi-filament arrangement driven by the same HV pulses with variable pulse width was performed in a gas mixture of 0.1 vol% O_2 in N_2 at 1 bar. Both arrangements feature a 1 mm gap with alumina-covered electrodes, with two hemispherical electrodes for the single-filament and two parallel tube electrodes for the multi-filament arrangement. The DBDs were characterised by electrical measurements (for energy, power, transferred charge, peak current) accompanied by synchronised iCCD imaging determining the filament number and the discharge development in the gas gap and on the surfaces. Generally, most physical quantities scale with the filament number. The impact of pre-ionisation on the DBD characteristics is very similar, although the filament number depends on the pre-ionisation.

This work was supported by the DFG-project MultiFil (DFG project number 408777255).

P 14.3 Thu 14:45 H5

Spatiotemporal emission of an atmospheric plasmoid — •Roland Friedl[1], Saskia Steibel[1], Victor Slavov[2,3], and Ursel Fantz[1,3] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Faculty of Physics, University of Sofia, 1164 Sofia, Bulgaria — [3]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

An atmospheric pressure plasmoid is generated via a high voltage discharge (4.8 kV) above a water surface. After around 150 ms the connection to the power supply is interrupted and the plasmoid enters an autonomous phase which lasts up to 400 ms. The plasmoid has a diameter of around 30 cm and ascends in air with a velocity of about 1–2 m/s. High speed video analysis (600 fps) and optical emission spectroscopy is applied to gain insight into the plasma dynamics.

Survey spectrometers ($\Delta\lambda \sim 1.4$ nm) are applied to determine the dominant radiating plasma constituents for the three main evolution phases of the plasmoid: ignition, formation, and autonomous phase. Photo diodes with interference filters ($\Delta\lambda \sim 10$ nm) are used for monitoring the emission of specific plasma constituents (H, OH, Na) with high temporal resolution (0.5 ms). High resolution spectroscopy ($\Delta\lambda \sim 0.16$ nm) with a high speed trigger system is applied to measure the OH-A-X emission system during the temporal evolution of the plasmoid. In order to gain access to the plasma chemistry, rotational and vibrational temperatures of the hydroxyl molecule are evaluated using Lifbase, while its absolute emissivity is analyzed by collisional-radiative modeling.

P 14.4 Thu 15:00 H5

Atomic oxygen density distributions in an atmospheric pressure plasma jet and its effluent — •David Steuer, Ihor Korolov, Sascha Chur, Julian Schulze, Volker Schulz-von der Gathen, Judith Golda, and Marc Böke — Ruhr-University Bochum, D-44801 Bochum, Germany

Micro atmospheric pressure plasma jets (μAPPJs) are attracting high attention due to their potential to treat temperature sensitive surfaces. For these applications, reactive species are produced in the plasma. In this work two-dimensional spatially resolved absolute atomic oxygen densities are measured within a μAPPJ (COST-Jet) and in its effluent. The plasma is operated in helium with an admixture of 0.5% of oxygen at 13.56 MHz and with a power of 1 W. Absolute atomic oxygen densities are obtained using two photon absorption laser induced fluorescence spectroscopy (TALIF). The results are reproduced by a combination of phase resolved optical emission spectroscopy (PROES) measurements and simple model calculations. Within the discharge, the atomic oxygen density builds up with a rise time of 600 μs along the gas flow and reaches a plateau of 8×10^{15} cm^{-3}. In the effluent, the density decays exponentially with a decay time of 180 μs (corresponding to a decay length of 3 mm at a gas flow of 1.0 slm). It is found that both, the species formation behavior and the maximum distance between the jet nozzle and substrates for possible oxygen treatments of surfaces can be controlled by adjusting the gas flow.

P 14.5 Thu 15:15 H5

Reaction kinetics of H2O2 in a cold atmospheric pressure plasma jet — •Sarah-Johanna Klose[1], Levin Krös[2], Igor L Semenov[1], and Jean-Pierre van Helden[1] — [1]Leibniz-Institut für Plasmaforschung und Technologie e.V. (INP), Felix-Hausdorff-Str. 2,

Greifswald — [2]Universität Greifswald, Greifswald

Since cold atmospheric pressure plasma jets have gained high interest particularly for biomedical applications, the tailoring of the reactive species composition produced by the plasma jet is an important issue. To be able to adapt the reactive species composition and to comprehend the impact of plasmas on cells, a good understanding of the production and consumption mechanisms in the plasma jet is pivotal. Hydrogen peroxide (H2O2) for example is a species with a high impact on cells that works as a signalling agent for intracellular communications when dissolved in a cell containing liquid.

In this work, we present the density distributions of H2O2, HO2, and H and O atoms in the gas phase of the plasma jet kINPen without contact to a liquid and deduce the most important reaction mechanisms by comparing the results to a reaction kinetics model. The distributions were obtained by continuous wave cavity ring-down spectroscopy and picosecond two-photon absorption laser-induced fluorescence spectroscopy. We will discuss the reactions in the plasma zone and the impact of the effluent's surrounding gas composition on the chemistry leading to the formation and consumption of H2O2 and its precursors.

P 14.6 Thu 15:30 H5

3-dimensional density distributions of NO in the effluent of the COST-Reference-Microplasmajet — •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, Angewandte Elektrotechnik und Plasmatechnik

Plasma jets are known to generate a huge number of different reactive species. In that context Nitric Oxide is one of the key players, as it triggers many biological processes. In this study absolute densities of NO are measured in the effluent of an RF-driven micro atmospheric pressure plasma jet, that is operated in a He/N2/O2 mixture, by means of Laser Induced Fluorescence, with 3-dimensional 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/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. It was found that the distribution as well as the absolute densities strongly depend on the surrounding atmosphere, due to quenching and collisions. Furthermore, the NO particles are strongly coupled to the He flow of the feed gas. 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.

P 14.7 Thu 15:45 H5

Loss processes of plasma-generated atomic oxygen in phenol solutions — •Kerstin Sgonina[1], Giuliana Bruno[2], Stefan Wyprich[1], Kristian Wende[2], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany

Aqueous solutions treated by cold atmospheric pressure plasma jets contain high amounts of reactive species. It has already been shown that atomic oxygen produced by a cold atmospheric pressure plasma jet effectively reacts with organic molecules like phenol dissolved in water without any intermediate reaction steps [1]. However, it is unknown whether the reactions with atomic oxygen are liquid-surface or liquid-volume dominated.

To investigate the loss processes of atomic oxygen in liquid solutions, experimental results are combined with simulations of the reaction kinetics [2]. Phenol solutions were treated with the effluent of a He/O_2-plasma ignited in the COST-Jet which provides well-known densities of reactive oxygen species [3]. Variation of the phenol concentration allows an insight into the competing O-loss reactions in gas phase, liquid phase or at the liquid surface. The comparison to simulations of the reaction kinetics and transport from gas into liquid phase reveal the predominance of reactions of atomic oxygen at the liquid surface.

[1] J. Benedikt et al., Phys. Chem. Chem. Phys. 20 12037 (2018).
[2] K. Sgonina et al., J. Appl. Phys. accepted (2021).
[3] G. Willems et al., New J. Phys. 21 059501 (2019).

P 15: Magnetic Confinement V & Helmholtz Graduate School V

Time: Thursday 16:30–18:15 Location: H5

Invited Talk P 15.1 Thu 16:30 H5

Physics studies with high-power electron cyclotron heating (ECRH) on ASDEX Upgrade — •Jörg Stober and ASDEX Upgrade Team — MPI für Plasmaphysik, Garching, Germany

The ECRH system of ASDEX Upgrade has been upgraded over the last 15 years from a 2 MW, 2 s, 140 GHz system to an 8 MW, 10 s, dual frequency system (105/140 GHz). The power roughly equals the installed ion cyclotron resonance (ICRF) power. The power of both wave heating systems together (> 10 MW in the plasma) is about half of the available power from the neutral beam heating (NBI), allowing significant variations of torque input, of the shape of the electron and ion heating profiles even at high heating power.

This system allows addressing important issues fundamental to a fusion reactor: H-mode operation with dominant electron heating, accessing low collisionalities in full metal devices, novel scenarios without edge eruptions (ELMs), influence of Te/Ti and rotational shear on transport, dependence of impurity accumulation on heating profiles. Experiments on these subjects will be presented here. The adjustable localized current drive capability of ECRH allows dedicated variations of the shape of the q-profile and studying their influence on non-inductive Tokamak operation. The ultimate goal of these experiments is to use the experimental findings to refine theoretical models such that they allow a reliable design of operational schemes for reactor size devices. In this respect, recent studies comparing gyrofluid (TGLF) and gyrokinetic (GENE) modelling of non-inductive high beta plasmas will be reported.

P 15.2 Thu 17:00 H5

Investigation of increased core ion temperatures in high-beta advanced scenarios in ASDEX Upgrade — •Maximilian Reisner[1], Jörg Stober[1], Alessandro Di Siena[2], Rainer Fischer[1], Andreas Burckhart[1], Alexander Bock[1], Emiliano Fable[1], Rachael McDermott[1], Alejandro Bañon Navarro[1], and the ASDEX Upgrade Team[3] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching bei München, Germany — [2]UT Austin, 201 E 24th St, Austin, Texas, USA — [3]See the author list of H. Meyer et al, Nucl. Fusion 59, 112014 (2019)

Non-inductive advanced scenarios are a possible way for future nuclear fusion power plants based on the tokamak design to run in non-pulsed operation. In these scenarios, the ohmic current is replaced by externally driven currents and the intrinsic bootstrap-current. Since the bootstrap-current is produced in the presence of pressure gradients, internal transport barriers or regions of reduced turbulent transport are favourable to such scenarios. Such local reductions in transport have been observed in non-inductive ASDEX Upgrade discharges. There are several parameters that are thought to be connected to local reductions of transport in the plasma core, such as the ExB-shear, the magnetic shear and the fast ion pressure. In this contribution, results of experiments conducted in the Tokamak ASDEX Upgrade will be presented, which aim to study the individual contributions of these parameters to the observed reductions in transport. These experimental findings are backed up by simulations using the quasilinear transport model TGLF and the gyrokinetic code GENE.

P 15.3 Thu 17:25 H5

Localization of magnetic reconnection during sawtooth crash in ASDEX Upgrade — •Oleg Samoylov, Valentine Igochine, Andreas Stegmeir, Hartmut Zohm, and The ASDEX Upgrade Team — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

The work discusses the toroidal localization of magnetic reconnection during sawtooth crashes. Numerical analysis with realistic heat diffusion coefficients shows that heat distributes itself helically along the torus faster than the temporal resolution of any existing ECE diagnostics. It makes local and global (helically axisymmetric) magnetic reconnection indistinguishable for an observer, while a local crash in which the heat stays confined within a finite helical region could be distinguished. Statistical analysis of sawtooth crashes with the ECEI diagnostic is conducted in ASDEX Upgrade. Our data reveals no evidence of a local sawtooth crash and supports the numerical results.

P 15.4 Thu 17:50 H5

Plasma electron acceleration up to 100 keV in the TJ-K stellarator — •Alf Köhn-Seemann[1], Gregor Birkenmeier[2,3], Eberhard Holzhauer[1], Mirko Ramisch[1], Gabriel Sichardt[1], and Ulrich Stroth[2,3] — [1]IGVP, University of Stuttgart — [2]Max Planck Institute for Plasma Physics, Garching — [3]Physics Department E28, TUM, Garching

In conventional microwave heating scenarios, the injected microwaves' frequency must be equal to or higher than the electron cyclotron frequency (ECF) to transfer their energy to the plasma. Here, we describe in contrast an operational regime at the stellarator TJ-K where the heating occurs well below the ECF, but still above the lower-hybrid frequency: energy is deposited at the so-called O-resonance. A population of high-energy electrons observed in the scenario is attributed to strong wave electric fields at this resonance. Simple physics considerations estimating the energy gain during a half-cycle of the wave electric field have been used to describe this acceleration scheme for plasma electrons. The model has been successfully compared with measurements using a pulse-height analyzer allowing to determine the fast electrons' energy.

P 16: Low Pressure Plasmas II & Dusty Plasmas II

Time: Friday 11:00–12:30 Location: H2

Invited Talk P 16.1 Fri 11:00 H2

Configurational temperature of multi species complex (dusty) plasmas — •Dietmar Block[1], Frank Wieben[1], Michael Himpel[2], and Andre Melzer[2] — [1]IEAP, Universität Kiel, Germany — [2]Institut für Physik, Universität Greifswald, Germany

The dust charge of the two species in a binary mixture of particles in a dusty plasma has been measured using the concept of configurational temperature. There, the dust charge and the respective dust charge ratio is determined from the comparison of the instantaneous particle positions and the kinetic temperature. For that purpose, experiments of binary mixtures of melamine-formaldehyde and silica particles have been evaluated. The configurational temperature approach has also been checked against simulations. From these analyses it is found that the charge ratio of the two species can be obtained quite accurately, whereas for the determination of the absolute charge values a good knowledge of the confining potential is required.

P 16.2 Fri 11:30 H2

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

Molecular dynamics simulations of binary dusty plasmas have been performed and their behavior with respect to the phase separation process has been analyzed. The simulated system was inspired by experimental research on phase separation in dusty plasmas under microgravity on parabolic flights. Despite vortex formation in the experiment and in the simulations the phase separation could be identified. From the simulations it is found that even the smallest charge disparities lead to phase separation. The separation is due to the force imbalance on the two species and it becomes stronger with increasing size disparity or decreasing mean particle size. In comparison, experiments on phase separation have been performed and analyzed in view of the separation dynamics. It is found that the experimental results are reproduced by the simulation regarding the dependency on the size disparity of the two particle species.

P 16.3 Fri 11:45 H2

Waves in binary dusty plasmas — •Lasse Bruhn and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Complex plasmas containing charged dust particles are an ideal model system for research on strong coupling phenomena. In two-dimensional systems waves can be excited either thermally or by external manipulation. The dispersion of waves propagating in monodisperse complex plasmas is well understood. However, the dynamics of waves in binary mixtures, containing two differently sized particle species, are less examined, but an interesting field of research. In this contribution, a method to derive the dust charge ratio as well as the absolute charges of the two particle species from the thermal dispersion is presented.

P 16.4 Fri 12:00 H2

Wave turbulence in fluid complex plasmas — •Prapti Bajaj[1], Christoph Räth[1], Alexei Ivlev[2], 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 physical phenomenon observed in out of equilibrium systems exhibiting non-linear properties, and it is being studied intensively in a plethora of fields like fluid dynamics, plasma physics et cetera. Here, we study wave turbulence in a complex plasma, which is a system of micrometer-sized particles embedded in a low-temperature plasma. Our experiment was conducted 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. This makes it possible to study particle behaviour at the kinetic level by using high-speed imaging. Waves form spontaneously in the cloud of confined microparticles due to ion-streaming instability. Our analysis shows that the power spectrum exhibits a slope of -5/3 in Frequency-Fourier space, corresponding to the scaling law predicted for Kolmogorovian turbulence, also observed in many classically turbulent systems. Our aim is to investigate the spectrum of short-scale disturbances generated due to the cascade of different wave modes, and their isotropisation.

P 16.5 Fri 12:15 H2

Correlation of the void dynamics with transition events of the growth chain of nanodust in a reactive argon-acetylene plasma — Sebastian Groth[1], Nancy Fassheber[2], Gernot Friedrichs[2], and •Franko Greiner[1] — [1]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel — [2]Institut für Physikalische Chemie, Christian-Albrechts-Universität zu Kiel

Using imaging Mie ellipsometry in combination with 1D extinction measurements we have fully characterized the spatio-temporal size and density evolution of nanoparticles grown in a reactive argon acetylene plasma [Groth et al. PSST 2019, https://iopscience.iop.org/article/10.1088/1361-6595/ab5412]. The growth process is usually divided into four phases: (i) creation of precursors from acetylene, (ii) nucleation of nanometer-sized a:C-H clusters (nucleation phase), (iii) coagulation of the clusters to 50 nm nanoparticles (coagulation phase), and finally (iv) further growth of negatively charged particles by sticking of molecules and molecular ions (accretion phase).

The analysis of the dynamical behavior of a nanodust cloud completely embedded in another cloud, consisting of larger particles, can link events in the spatio-temporal evolution of the nanodust cloud to events along the growth chain of the nanoparticles. This permits the verification of theoretical predictions about the occurrence of specific plasma chemical events along the growth chain by means of laser spectroscopy.

P 17: Poster II

Time: Friday 14:00–16:00 Location: P

P 17.1 Fri 14:00 P

Minimal invasive extraction and ex situ analysis of nanoparticles synthesized in a reactive plasma — •Maren Dworschak, Franko Greiner, and Oguz Han Asnaz — Institut für Experimentelle und Angewandte Physik, CAU Kiel

Plasma systems generating nanometer-sized particles are relevant for a broad range of applications from biomedicine to catalysis and batteries where knowledge about the size of the generated particles and their size distribution is critical. In situ analysis of nanoparticles created in a reactive Ar/C2H2-plasma using kinetic Mie-ellipsometry encounters problems when trying to detect particles at both extremes of the size scale. Because it reaches its limits for small (<50 nm, Rayleigh regime) and very large particles (>250 nm, multiple scattering) ex situ analysis has to be done. An optimal particle extractor should (i) not disturb the plasma chemistry, (ii) not change the discharge properties, and (iii) be able to extract several samples during one growth cycle.

We present a device to extract nanoparticles at multiple moments during a single growth cycle, while not disturbing the process itself. The extraction method is based on the electrostatic force and allows to extract particles at eight stages of the growth process. During extraction, we monitor the dynamics of the particle cloud with a camera and the particle size via Mie-ellipsometry. The particles are diagnosed ex situ with atomic force microscopy to determine the particle size distribution. The particle charge can be estimated using force balance equations. [Dworschak et al., Plasma Sources Sci. Technol. (2021), https://iopscience.iop.org/article/10.1088/1361-6595/abe4c0]

P 17.2 Fri 14:00 P

Structural properties of binary dusty plasmas — •Charlotte Büschel, Lasse Bruhn, and Dietmar Block — Institut für Experimentelle Plasmaphysik der Christian-Albrechts-Universität zu Kiel, Leibnizstraße 11-19, 24118 Kiel, Deutschland

Complex plasmas with microparticles can be used to analyze strongly coupled systems on an individual particle level. Using binary mixtures of particles, i.e. two particle species of different material and size and thus different charge but at similar confinement conditions, opens up new possibilities to study polydisperse systems. To generate a binary mixture, both species have to have identical confinement conditions. Even small differences result in a separation of the species. That a fully mixed state is nevertheless possible was shown by Wieben et al. [1], where the size loss due to etching processes in the plasma was utilized. First experiments on binary mixtures studied waves [2] as well as thermodynamics [3] . These investigations focused on particle systems in a mixed state. So far, there were no studies about the process of mixing. In this contribution structural properties of binary systems are analyzed on their way from a demixed to a mixed state. Special emphasis is put on the density profile and configurational changes during the mixing process. Thus, this study aims at a global as well as local description of the structure of binary systems as a function of their mixing state.

1. F. Wieben et al., Phys. Plasmas , Vol. 24, No. 3, 2017)
2. Yang et al., EPL , Vol. 117, No. 2, 2017
3. Wieben and Block, Phys. Rev. Lett. , Vol. 100, 2019)

P 17.3 Fri 14:00 P

Fast 3D particle position reconstruction using a neural network — •Michael Himpel and André Melzer — Institut für Physik, Universität Greifswald

We present an algorithm to reconstruct the three-dimensional positions of a particle cloud using a convolutional neural network. The approach is found to be very fast (thousands of particles in less than one second) despite its relatively high accuracy. It is special to this algorithm that the computing workload is separated into two parts: The energy- and time comsuming training, followed by the framewise non-intense and fast reconstruction. This makes this algorighm especially suitable for remote applications. The algorithm is applied to synthetic as well as experimental data from parabolic flights.

P 17.4 Fri 14:00 P

Stereoscopic Meassurements of Dusty Plasmas under Microgravity — •Daniel Maier, Michael Himpel, Stefan Schütt, and André Melzer — Institut für Physik der Universität Greifswald, Greifswald, Deutschland

Stereoscopic measurements to calculate 3d positions and trajectories of particles in a dusty plasma are a key item for the investigation of transport processes in complex particle systems. Stereoscopy is used in our group for many years now and the experimental set-up is constantly developed further, with the implementation of new faster cameras with higher recording rates as the latest improvement. In this contribution the present state of our measurement set-up, the procedure to detect the dust particles and to calculate their 3d trajectories will be shown. This includes first results on the observation of particle chains in dusty plasmas.

P 17.5 Fri 14:00 P

Thermal gradient induced dust convections in a dc plasma under microgravity conditions — •Andreas Schmitz, Ivo Schulz, Michael Kretschmer, and Markus Thoma — I. Physikalisches Institut, Justus-Liebig-Universität, Gießen, Germany

Experiments with complex plasmas were conducted in an engineering model of the International Space Station's laboratory setup Plasmakristall 4 during ESA's 71th parabolic flight campaign in the A310 ZERO-G aircraft in May 2019. In some of these microgravity experiments a DC discharge plasma was generated within the elongated glass tube of PK-4. The investigated complex plasma was introduced to a thermal gradient caused by a heater ring mounted around the plasma chamber. The dust cloud was trapped near the heater where the cloud convected. It was concluded that this dust cloud convection was induced by a gas flow via drag. Analysis of the dust cloud convection showed this gas flow to have been caused by thermal creep, a phenomenon which is common in rarefied gases with a temperature gradient along a boundary.

P 17.6 Fri 14:00 P

"Zyflex": next generation plasma chamber for complex plasma research in space — •Christina A. Knapek[1], Uwe Konopka[2], Daniel P. Mohr[1], Peter Huber[1], Andrey M. Lipaev[3], and Hubertus M. Thomas[1] — [1]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Weßling, Germany — [2]Auburn University, Auburn, AL, USA — [3]Joint Institute for High Temperatures of the Russian Academy of Sciences, Moscow, Russia

Complex plasmas consist of highly charged micrometer-sized grains injected into a low temperature noble gas discharge. Since gravity has a strong influence on the particle system, experiments under microgravity conditions are essential. A novel plasma chamber (the "Zyflex" chamber) has been designed for complex plasma research in a future facility on the International Space Station (ISS). The cylindrical, radiofrequency driven discharge device includes a variety of innovations that for example allow to flexibly adjust plasma parameters and its volume. Compared to former chambers used in space based complex plasma facilities, it also supports much larger particle systems and can be operated at much lower gas pressures, thus reducing the damping of particle motion considerably. Beyond the technical description and particle-in-cell (PIC) simulation based characterization of the plasma vessel, we show sample results from experiments performed with this device in the lab as well as during parabolic flights. Further, an outlook on the future ISS facility COMPACT with the Zyflex chamber at its core is given. This work is funded by DLR/BMWi (FKZ 50WM1441).

P 17.7 Fri 14:00 P

Influence of the surface roughness on the adhesion of thermal plasma spray Al2O3 coatings — •Tony Krüger[1], Thorben Kewitz[1], Holger Testrich[1], Rüdiger Foest[1], and Franz Faupel[2] — [1]Leibniz Institute for Plasma Science and Technology, 17489 Greifswald, DE — [2]Kiel University, 24143 Kiel, DE

In industrial plasma spray processes, masks are used to protect areas of the work piece from unwanted coating. However, gradual accumulation of material on masks can lead to changes in the flow dynamics near masks causing loss of contour accuracy and coating quality. Hence, generating surfaces conditions for masks that affect film adhesion and promote swift delamination becomes attractive. In thermal spray processes, bonding between the coating and a substrate surface is mainly established by mechanical anchoring, next to physical and chemical interactions. Here, the influence of the surface roughness on the coating adhesion is studied systematically. The surface roughness of steel was varied by means of plasma electrolytic polishing in order to provide a series of samples with a defined range from $2.5\mu m \geq$Ra$\geq 0.02\mu m$, measured using surface profilometry and white light interferometry, for critical method comparison. Moreover, the effect of additional interface layers (TiN, SiOx) on the film adhesion was investigated. Samples were spray coated with Al2O3 (2kg/h) using a Oerlicon Metco F4MB-XL Spray Gun (DC, I=600A, gases: Ar (41 NLPM), H2 (14NLPM)). The relation between thin film adhesion and surface conditions (roughness and presence of interface layers) is examined (Funded by the EU and the State of Mecklenburg-Western Pomerania (TBIV-1-321)).

P 17.8 Fri 14:00 P

Control and monitoring of spatial discharge distribution in a barrier corona discharge at elevated pressures — •Hamed Mahdikia, Michael Schmidt, 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), full or partial coverage of the electrodes is obtained. This so-called partial discharging is monitored by the variation of the effective dielectric capacitance. It increases exponentially for a mixture of Ar and CO2 (1:4) at 1 bar and reaches its maximum (i.e. fully electrode covering discharge) as the amplitude of the applied high voltage exceeds 8 kV. It decreases linearly with the increasing the pressure. The cell capacitance remains constant under variation of gas and pressure. The higher the pressure the higher the sustaining voltage and the lower the surface coverage fraction of the plasma. This may be due to the fewer and weaker micro discharges due to the lower ionization rate at higher pressures.

P 17.9 Fri 14:00 P

Splitting of CO2 with negative nanosecond pulsed dielectric barrier discharge — •Sepideh Mousazadeh borghei, Raphael Rataj, Volker Brüser, and Juergen F Kolb — Leibniz Institute for Plasma Science and Technology (INP),Greifswald, Germany

Carbone dioxide, one of the inevitable by-products of human activities, is a notable contribution to the current climate change. Conversion of CO2 into value added chemicals and fuels namely CO and CH3OH has drawn remarkable attention as a potential solution. For the splitting of CO2 into CO and O2, harsh conditions are required, owing to the high stability of the CO2-bonds. Non-thermal plasma has provided an innovative way. The goal is to provide electrons with sufficient energy, i.e. temperature, while the gas temperature can remain close to room temperature. In the first step of our project, we studied the effects of gas flow rates and mixture ratios of CO2 with argon on CO2-splitting. Therefore, a cylindrical dielectric barrier discharge reactor was set up to investigate efficacies and efficiencies. The plasma was generated by the application of negative high voltage pulses of nominally -20 kV and a pulse duration of 500 ns to an inner rod-electrode that was insulated by a glass wall with gap distance of 4 mm from the surrounding grounded electrode with 90 mm in length. Pulse repetition rates were set to 1 kHz. Gas compositions after treatment were investigated by FTIR spectroscopy. The results demonstrated that the flow of the feed gases played a significant role in CO2-conversion. The highest conversion rate was achieved for the lowest flow rate of 30 sccm, yielding 6% of CO.

P 17.10 Fri 14:00 P

Plasma catalytic synergies of a non-equilibrium atmospheric pressure plasma jet and MnO_2 surface catalyst — •Christoph Stewig, Theresa Urbanietz, Laura Chauvet, Marc Böke, and Achim von Keudell — Ruhr-University-Bochum, Germany

Plasma catalysis has the goal to exploit potential synergies between plasma and surface catalytic reactions. With the advent of renewable energies, this could allow the utilization of excess electrical energy to produce value-added molecules and thus provide the chemical industry with important reactants or store this energy.

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.

Due to the temperature dependence of surface catalysis, it is necessary to avoid intense surface heating. Thus, we employ a RF driven temperature-controlled capacity coupled plasma jet. 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 an MnO_2 surface catalyst for temperatures between 20°C and 200°C on the dissociation of CO_2 and n-butan is presented.

P 17.11 Fri 14:00 P

Diagnostic of temporal behavior of a plasma electrolytic polishing process — •Sehoon An[1], Luka Hansen[2], Thorben Kewitz[1], Gregor Gött[1], Sehyun Kwak[3], Maik Fröhlich[4], Rüdiger Foest[1], Katja Fricke[1], Antje Quade[1], Klaus-Dieter Weltmann[1], and Holger Kersten[2] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [3]Max Plank Institute for Plasma Physics, Greifswald, Germany — [4]Leupold Institute of Applied Sciences, University of Applied Sciences Zwickau, Zwickau, Germany

Plasma electrolytic polishing (PEP) has gained much attention owing to various surface modifications including oxidation or removal of material by selective dissolution of chemical compounds. During the PEP process, a volatilization of the electrolyte leads to a gas layer around the working electrode accompanied with spark discharges. The stability of the gaseous layer directly influences the material removal rate. Here, we investigate the temporal behavior of the gaseous layer involving numerous single discharges by synchronized electrical monitoring (current and voltage waveforms) and optical inspection (high-speed video, 1000 fps). We report on observations regarding oscillating discharge current and characteristic frequencies obtained by fast Fourier transformation (FFT) in relation to the process parameters and the temporal evolution of the workpiece temperature.

P 17.12 Fri 14:00 P

Diagnostics for the JT-60SA pellet source commissioning — •Jan-Henrik Ufer[1], Peter Lang[2], Bernhard Plöckl[2], Martin Prechtl[1], and ASDEX Uprade Team[2] — [1]Hochschule Coburg — [2]Max-Planck-Institut für Plasmaphsyik

JT-60SA is a superconducting tokamak currently under commissioning in Naka, Japan. It was built in a collaboration between Europe and Japan aiming to resolve key physics and engineering issues for ITER and a future fusion reactor. Equipped with superconducting coils it will be capable to investigate long lasting advanced modes of plasma operation for pulse durations up to 100 s. In this context, exploration of the high density regime and ELM control is envisaged. Therefore, a novel pellet system - pellets are mm sized solid hydrogen bodies - is under construction serving for both tasks. Any task got an accordingly designed pellet source attributed. Both the commercially supplied sources will be tested and commissioned in a dedicated European test stand. There, quality and mass throughput of the extruded ice rod as well as the quality and maximum achievable rate of pellets cut from this rod have to be diagnosed. A monochrome camera system comprises a video mode to record the initial ice extrusion and a stroboscopic mode to monitor pellet production with a flash laser. The laser is synchronised with the cutter actuation, emitting short light pulses imaging pellets avoiding movement blur. The contribution will show the designed layout of the pellet system, our diagnostics unit and the planned test sequences for the fuelling and the pacing pellet sources.

P 17.13 Fri 14:00 P

Towards the operation of a high-resolution mass spectrometer for exhaust gas analysis at ASDEX Upgrade — •Antonello Zito[1,2], Thomas Schwarz-Selinger[1], Volker Rohde[1], Athina Kappatou[1], and Marco Wischmeier[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Physik-Department E28, Technische Universität München, Garching, Germany

The removal of helium, which is the product of the D-T reaction, in magnetic fusion devices must be as efficient as possible in order to avoid fuel dilution and not degrade the confinement properties. Optimizing the strategies for a good helium pumping is possible by monitoring the behavior of the exhaust gas in helium-seeded plasma discharges in currently operating devices. In the framework of helium exhaust studies, a high-resolution quadrupole mass spectrometer has been recently installed at the pumping ducts of the ASDEX Upgrade tokamak. This diagnostic has been proven successful in discriminating molecules of deuterium and atoms of helium, which have a tiny mass difference of only 0,025 AMU, with elevated accuracy. The capability of detecting even trace levels of helium ($< 5\%$) in a deuterium gas has been confirmed. However, the harsh environment involving the presence of radiations and intense currents in proximity of the instrument is seen to strongly affect the reliability of the measurements during plasma operations. In this work we will present some of the challenges which were faced during the efforts towards the detection of helium in the exhaust gas of ASDEX Upgrade using this technique.

P 17.14 Fri 14:00 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), 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 fluxes 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 blobs have to be determined. While the measurements of mean blob velocities are possible with various diagnostics, the simultaneous non-invasive measurement of temperatures and densities of single filaments is now possible with the thermal helium beam diagnostic. By means of a grid of poloidally and radially distributed lines of sight, the temperature, density and velocities as well as the blob shape can be determined in two dimensions. Another way of measuring the filament temperature and density is beam emission spectroscopy, in the case here measured with a thermal helium beam diagnostic. First results of blob temperatures and densities will be shown and an extended collisional-radiative model will be presented.

P 17.15 Fri 14:00 P

Challenges in the tomographic reconstruction of radiation distributions of high temperature plasmas in Wendelstein 7-X stellarator — •Henning Thomsen, Christian Brandt, Sara Vaz Mendes, Kian Rahbarnbia, and Jonathan Schilling — MPI f. Plasmaphysics, Wendelsteinstr 1, 17491 Greifswald

The spatial-temporal dynamics of plasma radiation in the soft-X ray range is studied by means of the tomography diagnostic system (XMCTS) in Wendelstein 7-X stellarator. The radiation in this energy range originates mainly from Bremsstrahlung of the confined plasma. The quality tomographic inversion, the reconstruction of the radiation distribution in the plane spanned by the pinhole cameras from the line-integrated measurements, is strongly dependent on an accurate modelling of the diagnostic geometry. In this contribution we study the effect of the 3D shaped plasma in the observation volume. This effect is potentially more relevant in stellarators than in other magnetic confinement devices with simpler flux surfaces (like tokamaks).

P 17.16 Fri 14:00 P

Modelling of plasma ion heat flux in the edge of ASDEX Upgrade with EMC3-EIRENE for an improved understanding of the H-mode access — •Philipp Sauter[1,2], Thomas Eich[1], Dominik Brida[1], Marco Cavedon[1], Tilmann Lunt[1], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Universität Tübingen, 72074 Tübingen, Germany

The future nuclear fusion device ITER will be operated in an improved confinement regime.. The access to H-mode relies critically on the ion heat flux crossing the edge region of the plasma [1]. This work analyses the role of the ion heat flux on the transition from L-Mode to H-Mode The EMC3-Eirene simulation code is used to simulate plasma discharges in ASDEX Upgrade at different powers and densities with varying proportions of heating in electrons and ions. Parallel and perpendicular heat fluxes are obtained in order to quantify heat fluxes crossing the separatrix and being transported to the divertor. In particular, it is investigated if the collisional heat exchange from ions to electrons at high collisonalities is able to reduce the ion heat flux to a level where an H-L back transition is triggered. Also, the correlation of the ion electron temperature ratio at the separatrix with various plasma parameters is investigated. Here it is found that the ratio of ion to electron heat fluxes crossing the separatrix correlates with that ratio, while no correlation with the collisionality parameter suggested previously [2] was found. [1] Ryter F. et al 2016 PPCF 58 014007 [2] Stangeby P. 2000, The Plasma Boundary of Magnetic Confinement

P 17.17 Fri 14:00 P

Transport coefficients at W7-X based on target heat loads — •David Bold, Felix Reimold, Holger Niemann, Yu Gau, Marcin Jakubowski, and the W7-X team — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

In the current study the divertor heat load distribution of Wendelstein 7-X (W7-X) has been analysed based on heatfluxes reconstructed from infrared temperature measurements. Due to the inherent 3D nature of the scrape-off layer (SOL) of W7-X, also the heatflux pattern is 2D on the target in nature, unlike in Tokamaks, where a 1D representation is regularly used.

At low densities most of the heatflux is deposited on the low-iota target, as expected from modelling. A narrow strike line, overlayed by a broad feature is observed. The narrow strike line is of the range of 2 to 4 cm, while the broad feature is around 10 to 20 cm wide for an attached case with low radiated power. Additionally to studying the strike line width, also the toroidal distribution on the target is studied. It is observed that in the experiment a significant amount of the power is deposited at the far end of the low-iota target, while with increasing density the power is more evenly distributed on the low-iota target.

The analysis of the experimental data is compared to EMC3-EIRENE simulations, where the diffusion coefficients are varied in order to match the experimental results. It is observed that a simple, constant diffusion coefficient is not sufficient to reproduce the experimental measurements. The impact of spatially varying diffusion coefficients is studied.

P 17.18 Fri 14:00 P

Causality study on the drift-wave turbulence – zonal-flow coupling at the TJ-K stellarator. — •Nicolas Dumérat, Bernhard Schmid, and Mirko Ramisch — IGVP, University of Stuttgart

We present a set of two non-parametric methods used for inferring causality amongst parameters measured in the same complex system. Convergent cross-mapping, a forecasting approach is introduced, based on time-delay embedding and state space reconstruction. This method showed good results for measuring the strength and direction of influence of causal relationships in synthetic datasets. A second method, called transfer entropy, is also investigated, the basis of which is the measurement of information flow between variables. The use of these methods allows for the identification of causal links between variables and can be extended to turbulence studies. In this frame, it is known that zonal flows are driven by the localized tilting of ambient turbulent structures. This deformation of the eddies can be caused by existing shear flows and measured experimentally via Reynolds stress. Langmuir probe measurements from the TJ-K stellarator are then used as experimental inputs for the presented methods. The results support the theoretically expected causal connection of eddy tilting to zonal-flows occurance.

P 17.19 Fri 14:00 P

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

Magnetron Sputtering is a Plasma Vapour Deposition (PVD) process widely used in industry and scientific communities. HiPIMS (High Power Impulse Magnetron Sputtering) produces plasma pulses of very high density of the order of $10^{19}\mathrm{m}^{-3}$ without overheating the target. The plasma appears to be homogeneous to the human eye, but shows localised zones of high brightness rotating in the **E x B** direction when observed with an ICCD camera with exposure times below 1μs. These local ionization zones, also called 'spokes' are assumed to play a role in the transport of particles and energy away from the target. This anomalous transport results in an enhanced deposition rate by counteracting the return effect. The primary objective of this project is to control spoke frequency in HiPIMS in-order to study its influence on the IEDF and metal ion flux from the target. Controlling metal ion flux from the target would lead to a better deposition rate and quality of the film. 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.

P 17.20 Fri 14:00 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 Plasma Vapour Deposition (PVD) process widely used in industry and scientific communities. The plasma appears to be homogeneous to the human eye, but shows localised zones of high brightness rotating in the **E x B** direction when observed with an ICCD camera with exposure times below 1μs. These local ionization zones, also called 'spokes' are assumed to play a role in the transport of particles and energy away from the target. This anomalous transport results in an enhanced deposition rate by counteracting the return effect. The primary objective of this project is to control spoke frequency in HiPIMS in-order to study its influence on the IEDF and metal ion flux from the target. Controlling metal ion flux from the target would lead to a better deposition rate and quality of the film. 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 a Langmuir probe to draw electron current from the plasma at the highest gradients in the **E x B** direction. The responses of the spoke frequency and intensity to the applied signal are measured with a flat probe. The metal ion flux from the target surface is measured time and energy resolved with a mass spectrometer. This study is then further extended to HiPIMS spokes by applying signals on multiple probes to achieve an effective control of spokes.

P 17.21 Fri 14:00 P

Updates on The He/Ne beam diagnostic for line ratio spectroscopy in the Island Divertor of Wendelstein 7-X — Erik Flom[1], Tullio Barbui[1,2], Oliver Schmitz[1], Marcin Jakubowski[3], Frederik Henke[3], Carsten Killer[3], Maciej Krychowiak[3], Ralf Koenig[3], Stuart Loch[4], Jorge Munoz-Burgos[5], John Schmitt[4], and •The W7-X Team[3] — [1]University of Wisconsin-Madison, Madison, WI — [2]Princeton Plasma Physics Laboratory, Princeton, NJ — [3]Max Planck Institute for Plasma Physics, Greifswald, Germany — [4]Auburn University, Auburn, AL — [5]Astro Fusion Spectre, San Diego, CA

A line-ratio spectroscopy system based on thermal helium and neon collisional radiative models (CRM) has been implemented and successfully shown to enable measurement of ne and Te above the horizontal divertor targets in two in the standard divertor configuration magnetically connected modules of the Wendelstein 7-X optimized stellarator. In this work, modeling results are presented for standard attached and detached conditions in the divertor of Wendelstein 7-X to show the helium and neon emissivity as a function of radial position above the divertor target. This work also includes first in-situ measurements of gas cloud atomic density distribution from an gas injector identical to the one utilized at W7-X. Also shown are comparisons between helium beam data and multipurpose manipulator probe data using a novel flux coordinate system, an improvement over previous field-tracing methods for diagnostic comparison within the 5/5 island chain.

P 17.22 Fri 14:00 P

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

A tearing mode can be measured by various magnetic pick-up coil types characterized by their orientation and distance to the plasma and the surrounding conducting structures. Depending on the rotation frequency of the mode, screening currents are induced in these conductors that influence the magnetic measurements differently. A fast rotating mode can only be detected by the one coil type, whereas a locked mode signal is only available for the other type. In order to get a continuous description for all frequencies, a three-dimensional finite element model of the tokamak ASDEX Upgrade, including the geometry of the resonant surface of the tearing mode, the conducting vessel and passive stabilization loop (PSL), is implemented. The mode itself is described by a perturbation current density on the respective resonant surface from the equilibrium reconstruction. The simulated magnetic measurements of the mode, including the field of the mirror currents in the conducting structures, are used for a frequency dependent adaption of the experimentally determined magnetic perturbation field. The approach for adjusting the signals of the different types of magnetic measurements for various frequencies to get a unique perturbation amplitude, using the newly developed tool, is established and can be extended for the locked phase of the MHD mode.

P 17.23 Fri 14:00 P

Gaussian Process Surrogate Models for Uncertainty Quantification in Multiscale Turbulent Transport Simulations — •Yehor Yudin, Jalal Lakhlili, Onnie Luk, Udo von Toussaint, and David Coster — Max Planck Institute for Plasma Physics, Boltzmannstrasse2, 85748 Garching, Germany

One of the challenges in understanding fusion plasmas is quantifying the effects of micro-scale turbulent dynamics on energy and particle transport processes in a fusion device. In order to analyze such effects, one should numerically solve a model which couples system evolution on disparate spatial and temporal scales, as well as consider both aleatoric and epistemic uncertainty of such model. For such a solution the largest share of computational expense is spent on resolving turbulence related scales. This work proposes an application of a surrogate modelling approach to reduce computational costs for a solution in a case close to a quasi-steady state when it is sufficient to capture only statistics of turbulent dynamics. We studied a Multiscale Fusion Workflow that couples gyrofluid turbulence code GEM in flux tube approximation with core transport code ETS, and calculates transport coefficients from turbulent energy and particle fluxes. For that, we applied the VECMA toolkit to perform uncertainty quantification, as well as to train, test and utilize surrogate models. 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.

P 17.24 Fri 14:00 P

Extension of GENE-3D to a global electromagnetic turbulence code for stellarators — •Felix Wilms[1], Alejandro Bañón Navarro[1], Gabriele Merlo[2], Leonhard Leppin[1], Tobias Görler[1], Tilman Dannert[3], Florian Hindenlang[1], and Frank Jenko[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching b. München, Germany — [2]Oden Institute for Computational Engineering and Sciences, Austin,Texas 78712, USA — [3]Max Planck Computing and Data Facility, 85748 Garching, 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. In this work, we present the underlying algorithm, together with verification studies against the established global tokamak code GENE (Jenko et al., Physics of Plasmas, 2000). Finally, we present a first application to stellarator physics, by investigating the influence of finite plasma-β on ITG turbulence in Wendelstein 7-X.

P 17.25 Fri 14:00 P

Study of slow wave propagation in IShTAR — •Felix Paulus, Volodymyr Bobkov, Roman Ochoukov, and Oleksii Girka — Max-Planck-Institute fürPlasmaphysik, Boltzmannstr. 2, 85748 Garching

Ion cyclotron resonance heating (ICRH) is an established technique to reach fusion relevant temperatures in modern tokamaks. While the fast Alfven wave is launched intentionally to heat the plasma, it is believed that the parasitically launched slow wave is a source for electric fields parallel to the background magnetic field (Myra & D'Ippolito, 2008). Since the slow wave (sw) propagates in low density plasma its existence remained unconsidered in tokamaks for a long time. Recent developments suggest, that the plasma density in the far SOL of a tokamak drops below the lower hybrid resonance density opening a channel for sw propagation which might induce further plasma dynamics.

Here we show results from experiments carried out on IShTAR - a linear plasma device - where we measure the slow wave, that is launched into a magnetized low-density plasma by a wire loop antenna, with a floating probe. The results are compared to FEM simulations from RAPLICASOL (Tierens, et al., 2019) and further analytical considerations. Based on these results future experiments on the ASDEX Upgrade tokamak are proposed.

P 17.26 Fri 14:00 P

Divertor optimization for the stellarator experiment W7-X —

•Amit Kharwandikar, Dirk Naujoks, Thomas Sunn Pedersen, Felix Reimold, and The W7X Team — Max Planck Institute for Plasma Physics, Greifswald, Germany

The Wendelstein 7-X (W7-X) is an advanced stellarator device operated in Greifswald, to provide the proof of principle that the stellarator concept can meet the requirements of a future fusion reactor. To fulfil this goal, several experimental campaigns have been conducted over the years. In the recent OP1.2 campaign, ten adiabatically loaded divertor units (Test Divertor Units (TDU)) have been installed in the plasma vessel together with baffles, toroidal/poloidal closures, etc. During the experiments, high heat loads onto in-vessel components have been observed, that exceed the specified limits under certain conditions. This immediate concern and the need to transition to fusion reactor relevant material (e.g. Tungsten) for plasma facing components (PFC) to achieve the long-term goals, motivate the need for a new divertor design. This poster discusses the investigation of the physics basis for such a new divertor concept with the objectives as heat load reduction and high gas exhaust. The important technical constraints are specified as well as the main modelling tools to be used, namely the Field Line Transport (FLT) code and EMC3-Eirene. As a current activity, example applications of FLT for studying erosion-redeposition and certain baffle overload scenarios have been described. Finally, the main conceptional ideas to achieve the desired optimized plasma facing surface for the W7-X divertor and baffle are presented.

P 17.27 Fri 14:00 P

Manipulating the radial deposition of positrons in a magnetic dipole trap — •Stefan Nissl[1,2], Eve Stenson[1,2,3], Juliane Horn-Stanja[1], Uwe Hergenhahn[1,7], Thomas Sunn Pedersen[1,4], Haruhiko Saitoh[6], Christoph Hugenschmidt[2], Markus Singer[2], Matthew Stoneking[1,5], and James Danielson[3] — [1]Max-Planck-Institute for Plasma Physics, Greifswald & Garching, Germany — [2]Technische Universität München, Garching, Germany — [3]University of California, San Diego, La Jolla, CA — [4]University of Greifswald, Greifswald, Germany — [5]Lawrence University, Appleton, WI — [6]The University of Tokyo, Tokyo, Japan — [7]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

In a pair plasma, both particle species have the same mass. Compared to an electron-ion plasma, a pair plasma is predicted to have unique characteristics and excellent stability properties. A Positron-Electron eXperiment (APEX) has the goal to create such a kind of plasma in a magnetic dipole trap for the first time. An important step towards this goal is to know how parameters of the experiment, such as electrode biases, effect the radial deposition of positrons in the magnetic dipole field. For that, we reanalyzed experimental data, compared them to numerical single-particle simulations, and found multiple parameters that modify the radial deposition of positrons without deteriorating the required high injection efficiency. These results can be used to design upcoming experiments about long confinement and pulse stacking.

P 17.28 Fri 14:00 P

Investigating impurity transport at the plasma edge in different confinement regimes at ASDEX Upgrade via charge exchange recombination spectroscopy — •Tabea Gleiter[1,2], Ralph Dux[1], Marco Cavedon[1], Rachael McDermott[1], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Physik-Department E28, Technische Universität München, Garching, Germany

In our recently started project, we investigate the impurity transport at the plasma edge in different confinement regimes at ASDEX Upgrade. In particular, we look at scenarios without or with only small (type-II) edge localized modes (ELMs), such as the I-mode, QCE-mode and EDA-H mode, in comparison to the standard type-I ELMy H-mode. Due to the considerable influence of ELMs on the particle exhaust at the plasma edge, the impurity transport is expected to differ significantly. This is especially of interest since future tokamaks such as ITER and DEMO could benefit from the reduced peak power fluxes at the divertor in 'ELM-free' regimes, but are also reliant on small impurity concentrations in the plasma core. In our experiments, we use active charge exchange recombination spectroscopy (CXRS) to study the temporal and radial evolution of the impurity densities. The detailed approach and first results will be presented.

P 17.29 Fri 14:00 P

Early stages of He cluster formation in tungsten single crystals — •Annemarie Kärcher[1,2], Vassily V. Burwitz[2], Thomas Schwarz-Selinger[1], and Wolfgang Jacob[1] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Technische Universität München, 85747 Garching, Germany

Tungsten (W) has been established as a main candidate for plasma-facing materials (PFMs) in future nuclear fusion reactors due to its favorable properties regarding the fusion environment. As PFM, tungsten will be subjected to intense impinging fluxes of helium (He). While the consequences of high He fluxes on the surface of tungsten materials have already been thoroughly studied, the mechanisms behind the early stages of the He cluster formation are still unclear. In order to understand the initial steps of the interaction of He with W, especially the impact of pre-existing defects, defined defects are induced in W111 single crystals and characterized by positron annihilation spectroscopy (PAS). Then, these are exposed to a low-temperature He plasma using an implantation energy below the displacement theshold. These He implanted samples are measured by PAS, elastic recoil detection analysis and thermal desorption spectroscopy. The experimental results are compared to simulation data.

P 17.30 Fri 14:00 P

Semilagrangian hybrid kinetic/driftkinetic code for the studying of fusion plasmas — •Aleksandr Mustonen[1], Felipe Nathan de Oliveira[1], Ken Hagiwara[2], Karen Pommois[1], Florian Allman-Rahn[3], Simon Lautenbach[3], Rainer Grauer[3], and Aleksandr Mustonen[3] — [1]Max-Planck-Institut für Plasmaphysik — [2]Ludwig-Maximilians-Universität München — [3]Ruhr-Universität Bochum

Modeling of the tokamak edge plasma is one of the most important problems we have to solve to achieve understanding of physics, taking place in the device. A lot of currently existing and well known codes used by the community employ gyrokinetic system of equations. This is a framework to resolve kinetic equations on a reduced 5D space, applicable for charged particles moving in a strong background magnetic field and valid until the phenomena scale gets as small as the Larmor radius. Presence of steep gradients at the edge region prevents us from usage of GK models in their present state.

One of the ways to avoid this complication is to use a fully kinetic 6D framework. However, the immense computational cost of such a direct approach makes it ill-suited for longtime simulations. Here we discuss the hybrid framework and its implementation in the ssV: a semi Lagrangian electrostatic code with fully kinetic ions and driftkinetic electrons to completely resolve ion physics and save computational resources on electrons, while retaining the most important kinetic effects. New found hybrid wave explained with the help of analytical dispersion solver FIDEL. Slab ITG testcase discussed.

P 17.31 Fri 14:00 P

Steps for implementation of divertor protection algorithms at Wendelstein 7-X — •Manuel Agredano-Torres[1], Simon Fischer[1], Heike Laqua[1], Aleix Puig Sitjes[1], Hans-Stephan Bosch[1], Wolfgang Treutterer[2], Axel Winter[1], and Wendelstein 7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Max-Planck-Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

Wendelstein 7-X (W7-X) is the world's largest stellarator experiment and aims to proof the viability of stellarator devices as power plants. It is being upgraded including the installation of actively cooled divertors. In order to avoid damage in the divertors, their temperatures have to be kept below their maximum limit and a protection system, as part of W7-X control system, is required to ensure it. The divertors protection is based on the data obtained from thermography diagnostics. Fast Control Stations process the data in real-time to determine the risk of surpassing a temperature limit. In the next operational campaign, if the risk reaches a determined threshold, an alarm is triggered so the Safety System can act on time and stop the operation of the device. The final goal of the protection system is to allow a continuous operation W7-X, avoiding the overheating of the divertors by feedback control of heating systems and control coils. This contribution presents the overall system required for the divertors protection including relevant diagnostics and W-7X control system, an overview of the protection algorithms and the planning for their real-time implementation in the control system before the next operational campaign.

P 17.32 Fri 14:00 P

3D Monte-Carlo PIC modeling of plasma grid biasing and the co-extraction of electrons in negative ion sources — •Max Lindqvist[1], Dirk Wünderlich[1], Alessandro Mimo[1], Serhiy Mochalskyy[1], Adrien Revel[2], Tiberiu Minea[2], and Ursel

Fantz[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Universite Paris-Saclay, CNRS, LPGP, Orsay, France

One of the factors limiting the performance of negative ion sources for the ITER Neutral Beam Injection (NBI) system is the co-extraction of e^-. By varying the positive bias potential of the Plasma Grid (PG) with respect to the source walls, the amount and temporal instability of co-extracted e^- is strongly decreased. This study investigates the mechanisms of this process by varying the bias of the PG using the already established 3D Monte-Carlo PIC code ONIX. The simulation domain covers the extraction region near one of the PG apertures in the ELISE ion source. In previous PIC simulations of this type, the boundary from the bulk plasma to the simulation domain is characterized by an artificial plasma sheath. Here, for the first time in a 3D PIC code for NBI sources, a flat potential transition is simulated, which allows for biasing the PG without extending the simulation domain to the source walls. Instead, the bias has been indirectly applied by varying the PG potential from −5 V (close to floating) to 1 V (e^- attracting sheath) with respect to the plasma potential. In agreement with experimental results, the co-extracted e^- current is decreased by over 50 %, caused by an increased flux of e^- towards the top and bottom of the PG, following the magnetic field lines.

P 17.33 Fri 14:00 P

Gyrokinetic modelling of anisotropic energeticparticle driven instabilities in tokamak plasmas — •Brando Rettino, Alberto Bottino, Alessandro Biancalani, Thomas Hayward-Schneider, Philipp Lauber, and Markus Weiland — Max Planck Institute for Plasma Physics, Garching, Germany

Energetic particles produced by plasma heating can excite instabilities in tokamaks. We study the effects of anisotropy of distribution functions on the excitation of such instabilities with ORB5, a gyrokinetic particle in cell code. Analytical anisotropic expressions for the distribution function are implemented and 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. Realistic neutral beam energetic particle anisotropic distributions are obtained from the heating solver RABBIT and are introduced in ORB5 as input distribution function.

P 17.34 Fri 14:00 P

Non-local neoclassical PIC simulations for the radial electric field in stellarators — •Michal Kuczynski, Ralf Kleiber, and Hakan Smith — Wendelsteinstraße 1, 17491 Greifswald

Transport in fusion plasma devices has typically two contributions: turbulent and neoclassical. The latter is most significant in stellarators and thus, for further experimental advances, a thorough understanding of the neoclassical transport is required. Perhaps one of the greatest achievements of the (local) neoclassical theory is the prediction of the neoclassical radial electric field. However, the theory has its limitations. For instance, when the electric field changes sign (at the transition zone between the ion and electron roots), the theory may predict multiple values of the radial electric field, which is unphysical. To understand the physics in such scenarios we perform neoclassical PIC simulations with the addition of non-local terms and calculate the resultant electric field self-consistently.

P 17.35 Fri 14:00 P

Analysis of optimal quasi-isodynamic stellarator magnetic equilibria using a direct construction approach — •Katia Camacho Mata, Gabriel Plunk, Per Helander, and Michael Drevlak — 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, those in which the time-averaged radial drift is zero, fulfill the good confinement properties requirement. Such configurations are traditionally found by numerical optimization, but these designs have been generally found to feature complex coils. However, it is unknown whether such complexity is fundamentally necessary. To explore this question, we will use a recently developed [1] method for the direct construction of omnigenous MHD(Magnetohydrodynamic) equilibria, which avoids the computational cost of conventional optimization, allowing a thorough survey of the space of omnigenous stellarators at large aspect ratio. We present an analysis of such solutions, focusing on the quasi-isodynamic case, a particular case of omnigeneity.

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

P 17.36 Fri 14:00 P

Active learning and data augmentation using surrogate models of time series — •Katharina Rath[1,2], Christopher G. Albert[2], Bernd Bischl[1], and Udo von Toussaint[2] — [1]Ludwig-Maximilians-Universität München, Munich, Germany — [2]Max-Planck-Institut für Plasmaphysik, Garching, Germany

A comprehensive training data base is important to obtain satisfying and reliable results when working with neural networks. Gaussian processes (GPs) can act as surrogate models to enlarge the training data base and additionally provide the covariance structure. However, the computational complexity of standard GP regression increases with the third power of training data points and outliers are punished very severely, leading to unreliable uncertainty estimates. These drawbacks complicate the application of standard GP regression to noisy high-resolution time series data. Here, these difficulties are addressed using Student-t processes allowing a heavy tailed noise distribution in combination with a state space representation. While the Student-t process itself is more robust against outliers, the state space representation allows regression with computational complexity of order n, and thus can also be used if the time resolution is high. Besides a robust surrogate model for a comprehensive data base, the uncertainty estimates resulting from the stochastic process can be used in an active learning framework to determine which additional measurement data need to be incorporated in the training data set. The intended application is the robust augmentation of the training data base for the prediction of plasma disruptions.

P 17.37 Fri 14:00 P

Simulations of massive Deuterium injection into an MHD active ASDEX Upgrade plasma — •Fabian Wieschollek[1], Matthias Hoelzl[1], Eric Nardon[2], the JOREK Team[3], and the ASDEX Upgrade Team[4] — [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 — [4]See the author list of H. Meyer et al 2019, NF 59, 112014

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.

In this work, we investigate the interaction of Deuterium SPI and a pre-existing 2/1 NTM in ASDEX Upgrade to assess its potential impact onto the mitigation strategy by means of the non-linear MHD code JOREK. Scans are performed of the initial island width, the number of atoms injected, and the relative injection phase with respect to the island O-point. Results indicate that preexisting islands do not render the mitigation ineffective. In case of small initial island sizes, no significant influence onto thermal quench (TQ) timing is observed independently of the injection phase. In case of larger islands, a delayed island growth and TQ onset is observed. This observation only changes when the injection is located to the direct vicinity of the X-point.

The studies are currently extended to take background impurities and multiple injection points into account.

P 17.38 Fri 14:00 P

Innovative Non-Resonant Divertors Applied to Compact Toroidal Hybrid (CTH) — •Kelly Garcia[1], Aaron Bader[1], Oliver Schmitz[1], John Schmitt[2], and Gregory Hartwell[2] — [1]University of Wisconsin-Madison, Madison, WI, United States of America — [2]Auburn University, Auburn, AL, United States of America

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. In contrast, island divertor configurations make use of low order rational surfaces with large islands mediating the confined plasma and the wall. These islands are highly sensitive to the value and shear of the rotational transform which can be affected by the evolution of the plasma equilibrium. CTH (Compact Toroidal Hybrid) can serve as a test-bed for the non-resonant divertor solution for divertor optimization. The currents in the field coil and ohmic current drive systems of CTH are controlled to alter the rotational transform between $0.3 < \iota < 0.75$. Utilizing the FLARE field-line following code, we calculate strike point locations for the exiting plasma for multiple ohmic current values. These calculations provide possible locations for divertor plates that will be built in the experiment to test non-resonant divertor resiliencies. These same techniques can be applied to other machines including ones that use the island divertor in the standard operation, like W-7X.

P 17.39 Fri 14:00 P

Experimental Survey of Plasma-Terminating Events in the Wendelstein 7-X Stellarator — •Jonathan Schilling, Henning Thomsen, Christian Brandt, Kian Rahbarnia, Ekkehard Pasch, Marc Beurskens, Sergey Bozhenkov, Hannes Damm, Golo Furchert, Evan Scott, Matthias Hirsch, Neha Chaudhary, Karsten Ewert, Udo Höfl, Johan Willem Oosterbeek, Torsten Stange, Gavin Weir, Jens Knauer, Tsuyoshi Akiyama, Kai Jacob Brunner, Tamara Andreeva, Ulrich Neuner, Oliver Ford, Sehyun Kwak, Andera Pavone, Jakob Svensson, Marco Zanini, and the W7-W Team 1 — Max-Planck-Institute for Plasma Physics, Greifswald, Germany

An experimental data survey is conducted with a focus on global fast plasma-terminating events in the Wendelstein 7-X stellarator. These events associated with significant current drive may pose a risk for machine safety and need to be understood for reliable plasma operation in a future fusion power plant. Several such events were observed in recent campaigns of Wendelstein 7-X. Tomographic reconstruction of the soft X-ray emission pattern from the plasma allows to assess the spatio-temporal dynamics of these events with the necessary high resolution ($f_s = 2$ MHz; $\Delta R = \Delta Z = 4$ cm). Those results are subsequently compared to experimental data from the Thomson scattering diagnostic (n_e, T_e profiles), the electron cyclotron emission diagnostic (T_e profile) and the single-channel interferometer ($\int n_e dl$).

P 17.40 Fri 14:00 P

Single-shot grating-based phase-contrast imaging at a laser-driven x-ray backlighter source — •Bernhard Akstaller, Stephan Schreiner, Max Schuster, Andreas Wolf, Veronika Ludwig, Thilo Michel, Gisela Anton, and Stefan Funk — Friedrich-Alexander Universität Erlangen-Nürnberg

We used a sub-picosecond x-ray flash, produced by a high-power laser and a tungsten backlighter wire, for phase-contrast imaging with short exposure times. With this, we demonstrated the feasibility of imaging a micron-sized (static) sample with a single-shot grating-based phase-contrast imaging setup. The obtained data is quantitatively analyzed and an enhancement of image quality is evaluated. The presented imaging technique allows to capture sharp images of fast dynamic processes like laser-produced plasma shock waves in the field of laboratory astrophysics, even if the absorption contrast is very low. The data was taken at the Petawatt High-Energy Laser for Heavy Ion Experiments at the GSI Helmholtzzentrum für Schwerionenforschung GmbH.

P 17.41 Fri 14:00 P

Comparison of Laser Induced Breakdown Spectroscopy (LIBS) results on deuterium loaded high Z materials from lasers of different pulse durations — •Steffen Mittelmann[1], Jannis Oelmann[2], Ding Wu[3], Gennady Sergienko[2], Sebastijan Brezinsek[2], Hongbin Ding[3], and Georg Pretzler[1] — [1]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf, Germany — [2]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, Germany — [3]Key Laboratory of Material Modification by Laser, Ion and Electron Beams, Dalian University of Technology, China

Impurities in the wall material of upcoming fusion reactors can endanger the lifetime and quality of the confined plasma. To get an idea of deuterium or tritium retention at the wall the diagnostic Laser induced breakdown spectroscopy (LIBS) is used. This widely applied technique is executed by lasers with different pulse durations from ns to fs. A big advantage of ultrashort laser pulses is the well-defined ablation area which leads to a high depth resolution. The results from LIBS experiments on tantalum exposed by deuterium in the linear plasma device PSI-2 with this laser system can be compared to ns- and ps-LIBS signals produced at Dalian University of Technology in China and the FZ Jülich, which are shown here. An important aim of these studies is to reach a deeper understanding of the basic processes governing ablation, plasma formation and spectral emission in the different pulse duration regimes for finally deciding which type of laser pulses is the most promising for future fusion reactor wall analysis.

P 17.42 Fri 14:00 P

The uniform electron gas in the thermodynamic limit: fermionic path integral Monte Carlo simulations — •Alexey Filinov[1,2], Pavel Levashov[2], and MichaeI Bonitz[1] — [1]Institut für Theoretische Physik und Astrophysik, CAU Kiel — [2]Joint Institute for High Temperatures, RAS, Moscow

The uniform electron gas (UEG) is one of the key models for the understanding of warm dense matter–an exotic, highly compressed state of matter between solid and plasma phases. The difficulty in modeling the UEG arises from the need to simultaneously account for Coulomb correlations, quantum and exchange effects. The most accurate results so far were obtained from QMC simulations. However, QMC for electrons is hampered by the fermion sign problem. Here we present results from a novel fermionic-propagator path integral Monte Carlo (FP-PIMC) in the restricted grand canonical ensemble (R-GCE). The ab-initio simulation results for the spin-resolved pair distribution functions and static structure factor are reported for two isotherms $T/T_F = 1, 2$. Furthermore, we combine the results from the linear response theory in the STLS-scheme with the QMC data to remove finite-size errors in the interaction energy. We present a new corrected parametrization for the interaction energy $v(r_s, \theta)$ and the exchange-correlation free energy $f_{\mathrm{xc}}(r_s, \theta)$ in the thermodynamic limit, and benchmark our results against the RPIMC by Brown *et al.* [Phys.Rev.Lett. **110**, 146405 (2013)] and PBPIMC by Dornheim *et al.* [Phys. Rev.Lett. **117**, 115701 (2016)].

P 17.43 Fri 14:00 P

Optimized electron injection into a linear plasma wakefield by means of laser-solid interaction — •Vadim Khudiakov and Alexander Pukhov — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

We explore a hybrid plasma acceleration scheme via numerical simulations. The key feature of the method is to inject an electron bunch generated from laser-solid interaction into appropriate phase of a plasma wave. Recent work [1] demonstrates that a femtosecond laser pulse with energy of tens of mJ hitting a dense plasma target at 45 degrees angle expels well collimated electrons and accelerates them up to several MeVs in a direction close to pulse refection. In our work we reproduce these results with 3d particle-in-cell simulations using VLPL code and examine different injection parameters: injection angle, phase of plasma wake, laser pulse amplitude, in order to optimize trapped charge. An approximate trapping condition is derived for theoretical estimation of optimal injection parameters and is verified in simulations. Acceleration in a linear quasi-static wave with the parameters of AWAKE experiment provides bunches feature ~100 pC charge, ~60 micrometers transverse normalized emittance, and energies of several GeV with spread ~1%.

[1] I. Tsymbalov et al., Plasma Phys. Control. Fusion 61 (2019) 075016.

P 17.44 Fri 14:00 P

Time-resolved simulations of laser-induced ionization in the tunneling regime — •Michael Stumpf and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Ionization rate calculations are a common and necessary tool to simulate the interaction of laser pulses with matter. We used the ADK model and compared it with experimental results. For our simulations, we calculated the exact temporal and spatial field distributions within a fs-laser focus with high precision and used quasi-static approximations to simulate the ionization rates. In order to verify our simulations, we experimented with a wide range of parameters using the PHASER few-cycle Ti:Sa-system in Düsseldorf and a novel pulse energy attenuator as well as a new beam-shaping device called AMBER (Axicon Mirror Beam ExpandeR). The results are used to design the internal injection of electrons inside of a Plasma Wakefield structure following the Trojan Horse Injection model.