Plasma Physics Division
Fachverband Plasmaphysik (P)

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Overview of Invited Talks and Sessions

(Lecture halls b302 and b305; Poster Empore Lichthof)

Invited Talks

P 2.1	Mon	11:00–11:30	b305	**Streamer inception and imaging in various atmospheres** — •Sander Nijdam, Siebe Dijcks, Shahriar Mirpour
P 3.1	Mon	14:00–14:30	b302	**Diagnostics of magnetized high frequency technological plasmas** — •Julian Schulze, Moritz Oberberg, Birk Berger, Jens Kallähn, Dennis Engel, Christian Wölfel, Jan Lunze, Ralf Peter Brinkmann, Peter Awakowicz
P 4.1	Mon	14:00–14:30	b305	**Physics studies with high-power electron cyclotron heating (ECRH) on ASDEX Upgrade** — •Jörg Stober, ASDEX Upgrade Team
P 6.1	Tue	11:00–11:30	b302	**Predictive modelling of beryllium erosion, transport and deposition during H, He and DT plasmas in ITER** — •Juri Romazanov, Sebastijan Brezinsek, Andreas Kirschner, Dmitriy Borodin, Alina Eksaeva, Richard A. Pitts, Vladislav S. Neverov, Christian Linsmeier
P 7.1	Tue	11:00–11:30	b305	**Simulation of microarcs: challenges and perspectives** — •Margarita Baeva, Detlef Loffhagen, Markus M. Becker, Erwan Siewert, Dirk Uhrlandt
P 9.1	Tue	14:00–14:30	b305	**The Wendelstein 7-X Scrape-Off Layer** — •Carsten Killer, W7-X Team
P 11.1	Wed	11:00–11:30	b302	**Visualizing the Dynamics of a Plasma-Based Particle Accelerator** — •Malte Kaluza
P 12.1	Wed	11:00–11:30	b305	**Surface modification with atmospheric-pressure plasmas - applications and challenges** — •Claus-Peter Klages, Lars Bröcker, Andreas Czerny, Stefan Kotula, Meret Leonie Lehner, Andris Martinovs, Vitaly Raev
P 15.1	Wed	14:00–14:30	b305	**How turbulence sets boundaries for fusion plasma operation** — •Peter Manz, Thomas Eich, the ASDEX Upgrade Team
P 18.1	Thu	11:00–11:30	b302	**Experiments on Binary Dust Mixtures** — •Frank Wieben, Dietmar Block
P 18.2	Thu	11:30–12:00	b302	**Structure and transport in magnetized gas discharges related to dusty plasmas** — •Peter Hartmann, Marlene Rosenberg
P 20.1	Thu	14:00–14:30	b302	**The interaction of lasers with material using pulse durations from fs to ns** — •Georg Pretzler, Steffen Mittelmann, Jannis Oelmann, Julian Wegner, Sebastijan Brezinsek
P 21.1	Thu	14:00–14:30	b305	**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

Invited talks of the joint symposium SYAI

See SYAI for the full program of the symposium.

SYAI 1.1	Mon	14:00–14:30	e415	**Atom interferometry and its applications for gravity sensing** — •Franck Pereira dos Santos, Luc Absil, Romain Caldani, Xiaobing Deng, Romain Karcher, Sébastien Merlet, Raphaël Piccon, Sumit Sarkar
SYAI 1.2	Mon	14:30–15:00	e415	**Atom interferometry for advanced geodesy and gravitational wave observation** — •Philippe Bouyer
SYAI 1.3	Mon	15:00–15:30	e415	**Fundamental physics with atom interferometry** — •Paul Hamilton
SYAI 1.4	Mon	15:30–16:00	e415	**Atoms and molecules interacting with light** — •Lucia Hackermüller

Invited talks of the joint symposium SYAD

See SYAD for the full program of the symposium.

SYAD 1.1	Tue	11:00–11:30	e415	**Electron Pulse Control with Terahertz Fields** — •Dominik Ehberger
SYAD 1.2	Tue	11:30–12:00	e415	**Laser-Based High-Voltage Metrology with ppm Accuracy** — •Kristian König, Christopher Geppert, Phillip Imgram, Jörg Krämer, Bernhard Maass, Johann Meisner, Ernst Otten, Stephan Passon, Tim Ratajczyk, Johannes Ullmann, Wilfried Nörtershäuser
SYAD 1.3	Tue	12:00–12:30	e415	**Structured singular light fields** — •Eileen Otte
SYAD 1.4	Tue	12:30–13:00	e415	**Coherent Coupling of a Single Molecule to a Fabry-Perot Microcavity** — •Daqing Wang

Sessions

P 1.1–1.2	Sun	16:00–18:00	a310	**Tutorial Plasma Physics (joint session AKjDPG/P)**
P 2.1–2.5	Mon	11:00–12:30	b305	**Atmospheric-pressure plasma and applications 1**
P 3.1–3.5	Mon	14:00–15:30	b302	**Low-temperature plasma and applications 1**
P 4.1–4.5	Mon	14:00–16:00	b305	**Helmholtz Graduate School 1 and Magnetic confinement 1**
P 5.1–5.38	Mon	16:30–18:30	Empore Lichthof	**Poster Session 1**
P 6.1–6.6	Tue	11:00–12:55	b302	**Plasma-surface interaction**
P 7.1–7.7	Tue	11:00–13:00	b305	**Atmospheric-pressure plasma and applications 2**
P 8.1–8.5	Tue	14:00–15:25	b302	**Low-temperature plasma and applications**
P 9.1–9.5	Tue	14:00–16:10	b305	**Helmholtz Graduate School 2 and Magnetic confinement 2**
P 10.1–10.35	Tue	16:30–18:30	Empore Lichthof	**Poster Session 2**
P 11.1–11.7	Wed	11:00–13:00	b302	**Laser plasma and laser applications 1**
P 12.1–12.6	Wed	11:00–12:45	b305	**Atmospheric-pressure plasma and applications 3**
P 13.1–13.1	Wed	13:10–13:55	f303	**Lunch talk: German Research Foundation (DFG) (joint session A/K/P/MO/MS/Q)**
P 14.1–14.7	Wed	14:00–15:55	b302	**Codes and modelling**
P 15.1–15.6	Wed	14:00–16:05	b305	**Helmholtz Graduate School 3 and Magnetic confinement 3**
P 16.1–16.33	Wed	16:30–18:30	Empore Lichthof	**Poster Session 3**
P 17	Wed	18:30–20:00	b305	**Mitgliederversammlung**
P 18.1–18.6	Thu	11:00–13:10	b302	**Complex plasma and Low-temperature plasma and applications 2**
P 19.1–19.6	Thu	11:00–13:10	b305	**Helmholtz Graduate School 4 and Magnetic confinement 4**
P 20.1–20.7	Thu	14:00–16:00	b302	**Laser plasma and laser applications 2**
P 21.1–21.5	Thu	14:00–16:00	b305	**Helmholtz Graduate School 5**

Annual General Meeting of the Plasma Physics Division

Wednesday 18:30–20:00 b305

- Bericht
- Wahl

- Verschiedenes

P 1: Tutorial Plasma Physics (joint session AKjDPG/P)

Time: Sunday 16:00–18:00 Location: a310

Tutorial P 1.1 Sun 16:00 a310

Plasmas at atmospheric pressure: Overview on Physics and Applications — •Ronny Brandenburg — Leibniz-Institut für Plasmaforschung und Technologie e.V., Greifswald, Germany — Universität Rostock, Rostock, Germany

Plasmas at atmospheric pressures gain more and more attention, both in research and industry. A variety of plasma sources exist and the applications span a wide spectrum from material processing and chemical conversion to surface treatment and therapeutic usage. Despite the wide use and application, there are still challenges from the fundamental point of view. These plasmas are often characterized by rapid gas breakdown, transient and erratic behaviour, and formation of instabilities.

The tutorial gives an introduction about plasmas at atmospheric pressure. The principles of plasma generation at elevated pressures, in particular the breakdown mechanisms will be explained in the first part of the tutorial.

Plasmas at atmospheric pressure span a wide range of types with different parameters. The most general distinction is made between thermal and non-thermal plasmas. Both forms, its generation and the technologcial applications are explained.

Tutorial P 1.2 Sun 17:00 a310

Introduction to High-Temperature Plasma Physics — •Golo Fuchert — Max-Planck-Institut für Plasmaphysik, Greifswald, Deutschland

Although not always noticed in daily life, plasmas are surprisingly common, both in the universe and in the lab. A plasma is a essentially a "gas" of electrons and ions with no net charge to the outside. This gives rise to collective behavior and complex dynamics of particles. This is especially true in the presence of magnetic fields, as it is often found in astrophysical plasmas and in magnetically confined plasmas for fusion research. In this tutorial lecture, after introduction the basic characteristics of plasmas, we are going to look at common examples of high-temperature plasmas, theoretical methods to describe their dynamics and experimental methods to study them.

P 2: Atmospheric-pressure plasma and applications 1

Time: Monday 11:00–12:30 Location: b305

Invited Talk P 2.1 Mon 11:00 b305

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 and can directly compare these against numerical results, thereby also giving unprecedented insights into the fundamentals of such discharges.

P 2.2 Mon 11:30 b305

Time and space resolved electron dynamics in a microplasma channel — •Simon Kreuznacht, Sebastian Dzikowski, Marc Böke, and Volker Schulz-von der Gathen — Experimental Physics II, Ruhr University Bochum, Germany

Microplasma arrays have been under investigation for a long time. These are special dielectric barrier discharges at atmospheric pressure. It is possible to generate a homogeneous discharge with these microplasma arrays over a large area by the parallel operation of many identical cavities. The microplasma arrays are operated in Helium with a triangular voltage with a frequency of about 10 kHz and an amplitude of about 700 V. The microplasma channel, that will be presented here, represents a single cavity of the microplasma arrays. This channel provides optical access to the inside of the cavity from the top and unlike the microplasma arrays from the side. A fast gated, intensified CCD camera was used to investigate the discharge. Phase-resolved images, that were taken with line of sight from the top into the channel, showed that the discharges in the microplasma channel and the microplasma arrays behave similar. With phase-resolved images from the side it was possible to gain new insights into the time and space resolved electron dynamics of the discharge.

P 2.3 Mon 11:45 b305

Breakdown and development of sub-ns pulsed spark discharges in short gaps under overvoltage conditions — •Hans Höft[1] and Tom Huiskamp[2] — [1]Leibniz-Institut für Plasmaforschung und Technologie e.V. (INP Greifswald), Felix-Hausdorff-Straße 2, 17489 Greifswald, Germany — [2]Eindhoven University of Technology, Dept. of Electr. Engineering, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

Spark discharges were ignited by unipolar positive and negative rectangular HV pulses with 200 ps rise time and (15 ± 2) kV amplitude with 3 ns duration (FWHM) in N_2 and synthetic air in a 1.2 mm pin-to-pin gap (tungsten electrodes) at atmospheric pressure. The breakdown and development of the discharges were tracked by synchronised iCCD and streak camera recordings (temporal resolution up to 5 ps, spatial resolution 2 μm) in single shot operation. A two-stage breakdown regime was found, which—to the best of our knowledge—was documented for the first time. The discharge starts with a fast initial breakdown over the complete gap ($\sim 10^7$ m/s) followed by a much slower ($\sim 10^5$ m/s) propagation from both electrodes towards gap centre. There is a significant difference between positive and negative HV pulses during the initial breakdown phase, while the general discharge structure stays more or less the same, and is only slightly affected by the gas mixture. A possible explanation of the initial rapid breakdown could be field emission caused by the extremely fast rising electric field due to the steep HV slope rising with > 50 kV/ns.

P 2.4 Mon 12:00 b305

Electric field measurements in ns-APPJ with sub-ns time resolution — •Nikita Lepikhin, Dirk Luggenhölscher, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany

The work is dedicated to electric field, E, measurements in a nanosecond pulsed atmospheric pressure plasma. Due to a high reduced electric field, E/N, providing efficient excitation of the electronic states of atoms or molecules, nanosecond discharges are widely used as a source of non-thermal reactive plasmas in a variety of applications: surface treatment, plasma medicine, plasma flow control, plasma assisted ignition and combustion. The reduced electric field is the key information for plasma kinetic studies. Known temporal profiles of E/N in the discharge allow to determine the electron energy distribution function evolution and, consequently, the discharge development. Experimentally measured E/N profile accompanied by electric current measurements can be used as a benchmark to verify plasma kinetic models. In this work, the electric field in a ns-discharge in a He:N_2 mixture is studied with sub-ns time resolution. Electric-Field Induced Second Harmonic generation (E-FISH) is used as a measurement technique [A. Dogariu et. al., Phys. Rev. Appl. 7 (2017)]. A laser beam is focused into the discharge gap and in the presence of an electric field a coherent signal beam at the second harmonic of the laser frequency is generated. The method is non-resonant and can be used for any gases. The technique provides the absolute value of the electric field as well as its direction. High temporal and spatial resolutions are achieved.

P 2.5 Mon 12:15 b305

Spacio-temporal emission of an atmospheric plasmoid — •Roland Friedl[1], Ursel Fantz[1,2], Saskia Steibel[1], Martin Kammerloher[2], and Alexander Oswald[2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]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 due to buoyancy. 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 used 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). Applying several diodes, the vertical dynamic as well as the horizontal structure and symmetry of the plasmoid emission is obtained. 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.

P 3: Low-temperature plasma and applications 1

Time: Monday 14:00–15:30 Location: b302

Invited Talk P 3.1 Mon 14:00 b302

Diagnostics of magnetized high frequency technological plasmas — •Julian Schulze[1,2], Moritz Oberberg[1], Birk Berger[1], Jens Kallähn[1], Dennis Engel[1], Christian Wölfel[1], Jan Lunze[1], Ralf Peter Brinkmann[1], and Peter Awakowicz[1] — [1]Institute of Electrical Engineering, Ruhr-University Bochum — [2]School of Physics, Dalian University of Technology, China

Capacitively coupled radio frequency (RF) magnetrons are frequently used for sputter deposition of ceramic layers. However, fundamentals of their operation such as the effects of the magnetic field on the electron power absorption dynamics and the formation of process relevant flux-energy distribution functions are not understood. In order to address these issues, we characterize such a discharge operated in argon with oxygen admixture at low pressure by a synergistic combination of different experimental diagnostics [current/voltage measurements, retarding field energy analyzer, multipole resonance probe, phase resolved optical emission spectroscopy (PROES), magnetic field measurements]. We find that the magnetron magnetic field induces a discharge asymmetry. This Magnetic Asymmetry Effect affects the DC self bias and ion flux-energy distribution functions at boundary surfaces, which can be controlled by adjusting the magnetic field. Tuning the magnetic field also 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.

P 3.2 Mon 14:30 b302

MEMS sensor for the determination of ion energy and ion angle distribution functions in low pressure plasmas — •Marcel Melzer[1], Kerstin Rössel[2], Jan Trieschmann[2], Chris Stöckel[1,3], Sven Zimmermann[1,3], and Thomas Mussenbrock[2] — [1]Technische Universität Chemnitz, Zentrum für Mikrotechnologien, 09126 Chemnitz — [2]Brandenburgische Technische Universität Cottbus-Senftenberg, Theoretische Elektrotechnik, 03046 Cottbus — [3]Fraunhofer-Institut für Elektronische Nanosysteme, Abteilung Multi Device Integration, 09126 Chemnitz

Low pressure plasmas are one of the most important tools for the manufacturing of integrated circuits and enable, for example, the dry etching of transistor structures with feature sizes below 14 nm. For such sophisticated plasma processes both the ion energy distribution function (IEDF) and the ion angular distribution function (IADF) of the applied plasmas are crucial parameters for the creation of the desired structures. By combining a silicon-manufactured retarding field analyzer and a microelectromechanical system (MEMS) for angular selection of the ions to be detected, the IEDF and the IADF are to be measured simultaneously by a novel sensor element. In this work, simulation results of the three-dimensional ion dynamics within the sensor system are presented. Furthermore, the first results of the measurements and the current experimental status are discussed.

P 3.3 Mon 14:45 b302

The transmission behavior of an energy selective mass spectrometer with a Bessel Box type energy filter — •Christian Schulze[1], Zoltán Donkó[2], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Hungary

Ions are responsible for the majority of plasma surface interactions, which are of scientific interest and widely used in commercial applications. Therefore, the accurate measurement of ion energy distributions (IED) for different ion species are essential for their understanding and control. In contrast to other ion diagnostics, energy selective mass spectrometry (ESMS) allows energy and mass selectivity. Unfortunately, ESMS is known to suffer from artifacts like chromatic aberration of ion lenses as well as an energy dependent acceptance angle, both effects distorting the measurement. Therefore, ESMS is typically used for qualitative measurements only. The thorough analysis of chromatic aberration effects on the accuracy of measured IEDs is available only for selected mass spectrometers in the literature. Even less information is available for effects of energy dependent acceptance angles on experimental results, where the angular distribution of sampled ions strongly depends on their energy. Here, results of ion trajectory simulations are presented in order to optimize the settings of the ion lenses and the Bessel Box energy filter. Additionally, measured IEDs will be compared with 1D-PIC simulations, which can provide an estimation of energy-dependent angular distributions of the ion flux.

P 3.4 Mon 15:00 b302

AC modulation technique for RFEA measurements — •Christian Lütke Stetzkamp, Tsanko Vaskov Tsankov, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany

Retarding field energy analyzers (RFEA) are an important diagnostic tool to measure the ion velocity distribution function (IVDF) in low-pressure plasmas. However, their dynamic range is usually limited to about one order of magnitude. RFEAs can in principle also measure the distribution function of the electrons that overcome the sheath potential and escape the plasma. However, in this case the capabilities of the devices are even more limited.

Here, a method is presented, that strongly increases the dynamic range of the RFEA measurements. It is based on an analog AC modulation technique that is similar to those used for Langmuir probe measurements. The modulated response signal is detected by a Lock-In amplifier to reduce the influence of noise on the measurement. First measurements show very promising results, in which a dynamic range of about 3 orders of magnitude is easily achieved. In this talk the method will be presented and its characteristics will be discussed.

P 3.5 Mon 15:15 b302

Kinetic modeling of the electric double layer at the plasma-wall interface — •Kristopher Rasek, Franz Xaver Bronold, and Holger Fehske — Institut für Physik, Universität Greifswald, 17489 Greifswald

If a solid is in contact with a plasma an electric double layer forms, with a positive space charge in the plasma, the plasma sheath, and a negative space charge in the solid. We develop a kinetic model for such a double layer at a dielectric wall based on the Poisson equation for the electric potential and two sets of Boltzmann equations for the charge carriers in the plasma and the wall. By solving the Boltzmann and Poisson equations we are able to determine the full distribution functions of all carriers and with them quantities like charge profiles or photon emission rates. Expanding our previous work of the collisionless case [1], the collision integrals in the Boltzmann equations for the wall include both relaxation and (radiative or non-radiative) recombination of conduction band electrons and valence band holes. Using only material parameters such as the dielectric function and the band gap of the wall material, we determine the potential curve as well as the carrier distribution functions which are responsible for it. The emerging picture of our model is thus a floating dielectric surface where the potential profile across the double layer is the result of a self-organization process balancing electron-ion generation in the plasma and electron-hole recombination/relaxation in the solid.

[1] F. X. Bronold, H. Fehske, J. Phys. D: Appl. Phys. **50** (2017) 294003

P 4: Helmholtz Graduate School 1 and Magnetic confinement 1

Time: Monday 14:00–16:00 Location: b305

Invited Talk P 4.1 Mon 14:00 b305

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 4.2 Mon 14:30 b305

Diagnostic capabilities of X3 mode of electron cyclotron emission for electron temperature in overdense plasmas at W7-X — •Neha Chaudhary, Johan W. Oosterbeek, Matthias Hirsch, Udo Hoefel, Robert C. Wolf, and The W7-X Team — Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

For magnetically confined plasmas, the lower harmonics of electron cyclotron emission (ECE) behave as a blackbody representing the electron temperature. The W7-X stellarator, for confinement reasons, is planned to work at high plasma densities aiming at detached steady state operation. For such scenarios at a magnetic field of 2.5T the ECE from the optically thick X2 mode (120-16 GHz) is in cut-off for densities more than 1.2e20/m3. Hence, electron temperature profiles cannot be accessed from ECE for over dense plasmas.

W7-X has a large aspect ratio that leads to spectrally well resolved higher harmonics of ECE compared to a tokamak with small aspect ratio. The emission from these harmonics is still present at high plasma densities and can be investigated to study plasma properties such as electron temperature and density. A Michelson interferometer was commissioned at W7-X to scan these harmonics for different plasma parameters covering broad spectral range 50-500 GHz. Initial experimental results and the radiation transport calculations (TRAVIS) suggest that X3 mode (180-220 GHz) of ECE is optically thick enough to be explored for its diagnostic capabilities as a high-density access to electron temperature. In addition, the forward modelling of experimental results is planned in the MINERVA framework.

P 4.3 Mon 14:55 b305

ECCD-induced electron temperature crashes at W7-X — •Marco Zanini, Heinrich Laqua, Torsten Stange, Henning Thomsen, Tamara Andreeva, Christian Brandt, Matthias Hirsch, Udo Höfel, Kian Rahbarnia, Robert C. Wolf, Alessandro Zocco, and W7-X Team — Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

The plasma in the superconducting optimized stellarator Wendelstein 7-X is mainly heated by an electron cyclotron resonance heating (ECRH), which allows up to 7.5 MW of injected power. ECRH itself can also be used to drive net toroidal current in the plasma (electron cyclotron current drive, ECCD). Toroidal current is not necessary for plasma confinement in stellarators, but the small amount of intrinsic toroidal current makes W7-X a perfect testbed for ECCD experiments. During ECCD experiments, fast and repetitive crashes of the electron temperature have been detected. A 1-D model for current evolution shows that the current drive deforms the rotational transform profile in such a way that low order rational values are crossed, leading the plasma in a condition where instabilities can be triggered. An initial attempt of mode analysis suggested an odd poloidal and toroidal number, thus being coherent with sawtooth oscillations in tokamaks. The pattern of collapses changes in time for long discharges, as the toroidal current evolves, and it was observed that, for relatively high toroidal currents, the change of magnetic topology coupled with these crashes can significantly affect plasma performances.

P 4.4 Mon 15:20 b305

Integrated modeling of tokamak plasma confinement — •Teobaldo Luda[1], Clemente Angioni[1], Micheal Dunne[1], Emiliano Fable[1], Arne Kallenbach[1], Philip Schneider[1], Mattia Siccinio[1], Giovanni Tardini[1], The ASDEX Upgrade team[1], and The EUROfusion MST1 Team[2] — [1]Max–Planck–Institut für Plasmaphysik, Boltzmannstrasse 2, D–85748 Garching, Germany — [2]See author list of B. Labit et al., 2019 Nucl. Fusion 59 086020

The design of future fusion reactors and their operational scenarios requires an accurate prediction of the plasma confinement. We have developed a new model that integrates different elements describing the main physics phenomena which determine plasma confinement. In particular, we are coupling a new pedestal transport model, based on empirical observations, to the ASTRA transport code, which, together with the TGLF turbulent transport model and the NCLASS neoclassical transport model, allows us to describe transport from the magnetic axis to the separatrix. We also coupled a simple scrape-off layer model to ASTRA, which provides the boundary conditions at the separatrix, which are a function of the main engineering parameters. By this way no experimental data of the kinetic profiles is needed, and the only inputs of the model are the magnetic field, the plasma current, the heating power, the fueling rate, the plasma geometry, and the effective charge. In the modeling work-flow, first a scan in pedestal pressure is performed, by changing the pedestal width. Then the pedestal top pressure is determined using the MISHKA MHD stability code. The model is tested by simulating ASDEX Upgrade discharges.

P 4.5 Mon 15:45 b305

Control of neoclassical tearing modes in fusion reactors — •Raphael Schramm[1], Ondrej Kudlacek[1], Hartmut Zohm[1], Emiliano Fable[1], Filip Janky[1], Olivier Sauter[2], Mattia Siccinio[1,3], Wolfgang Treuterer[1], and Emanuele Poli[1] — [1]Max-Planck-Institut für Plasmaphysik(IPP), D-85748 Garching b. München, Germany — [2]École Polytechnique Fédérale de Lausanne (EPFL), Swiss Plasma Center (SPC), CH-1015 Lausanne, Switzerland — [3]EUROfusion Consortium, PPP&T department, Boltzmannstr. 2, Garching

Neoclassical tearing modes (NTMs) are magneto-hydrodynamic instabilities in tokamak plasmas, that can cause a degradation of plasma confinement and eventually trigger a disruption. Since both of these are critical issues for a future tokamak reactor, NTM control is essential. This work presents a closed loop control simulation with realistic diagnostics and actuators, based on the tokamak plasma model implemented in ASTRA. The NTM amplitude evolution is based on the modified Rutherford equation and was benchmarked against an independent analytical estimate. The control action is executed by directing an electron-cyclotron (EC) beam, which drives a current in the island. The proper injection angles to hit the island are found by monitoring the NTM amplitude, while sweeping the beam around the estimated island position. Based on this work, first power estimates for the stabilization of the 2/1 NTM mode in EU-DEMO will be provided. This contribution will also deal with mode locking and study the effects of the EC beam broadening due to density fluctuations.

P 5: Poster Session 1

Time: Monday 16:30–18:30 Location: Empore Lichthof

P 5.1 Mon 16:30 Empore Lichthof

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

A dataset of pellet-fuelled 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 shows that the H06 scaling, see [1], is more appropriate to describe plasma confinement in this regime, than the H98(y,2) scaling. Additionally, the enhanced confinement gained by the different methods cannot be maintained when the density n_e exceeds the Greenwald density n_{Gw}. Confidence bands, obtained from statistical analysis confirm this feature. According to observations at JET (with carbon wall), see [2], 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 first wall), will be investigated. The reduced confinement when exceeding n_{Gw} can possibly be attributed to a rising separatrix density $n_{e,sep}$. The approximation that primarily the divertor density n_0^{Div} influences $n_{e,sep}$, see [3], is somewhat simplified. Therefore, potential other correlations between $n_{e,sep}$ and other plasma physical parameters will be analysed. [1] J. Johner, FST 59 (2010) 308 [2] V. Mukhovatov et al., PPCF 45 (2003) A235 [3] A. Kallenbach et al., PPCF 60 (2018) 308

P 5.2 Mon 16:30 Empore Lichthof

Comparison of Spatiotemporal Turbulent Structures Measured with Doppler Reflectometry in the Tokamak ASDEX Upgrade with Gyrokinetic Simulations — •David Stockinger[1,2], Klara Höfler[1,2], Tim Happel[2], Tobias Görler[2], Ulrich Stroth[1,2], and the ASDEX Upgrade Team[2] — [1]Physics Department TUM, E28, Garching, Germany — [2]Max Planck Institut für Plasmaphysik, Garching, Germany

Plasma turbulence drives transport of particles and energy in magnetically confined fusion plasmas and thus determines the energy confinement, which is of key importance for the development of a fusion reactor. A better knowledge of the turbulence properties is crucial for the prediction of the performance of future devices. Theory develops gyrokinetic simulation codes to describe the turbulence and its associated particle and heat transport. In order to comprehensively test the physical models implemented is such codes, detailed comparison with experiment is required. On the ASDEX Upgrade tokamak, Doppler reflectometry is used to measure turbulence properties at various structure sizes. The strategy for the comparison of experimental data and equivalent quantities deduced from simulation results will be presented together with the first measurements.

P 5.3 Mon 16:30 Empore Lichthof

Improving Tokamak pedestal prediction — •Jonas Puchmayr[1,2], Mike Dunne[2], and Hartmut Zohm[2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Schellingstraße 4, D-80799 München — [2]Max-Planck-Institut für Plasmaphysik, D-85748 Garching bei München

The high confinement mode (H-mode) is a regime where self-organized suppression of turbulence in the edge region leads to increased profile gradients. The pedestal is limited by the occurrence of edge localized modes (ELMs), quasi-periodic bursts of particles and energy at the plasma edge. ELMs can be described as coupled peeling-ballooning modes in an MHD framework where the edge pressure gradient and current density provide the free energy to create an instability. The EPED framework is a predictive model which calculates the bootstrap current and uses equilibrium and stability codes to scan intermediate toroidal mode numbers. The pedestal width is self-consistently determined by a scaling law, which in later versions of EPED is proposed to be a kinetic ballooning mode (KBM). For high triangularities, the EPED model predicts enhanced pedestal pressure, the Super H-mode. In this work, the EPED model was improved by implementing a more accurate bootstrap model and scanning a wider range of toroidal modes. The effect of including lower mode numbers, using a critical gradient instead of the KBM is analyzed and different bootstrap models on the predicted pedestal are shown. Recovering published Super H-mode results from other machines and extending the model to ASDEX Upgrade is envisaged.

P 5.4 Mon 16:30 Empore Lichthof

Pedestal turbulence studies with means of O-mode correlation reflectometry on EAST — •Haoming Xiang[1,2], Tao Zhang[2], Xiang Gao[2], Fei Wen[2], Yumin Wang[2], Xiang Han[1,2], Jianbin Liu[2], Andreas Krämer-Flecken[1], and Yunfeng Liang[1] — [1]Institut für Energie- und Klimaforschung, Forschungszentrum Jülich, 52425 Jülich — [2]Institute of Plasma Physics, Chinese Academy of Sciences, PO Box 1126, Hefei, Anhui 230031, People's Republic of China

A multi-frequency ordinary-mode correlation reflectometer has been developed and operated on EAST to measure plasma electron density fluctuations. Simultaneous four-frequency operation makes it possible to measure the correlation between fluctuations at different radially separated cut-off layers. Furthermore, two poloidally spaced receiving antennas allows to investigate the correlation between fluctuations at different poloidal positions and thus determine of turbulence velocity. During the EAST experimental campaign in 2018, a low-frequency coherent mode($f \approx$ 1kHz) in the pedestal region during the ELM-free phase is investigated. Magnetic probes measurements show that the low frequency mode exhibits a structure of toroidal number (n=0) and poloidal number (m=1). Correlation reflectometer analysis show that there is no phase difference radially, i.e., not a radial traveling wave. Further study shows that pedestal density fluctuation and thus the pedestal density/density gradient are modulated by this low-frequency mode,the measurements will be discussed in this presentation.

P 5.5 Mon 16:30 Empore Lichthof

Disentanglement of density and rotation dependences of the field penetration threshold on the J-TEXT tokamak — •Zhuo Huang[1,2], Yunfeng Liang[1,2,3], Qiming Hu[4], Nengchao Wang[1], Da Li[1], Xiaoyi Zhang[1], Bo Rao[1], Zhipeng Chen[1], Song Zhou[1], Qi Zhang[1], Chengshuo Shen[1], Ying He[1], and Yonghua Ding[1] — [1]International Joint Research Laboratory of Magnetic Confinement Fusion and Plasma Physics, Huazhong University of Science and Technology, Wuhan, 430074, People*s Republic of China — [2]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung * Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [3]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, People*s Republic of China — [4]Princeton Plasma Physics Laboratory, Princeton University, P.O. Box 451, New Jersey 08543, USA

Penetration of perturbed fields into the magnetized plasma is a fundamental issue in fusion plasmas. The field penetration threshold of magnetic perturbations has been observed to vary non-monotonically with an increase of density in ohmic plasmas on the J-TEXT tokamak. This observation appears contradicting the previous empirical density scaling law. Disentanglement of plasma density and rotation dependences of the field penetration threshold has been carried out. It shows that the field penetration threshold depends only weakly on the density but linearly on the plasma rotation. This result is important for the prediction of error field tolerance in fusion devices.

P 5.6 Mon 16:30 Empore Lichthof

Local radiated power sensitivity and intrinsic impurity correlation analysis at the stellarator Wendelstein 7-X — •Philipp Hacker, Felix Reimold, Daihong Zhang, Rainer Burhenn, and Thomas Klinger — Max-Planck Institute for Plasma Physics, Greifswald, Germany

The two-camera resistive bolometer system at the stellarator Wendelstein 7-X with its blackened gold absorbers has provided a real time evaluation of the total radiated power for plasma feedback during the last experiment campaign. Based on the assumption of poloidal symmetry the radiated power loss of the plasma can been estimated independently for both cameras and each channel from line-integrated measurements. Using a limited set out of the total available fan of sight lines covering most radial emission shells the radiation level was calculated for plasma feedback control with fast auxiliary gas fueling as an actuator. Investigations regarding the best set of sight lines predicting the radiated power loss have been done for all camera and channel combinations as well as different mathematical weighting methods. Normalisation with individual cross correlations functions of single line integrated signals yields a set of channels with particular relevance for the total radiated power. Incorporating results from the 1-D impurity transport code STRAHL and spectroscopic diagnostics we attempt to link the contribution of different intrinsic impurities to the loss distribution.

P 5.7 Mon 16:30 Empore Lichthof

Manipulating the radial deposition of positrons in a magnetic dipole trap — •Stefan Nissl[1,2], Eve V. Stenson[1,2,3], Juliane Horn-Stanja[1], Uwe Hergenhahn[1], Thomas Sunn Pedersen[1,4], Haruhiko Saitoh[6], Christoph Hugenschmidt[2], Markus Singer[2], Matthew R. Stoneking[1,5], and James R. Danielson[3] — [1]Max-Planck-Institute for Plasma Physics — [2]Technische Universität München — [3]University of California, San Diego — [4]University of Greifswald — [5]Lawrence University — [6]The University of Tokyo

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 5.8 Mon 16:30 Empore Lichthof

Positron accumulation in Multicell Penning traps — •Martin Singer[1], Stephan König[2], Lutz Schweikhard[2], Gerrit Marx[2], Cliff Surko[3], James Danielson[3], and Thomas Sunn Pedersen[1] — [1]Max-Planck-Institut für Plasma Physik, Wendelsteinstraße 1, 17491 Greifswald, Germany — [2]Institut für Physik, Universität Greifswald, Felix-Hausdorff-Straße 6, 17489 Greifswald, Germany — [3]Physics Department, University of California, San Diego, 9500 Gilman Drive, La Jolla, California 92093, USA

Positron-electron plasmas, also pair plasmas, have not yet been studied experimentally. Due to their equal mass, many features that can be 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 pair plasma with a spatial dimension of several Debye lengths so that collective behavior will be observable. To create such a plasma great care has to be taken since positrons are naturally rare. One crucial part is the accumulation of large numbers of moderated positrons. Therefore, a device is needed which is capable of storing up to 10^{12} positrons without heating and particle loss. One solution is the Multicell Penning trap (MCT) concept, which separates the space charge of the positrons into multiple radially arranged Penning traps. We will present first measurements with electrons stored in a single Penning trap in Greifswald and plans for the development of a MCT. This MCT will be used to confine plasmas simultaneously in different cells, investigate the confinement and different injection as well as ejection schemes.

P 5.9 Mon 16:30 Empore Lichthof

Investigation of disruptions at JET using interpretable machine learning methods. — •Victor Artigues and Frank Jenko — Max Planck Institute for Plasma Physics, Boltzmannstr.2, 85748 Garching, Germany

The sudden losses of plasma control in tokamaks, called disruptions, remain one of the main problems on the path towards fusion-based power plants. To address this problem, in parallel with the physics-based approaches, more and more data driven methods have been developed recently. These approaches compile a database made of disruptive shots and safe shots, and use more or less complex machine learning methods to answer different questions such as: disruption prediction, disruption type identification, transfer to future tokamaks,...

Although using complex machine learning algorithms have proven to be very powerful in many different domains, they often work as black-boxes and little knowledge can be extracted from them. This lack of interpretability slows the adoption of machine learning methods in, among others, the field of physics.

In an attempt to better understand the predictions, we investigate a two-step method. First, we train a standard recurrent neural network, the teacher, for disruption prediction. And in a second step, we train a student neural network, based on shapelets, to reproduce the results of the first. The teacher's goal is to provide a plausible prediction for the badly labeled data while the student network aims at providing insight into the decision through the learned shapelets.

P 5.10 Mon 16:30 Empore Lichthof

Integrated Data Analysis 2.0 — •Michael Bergmann, Frank Jenko, Rainer Fischer, and the ASDEX Upgrade Team — Max-Planck-Institute für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Using a combined analysis of multiple diagnostics as well as Bayesian probability theory the Integrated Data Analysis (IDA, see [Fischer 2010]) is capable of providing density and temperature radial profiles of ASDEX-Upgrade plasmas. These profiles can then be fed into transport codes for 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 existing transport solvers such as ASTRA and TGLF we have created a loop in which simulated profiles are fed back into IDA as another pseudo-measurement 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 using multiple transport solvers including machine learning in a multi-fidelity approach.

P 5.11 Mon 16:30 Empore Lichthof

Runaway electron modeling in massive material injection scenarios in ASDEX Upgrade — •Oliver Linder, Emiliano Fable, Frank Jenko, Gergely Papp, Gabriella Pautasso, and the ASDEX Upgrade Team — Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany

In current-carrying fusion devices, the conversion of a large fraction of the plasma current to runaway electrons (RE) following the sudden loss of thermal energy poses a threat to the integrity of the plasma vessel. However, RE formation may be suppressed by massive material injection (MMI); a concept presently being investigated experimentally across various devices. To complement extrapolation to future devices, RE model development and validation is mandatory.

This work reports on simulations of MMI scenarios in ASDEX Upgrade (AUG) with the transport toolset ASTRA-STRAHL, where recently developed (fluid) models for RE generation have been implemented. It is shown, that correct simulation of material penetration and consideration of the impact of partially ionized impurities on RE formation are a prerequisite to capture the RE response in AUG argon injection discharges. Within this framework, edge gas injection simulations for varying impurity amounts and types (such as D, Ne, Ar, Kr) are performed and compared to experimentally observed trends in RE behavior.

P 5.12 Mon 16:30 Empore Lichthof

Fast neural network surrogates for VMEC MHD equilibrium code — •Andrea Merlo, Daniel Böckenhoff, Thomas Sunn Pedersen, and The W7-X Team — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

MHD equilibrium codes, such as VMEC or PIES, are widely used among the fusion community for a variety of applications, ranging from MHD stability to reconstruction of plasma parameters. However, these codes usually require long computing times to converge, ranging from tens to hundreds of seconds per plasma configuration, preventing their adoption in real-time control scenarios or within extensive optimization runs. Data-driven methods for physical simulation codes allow to trade offline computation and memory footprint in favor for improved runtime performance. We are developing two machine-learning methods which act as fast surrogates for the VMEC code. These approaches comprise a Deep Neural Network (DNN) and a Physics-informed Neural Network (PiNN), where physical information regarding the system is provided via learning function. Additionally, to enable efficient training processes, our methods include subspace simulation techniques.

P 5.13 Mon 16:30 Empore Lichthof

Soft X-ray survey of high-performance experiments in Wendelstein 7-X — •Jonathan Schilling, Henning Thomsen, Christian Brandt, Sehyun Kwak, Jakob Svensson, and the W7-X - Team — Max-Planck-Institut für Plasmaphysik

Soft X-ray radiation emitted from a high-temperature plasma can be used to infer local information about the plasma temperature and density. The soft X-ray tomography diagnostic XMCTS in the superconducting stellarator Wendelstein 7-X has been used in the latest operational phases OP1.2a and OP1.2b to measure the soft X-ray radiation from the plasma in one plane of constant toroidal angle. Recent upgrades of the diagnostic model made it possible to compute tomographic inversions of the soft X-ray emissivity throughout the whole available dataset from OP1.2a and OP1.2b, even though significant influence of diagnostic effects have to be modelled along with the tomography. On this poster, a survey of the soft X-ray data focused on the high-performance experiments conducted in Wendelstein 7-X is presented. One aspect of this dataset is the direct measurement of the Shafranov shift due to high plasma pressure and quantitative comparison against theoretical predictions from equilibrium reconstructions.

P 5.14 Mon 16:30 Empore Lichthof

Low frequency fluctuations measured by soft X-ray and Mirnov diagnostic at the Wendelstein 7-X stellarator — •Sara Mendes, Christian Brandt, Kian Rahbarnia, Jonathan Schilling, Henning Thomsen, and Wendelstein 7-X Team — Max-Planck-Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

During the last divertor campaign at the Wendelstein 7-X (W7-X) stellarator fluctuations starting at a few kHz up to about 400 kHz have been observed by various diagnostics. Predominantly lower frequency components (<100 kHz) were found in the soft X-ray (SXR) intensities detected by the SXR tomography system XMCTS, a poloidal camera array with 360 lines-of-sight. Similar and slightly higher magnetic broadband fluctuations have been measured by the Mirnov diagnostic, which consists of 125 individual coils located in four out of five modules of W7-X. Part of the observed frequencies fit well into theoretically predicted gaps in corresponding Alfvén continua, but to ensure a precise analysis of the underlaying mode structures, a complete amplitude and phase calibration including all relevant data acquisition components is necessary, as it is performed for the Mirnov diagnostic. The nature of the observed mode activity specifically for the lower frequency components is discussed.

P 5.15 Mon 16:30 Empore Lichthof

Core plasma density fluctuations in Wendelstein 7-X — •Jan-Peter Bähner[1], Adrian von Stechow[1], Zhouji Huang[2], Jorge Alcuson[1], Eric Edlund[3], Miklos Porkolab[2], Olaf Grulke[1,4], and The W7-X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, 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

Recent analysis of Wendelstein 7-X experiments have shown that the ion heat diffusion in W7-X is dominated by anomalous transport processes. Consequently, the ion temperature is significantly smaller than expected from neoclassical transport estimates. Ion-scale turbulence is expected to be the main driver for anomalous transport, with the major instabilities on this scale being the ion temperature gradient (ITG) driven mode and the trapped electron mode (TEM).
The Phase Contrast Imaging (PCI) diagnostic provides density fluctuation measurements with temporal and wavenumber resolution spanning the ITG and TEM scales. A recent calibration of the wavelengths and relative fluctuation amplitudes measured by PCI for the majority of W7-X discharges enables a comparison of density fluctuations between a wide range of discharges. Investigations on the impact of magnetic configuration, heating power and density on the density fluctuations are presented, as well as linear growth rate calculations. Core plasma turbulence in W7-X will be characterized by fluctuation level, dominant phase velocity, and wavenumber distribution.

P 5.16 Mon 16:30 Empore Lichthof

Preparation of Triton Burn-Up Studies in Future Deuterium Plasmas of Wendelstein 7-X — •Jan Paul Koschinsky[1], Christoph Biedermann[1], Sergey A. Bozhenkov[1], Monika Koleva[2], G. A. Wurden[3], Andreas Zimbal[4], Robert C. Wolf[1], the W7-X Team[1], and the ASDEX Upgrade Team[2] — [1]Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, D-17491, Greifswald, Germany — [2]IPP, Garching — [3]LANL, US — [4]PTB, Braunschweig

Fast ion confinement is crucial for realizing burning fusion plasmas, both in tokamaks and stellarators. 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. Depending on confinement and slowing-down processes, the produced tritons will fuse with the surrounding deuterons. This triton burn-up fusion process gives birth to 14 MeV neutrons. Triton burn-up is studied with SciFi, which can discriminate between 14 MeV and 2.5 MeV neutrons.
The characterization of the SciFi detector, utilizing a mono-energetic neutron source at the German National Metrology Institute, PTB Braunschweig, and triton burn-up studies at the ASDEX Upgrade tokamak are presented. An update of a one-dimensional neutron rate estimation for purely ECRH heated W7-X deuterium plasmas is also given.

P 5.17 Mon 16:30 Empore Lichthof

Gyrokinetic investigation of the damping channels of Alfvén modes in ASDEX Upgrade — •Francesco Vannini, Alessandro Biancalani, Alberto Bottino, Thomas Hayward-Schneider, Philipp Lauber, Alexey Mishchenko, Ivan Novikau, Emanuele Poli, and ASDEX Upgrade Team — Max Planck Institute for Plasma Physics, Garching (Germany)

The linear destabilization and nonlinear saturation of energetic-particle driven Alfvénic instabilities in tokamaks strongly depend on the damping channels. In this work, the collisionless damping mechanisms of Alfvénic modes are investigated within a gyrokinetic framework, by means of global simulations with the particle-in-cell code ORB5, and compared with the eigenvalue code LIGKA and reduced models. In particular, the continuum damping and the Landau damping (of ions and electrons) are considered. The electron Landau damping is found to be dominant on the ion Landau damping for experimentally relevant cases. As an application, the linear and nonlinear dynamics of toroidicity induced Alfvén eigenmodes and energetic-particle driven modes in ASDEX Upgrade is investigated theoretically and compared with experimental measurements (see [Vannini-2019], submitted to Physics of Plasmas, arXiv:1910.14489).

P 5.18 Mon 16:30 Empore Lichthof

Fast-ion confinement studies in W7-X using active Balmer-alpha spectroscopy — •Peter Zs. Poloskei[1], Benedikt Geiger[2], Oliver Ford[1], Simppa Äkaslompolo[1], Annabelle Spanier[1], and the W7-X team[1] — [1]Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald, Greifswald, Germany — [2]University of Wisconsin, Madison, USA

Investigation of fast-ion transport in fusion plasmas plays a central role as good fast-particle confinement is essential for burning plasmas. For its recent experimental campaign, the W7-X stellarator was equipped with two neutral hydrogen beam injectors (NBI) which provide fast-particles of our interest and neutral hydrogen particles which make active Balmer-alpha spectroscopy possible.

Due to the complex shape of the measured spectra forward modelling is required for its interpretation. It is done with a code called FIDASIM which takes into account different assumed kinetic plasma profiles, fast-ion densities and information of the beam- and observation geometry.

It was found that most measured spectral components are well reproducible with FIDASIM but the observed active emission, coming from the beam neutral - confined fast-ion charge-exchange reaction (FIDA) cannot fully explain the measured intensities. This suggests that fast-ions in the plasma edge region could interact with the cold neutral population from the plasma vessel, causing additional passive FIDA emission. This needs to be understood in order to address the question of edge charge-exchange fast-ion losses and to infer information on the edge neutral density.

P 5.19 Mon 16:30 Empore Lichthof

Infrared study of CH_4 conversion in a non-equilibrium O_2/He atmospheric pressure plasma jet — •Theresa Urbanietz, Christoph Stewig, Marc Böke, and Achim von Keudell — Experimental Physics II, Ruhr-University Bochum, 44780 Bochum

The dissociation of CH_4 in a non-equilibrium atmospheric pressure O_2/He plasma jet is measured for varying absorbed plasma powers and different CH_4/O_2 ratios. Space resolved measurements are performed and analyzed by Fourier transform infrared spectroscopy. This diagnostic is used to evaluate the products of the reactions which are CH_4, CO_2, CO and H_2O. By comparing the measured spectra with calculated spectra the concentration as well as the rotational and vibrational excitation of the species are determined. It is shown that the CO concentration is independent of the CH_4/O_2 ratio. The consumption of CH_4 is limited by the oxygen admixture.

P 5.20 Mon 16:30 Empore Lichthof

Atmospheric Pressure Plasma for Nano Particle Generation — •Jessica Ruhnke, Sadegh Askari, Judith Golda, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Germany

Silicon nano particles have a wide range of applications from optoelectronic to photovoltaic and medicine. Atmospheric pressure plasmas are able to generate nano particles and nano crystals with excellent size control from even 1 nm diameter. However, the nano particle growth mechanism and the possible surface modifications are still not well understood and studied.

Here we present the characterization and comparison of two atmospheric pressure plasmas for nano particle generation driven by a radio frequency voltage in a mixture of Ar-He-SiH_4 gas: a smaller capillary source with planar electrodes and a bigger helix jet with specially designed electrodes. Various methods are used for analysis of the sources. Relevant plasma properties are determined by optical emission spectroscopy. The particle size can be analysed *in situ* by a 1 nm scanning mobility particle sizer and *ex situ* by Fourier-transform infrared spectroscopy and transmission electron microscopy.

P 5.21 Mon 16:30 Empore Lichthof

Spatially resolved atomic oxygen densities in the 'COST Reference Microplasma Jet' — •David Steuer, Patrick Preissing, Volker Schulz-von der Gathen, and Marc Böke — Experimental Physics II, Ruhr-University Bochum, Germany

Cold atmospheric pressure plasmas are used for activation of surfaces, etching, coating and biomedical treatments. For these applications, reactive species such as atomic oxygen are produced in the plasma and require monitoring. A non-invasive and less complex method than laser diagnostics (e.g. TALIF) is optical emission spectroscopy (OES), specifically actinometry. The method was applied to a micro-scaled atmospheric pressure plasma jet, namely the COST-Jet [1]. The capacitively coupled 13.56 MHz RF-discharge can be observed through quartz plates. The discharge channel is imaged on a fast, gated intensified CCD camera via electronically tunable filters. This setup allows ns-resolved measurements of oxygen and argon (actinometer gas) transitions, whereby the wavelength (550-1000 nm) can be switched within 100 ms, giving the opportunity to acquire a set of several spectral lines in a few seconds. A spatial resolution is given by a single measurement through the imaging of the complete discharge channel. Typical oxygen densities of 10^{15} cm^{-3} are obtained, which correspond to TALIF measurements.

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

P 5.22 Mon 16:30 Empore Lichthof

Study of a 2.45 GHz plasma torch for synthesis of fused silica: operation with different $Ar - O_2$ **mixtures** — •M. Stankov[1], T. Trautvetter[2], H. Baierl[2], R. Methling[1], F. Hempel[1], J. Schäfer[1], M. Baeva[1], R. Foest[1], and D. Loffhagen[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), 17489 Greifswald, Germany — [2]Leibniz Institute of Photonic Technology (IPHT), 07745 Jena, Germany

Simulation analysis and experimental studies of a 2.45 GHz (μW) torch are presented. The device is suitable for the deposition of synthetic fused silica including a simultaneous co-doping with Al-Yb-F. The plasma is generated in a quartz tube positioned in normal direction to a rectangular wave guide R26, at the maximum electric field (TE10). $Ar - O_2$ mixtures are fed through the tube and drive the discharge which develops in the tube outwards through the nozzle where the torch is formed. For investigations on material synthesis, the system can be completed by an external supply for the injection of precursors into the torch and a rotating substrate. The plasma is simulated using a time-dependent, 2D numerical model considering the plasma kinetics, the energy conservation of electrons and heavy particles, the electromagnetic field and the gas flow. The study comprises different gas compositions from pure Ar to pure O_2. The gas temperature is calculated and compared with results from optical emission spectroscopy where OH emissions are exploited to simulate the prevalent gas temperature. The experiments are complemented by IR thermography. (Supported by Leibniz-Gemeinschaft SAW-2017-IPHT-1)

P 5.23 Mon 16:30 Empore Lichthof

Study of the local segregation of multi-component powders during a plasma spray process — •Thorben Kewitz[1], Holger Testrich[1], Antje Quade[1], Katja Fricke[1], Maik Fröhlich[1,2], Rüdiger Foest[1], and Klaus-Dieter Weltmann[1] — [1]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany — [2]University of Applied Sciences Zwickau, Zwickau, Germany

Plasma spraying is an atmospheric pressure coating process. The coatings can be utilized e.g. for wear, corrosion and heat protection or for biomedical applications. The use of powder mixtures consisting of different components allows the extension of specific coating properties. For instance, by addition of a small amount of Cu to TiO2 powder antimicrobial coatings on implant surfaces can be achieved. Our investigations show that the different powders in the mixture can segregate during the plasma spray process on the way from the injection to the substrate. The segregation of the different powders can be ascribed to different material densities and particle sizes (a few tens microns in diameter) of the constituents. The segregation causes gradients in the chemical composition of the coating. During static deposition experiments with mixtures of TiO2 and 3% Cu, a segregation of the resulting profiles of up to 2 cm was observed and verified by XPS analysis. Depth profiles were prepared and analyzed with SEM. The results show that it is important that the particle sizes are selected carefully considering also the material densities as prerequisite for spatially homogeneous coatings. Yet, the segregation can also be used for generating coatings with controlled material gradients.

P 5.24 Mon 16:30 Empore Lichthof

Preliminary investigation of the island divertor configuration by applying 4/1 RMP on the J-TEXT tokamak — •song zhou[1,2], yunfeng liang[1,2,3], nengchao wang[2], bo rao[2], yonghua ding[2], and the j-text team[2] — [1]Institute of Energy and Climate Research, Plasma Physics IEK-4, Forschungszentrum Juelich GmbH, Juelich, Germany — [2]International Joint Research Laboratory of Magnetic Confinement Fusion and Plasma Physics, Huazhong University of Science and Technology, Wuhan, China — [3]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, China

The high heat load on divertor target plate is one of the essential issues for future fusion reactors. The island divertor configuration is a good way to reduce the peaking heat load on the target and also screen the impurity, which is proposed first in 1977 for tokamak but successfully established in various stellarators. In the last campaign of J-TEXT tokamak, an experimental attempt have been made to form an island divertor configuration by using the external resonant magnetic perturbation (RMP) with dominate m/n = 4/1 component. Once the 4/1 locked island has been excited, the radial and poloidal profiles of the floating potential, the intensity of CIII radiation varied significantly. The poloidal profiles of the floating potential measured at the limiters, varied during the formation of 4/1 locked island, indicating the impact of the 4/1 island on the footprints. However, the present RMP is not enough strong to excite a wider edge island, i.e. the width of island is smaller than the critical size. The preliminary design for building a new set of island divertor coils will also be discussed.

P 5.25 Mon 16:30 Empore Lichthof

LEIS Investigation of Cr Segregation in WCrY — •Hans Rudolf Koslowski[1], Janina Schmitz[1,2], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung – Plasmaphysik, 52428 Jülich, Germany — [2]Department of Applied Physics, Ghent University, 9000 Ghent,

Belgium

The temperature driven segregation of Cr to the surface of the tungsten-based W-11.4Cr-0.6Y (wt%) alloy is analysed with low energy ion scattering (LEIS) which probes only the composition of the outermost monolayer due to its high surface sensitvity.

The surface concentration of Cr increases slightly when the temperature of the sample is increased up to 700 K and exhibits a much stronger increase when the sample temperature is further raised. At a temperature of 1000 K LEIS detects almost no W atoms on the surface. A segregation enthalpy of 0.7 eV for Cr is obtained from the Langmuir-McLean relation. The modified surface composition due to the segregated Cr stays stable during cool-down of the sample.

Preferential sputtering is investigated using ion bombardment of 250 eV D atoms, resulting in an increase of the W surface density at room temperature. This effect is counteracted at elevated temperatures where segregation replenishes the Cr on the surface and prevents the formation of an all-W surface layer. The flux of segregating Cr atoms towards the surface is evaluated from the equilibrium between sputter erosion and segregation.

P 5.26 Mon 16:30 Empore Lichthof

Phase forming in the Be-Ti system — •Nicola Helfer[1], Jens Bröder[2], Nabi Aghdassi[1], Hans Rudolf Koslowski[1], Daniel Wortmann[2], Stefan Blügel[2], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany — [2]Forschungszentrum Jülich GmbH, Peter Grünberg Institut and Institute for Advanced Simulation, 52425 Jülich, Germany

As a possible blanket material in a future fusion reactor, phase decomposition processes of $Be_{12}Ti$, especially at reactor relevant temperatures, need to be understood. Thin film system are used as model system to elucidate temperature driven surface changes with X-ray photoelectron spectroscopy (XPS). XPS data for Be-Ti intermetallic compounds are lacking, therefore a novel fitting method is developed. Chemical shifts of each chemical environment within a phase unit cell are calculated with DFT (full-potential linearized augmented plane wave method, FLEUR code) and using Voigt profiles artificial pure phase spectra are generated. These pure phase spectra are used as eigenfunctions for the fit of experimental obtained data.

Titanium is evaporated on polycrystalline Beryllium, intermetallic phases form through annealing. At intermediate temperatures (starting at 600 K) mainly Be depleted phases form, with increasing temperature Be rich phases dominate. At high temperatures a metallic Be layer settles at the surfaces, shown by accomplishing angle resolved XPS. Possible mechanisms are segregation and diffusion but also phase decomposition, further measurements are needed to understand this.

P 5.27 Mon 16:30 Empore Lichthof

Production and characterisation of tungsten fiber-reinfoced tungsten (Wf/W) — •Daniel Schwalenberg[1,3], Jan W. Coenen[1], Johann Riesch[2], Leonard Raumann[1], Yiran Mao[1], Alexis Terra[1], Till Höschen[2], Rudolf Neu[2,3], and Christian Linsmeier[1] — [1]Institut für Energie und Klimaforschung, Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Max-Plank-Institut für Plasmaphysik, 85748 Garching bei München — [3]Technische Universität München, 85748 Garching bei München

The divertor of a fusion reactor is used for power and particle exhaust. Extreme conditions are expected in this area, leading to very high demands for material properties. Tungsten (W) satisfies many aspects of the requirements, e.g. excellent thermal properties, high sputter resistance and low hydrogen retention, but lacks mechanical robustness due to its brittleness. To improve the mechanical properties, a fibre reinforced composite material (Wf/W) has been developed. The material consists of ductile W fibres und and a brittle CVD matrix creating a pseudo-ductile behaviour, which prevents the material from failing catastrophically. In order to further characterise the material, larger amounts of Wf/W are being produced. These larger samples will be fabricated with the newly designed setups for chemical vapour deposition. As part of the qualification process of the material, the samples will undergo high heat flux tests at the ion beam facility GLADIS.

P 5.28 Mon 16:30 Empore Lichthof

The effect of Magnetic Geometry on Turbulence in Advanced Divertor Configurations — •Thomas Body, Wladimir Zholobenko, Andreas Stegmeir, David Coster, and Frank Jenko — Max-Planck-Institut für Plasmaphysik, Garching, Deutschland

Advanced Divertor Configurations (ADCs) promise improved control of the plasma exhaust in future fusion power plants such as DEMO. These alternative magnetic configurations modify the magnetic field of the SOL and divertor to achieve higher poloidal flux expansion, increased divertor parallel connection lengths and improved neutral baffling. This work will discuss the relative impact of physical mechanisms which determines the width of the directed heat- and particle-flux channels for fluid-turbulence simulations performed with GRILLIX. The advanced divertor configurations considered by the EUROFusion Work Package DTT1-ADC (namely the Snowflake, X, Super-X, Double-null divertor configurations) are compared to a 'conventional' Single-null divertor configuration. For these cases, "scaled-DEMO" simulations are performed due to computational limits. These simulations have the same magnetic geometry as the full device but have a spatial scale and parameter set similar to the COMPASS device. To investigate the effect of scaling to larger scales, we compare results for the same magnetic configuration run at several machine sizes.

P 5.29 Mon 16:30 Empore Lichthof

Viability of NN-based Predictor-Corrector Schemes for Plasma Simulations — •Robin Greif[1], Frank Jenko[1], and Nils Thuerey[2] — [1]Max-Planck-Institute für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [2]TU Munich, Boltzmannstr. 3, 85748 Garching, Germany

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

P 5.30 Mon 16:30 Empore Lichthof

Hybrid kinetic-MHD simulations using structure-preserving numerical methods — •Florian Holderied[1,2], Stefan Possanner[1,2], Ahmed Ratnani[3], 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 — [3]Mohammed VI Polytechnic University, Lot 660, Hay Moulay Rachid Ben Guerir, 43450, Morocco

Classical numerical methods do generally not guarantee anything about the preservation of invariants the simulated model, i.e. the set of partial differential equations, possesses on the continuous level, e.g. conservation of energy or the two divergence constraints arising in electrodynamics, $\nabla\cdot\mathbf{E} = \rho/\epsilon_0$ and $\nabla\cdot\mathbf{B} = 0$. However, as shown by Arnold, Falk and Winther (2010), the preservation of such invariants goes hand in hand with numerical stability. In order to ensure this especially for long-term simulations deep into the nonlinear phase, the preservation of such invariants can be very helpful. The goal of the present work is to explore the usage of numerical methods which are mostly related to finite element exterior calculus (FEEC) with the aim to preserve as many properties of the continuous model as possible. From a physics point of view, the model of interest is the nonlinear coupling of the linearized ideal magnetohydrodynamics (MHD) equations to a kinetic equation (either full-orbit or reduced Vlasov equation). Such hybrid fluid-kinetic models are a suitable way to describe the self-consistent interaction of a thermal fluid bulk plasma with an ensemble of energetic particles, e.g. fusion-born alpha-particles in nuclear fusion devices.

P 5.31 Mon 16:30 Empore Lichthof

Progress towards Gyrokinetic Turbulence in the SOL with GENE-X — •Dominik Michels, Denis Jarema, Andreas Stegmeir, and Frank Jenko — Max-Planck-Institut für Plasmaphysik, Garching, Deutschland

Understanding and predicting the effects of plasma turbulence in the Scrape-Off Layer of a tokamak is a crucial step in the optimisation of confinement for future fusion power plants. Our goal is to develop a new version of the GENE code [1], called GENE-X, to study gyrokinetic SOL turbulence. The Scrape-Off Layer poses several significant problems for gyrokinetic codes. Fluctuations of the plasma in the Scrape-Off Layer are known to be stronger than in the core. As such, nonlinear effects originating from the coupling between fluctuations become important, i.e. a 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-aligned coordinates. We solve this problem by implementing the flux-coordinate independent approach described in [2, 3]. We present first results on simulations with GENE-X in regions of closed field lines and give an outlook on how to expand GENE-X to open field line regions by introducing sheath boundary conditions.

[1] F. Jenko et al., Phys. Plasmas 7 (2000), 1904-1910
[2] F. Hariri et al., Computer Physics Communications, 184:2419 – 2429, 2013
[3] A. Stegmeir et al., Computer Physics Communications, 198:139 – 153, 2016

P 5.32 Mon 16:30 Empore Lichthof

Towards systems code studies for a general class of stellarators — •Jorrit Lion and Felix Warmer — 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 disruptions. 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. Here, we present general modules for the systems code PROCESS to enlarge the possible configuration space compared to earlier works, focusing on a modular coil model, a support structure model and a bootstrap current model for quasi-axisymmetric stellarators. These models reflect the full 3D geometry of the stellarator coils and are incorporated in PROCESS via scaling laws and fits for specific devices. We further present first results from a modified version of PROCESS using these models, applied on certain stellarator designs with different aspect ratios.

P 5.33 Mon 16:30 Empore Lichthof

Research of the plasma parameters based on CHF3/H2 for etching silicon and glass — •Alena Okhorzina and Norbert Bernhard — 06366, German, Köthen, Bernburger Str. 55

In this work, dry maskless plasma silicon etching was used to reduce light reflection. That method is called "Black silicon" and it is applicable for any type of silicon (mono and multi). By creating a nanostructure on the silicon surface, light reflection was reduced. In this research CHF3-based gas was used because that type of gases has less global warming potential than other gases like SF6-based (standard black silicon process). By manipulating the main parameters of the plasma (flow and amount of gases, CCP and ICP power, pressure in the chamber) the changing of the light reflection and mass of the silicon wafers were observed. It was found that the main factors affecting the etching process in CHF3/H2 are pressure, CCP and ICP powers, and the amount of hydrogen in the gas mixture. The voltage-current characteristics were obtained for plasma etching with the most significant parameters. Langmuir cylindrical probe was used to understand the plasma process. During the experiment, the necessary parameters to hold the process in the etching mode of the plasma (potential, electron temperature, electron/ion current density) were obtained.

P 5.34 Mon 16:30 Empore Lichthof

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, Christian-Albrechts-Universität zu 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/C_2H_2-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 thermophoretic force [Godde et al., IEEE Trans. Plas. Sci. (2011)] and allows extracting 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, scanning electron, and/or laser microscopy to determine the particle size distribution.

P 5.35 Mon 16:30 Empore Lichthof

TDLAS analysis of the magnetic field strength by Zeeman splitting and gas temperature by Doppler broadening in the linear plasma device PSI-2 — •Marc Sackers, Oleksandr Marchuk, Sven Dickheuer, Stephan Ertmer, and Arkadi Kreter — Forschungszentrum Jülich GmbH - Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany

Tunable diode laser absorption spectroscopy (TDLAS) is a promising technique to estimate the magnetic field strength in a low-density weakly magnetized plasma as well as the temperature of the gas constituents [1]. To obtain this information, the $4s^2 4p^5 (^2P^\circ_{3/2}) 5s$ J=2 –> $4s^2 4p^5 (^2P^\circ_{3/2}) 5p$ J=2 transition from metastable krypton was analyzed. Therefore, the wavelength of a tunable diode laser was tuned to the vacuum transition wavelength of 760.3638 nm and gradually scanned in both directions. A polarization cube was positioned in the optical path in front of the photodiode to detect the π- and σ-components of the transition individually and measure simultaneously. The obtained absorption spectrum of the signal was then used to create a suitable fit with the Doppler broadening and Zeeman splitting as the two dominant contributions to the line broadening.

[1] S. Dickheuer et al. *Atoms* **7(2)**, 48 (2019)

P 5.36 Mon 16:30 Empore Lichthof

A new longitudinal 1D extinction setup for density measurements of nanodusty clouds in low-pressure plasmas — •Alexander Schmitz, Andreas Petersen, Nils Rehbehn, Sebastian Groth, and Franko Greiner — Insitut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel

Clouds of nanometer-sized particles, grown from molecular precursors in reactive low-pressure plasmas, exhibit a wide range of unique characteristics and effects. Hence the detailed knowledge of dust properties is of central importance to understand these complex systems. Methods like computed tomography or 2D extinction measurements are powerful tools to determine the particle densities but come with the downside of usually being time-consuming and requiring full optical access to the system. This significantly limits the possibility of using different diagnostics simultaneously and one must rely on the reproducibility of the investigated phenomena.

Here, we present a new setup that combines 1D extinction measurements with a co-aligned video camera. This makes it possible to reconstruct the dust density profile of a cylindrical nanodust cloud, while only needing access along one optical axis. This leaves enough room for further simultaneous diagnostics. The advantages and drawbacks of the setup will be discussed.

P 5.37 Mon 16:30 Empore Lichthof

On the influence of plasma parameters on particle size — •Sören Wohlfahrt, Niklas Kohlmann, Frank Wieben, Oguz Han Asnaz, Franko Greiner, and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Microparticles are the essential component of a (dusty) complex plasma. The forces affecting these particles, as well as their accumulated charge, depend prominently on their size. Thus, a precise knowledge of the particle size is a key input parameter for a quantitative description and modelling. However, in interaction with the plasma the particle size can change. The size of particles can be determined with very high precision by means of angle- and polarisation-resolved light scattering (ARPLS), which is based on a comparison of experimental data with Lorentz-Mie theory [1]. We will present the size evolution of melamine-formaldehyde (MF) microparticles for various discharge conditions. Especially, variation of rf-power and neutral gas pressure and their effect on the particle size are discussed.

[1] N. Kohlmann, F. Wieben, O. H. Asnaz, D. Block, F. Greiner, Phys. Plasmas 26, 053701 (2019)

P 5.38 Mon 16:30 Empore Lichthof

Numerical investigations of wave propagation in binary complex plasmas — •Lasse Bruhn, Frank Wieben, 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, MD simulations are used to investigate feasible parameter regimes for future experiments.

P 6: Plasma-surface interaction

Time: Tuesday 11:00–12:55 Location: b302

Invited Talk P 6.1 Tue 11:00 b302

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], Dmitriy Borodin[1], Alina Eksaeva[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 6.2 Tue 11:30 b302

The impact of surface morphology on the erosion of metallic surfaces -modelling with the 3D Monte-Carlo code ERO2.0 — •Alina Eksaeva[1], Dmitry Borodin[1], Juri Romazanov[1], Andreas Kirschner[1], Arkadi Kreter[1], Beatrix Göths[1], Marcin Rasinski[1], Bernhard Unterberg[1], Sebastijan Brezinsek[1], Christian Linsmeier[1], Espedito Vassallo[2], Matteo Passoni[2,3], David Dellasega[2,3], Michele Sala[3], and Federica Romeo[3] — [1]Forschungszentrum Juelich GmbH, Institut fuer Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), Juelich, Germany — [2]Istituto per la Scienza e Tecnologia dei Plasmi, CNR, Milano, Italy — [3]Dipartimento di Energia, Politecnico di Milano, Via Ponzio 34/3, 20133 Milan, Italy

The surface roughness has a vital impact on the erosion of plasma-facing components. The 3D Monte-Carlo code ERO2.0 is a versatile tool for describing the erosion and transport of impurities in the plasma. A model describing the surface roughness effect on erosion was implemented into the ERO2.0 code. A series of plasma experiments on surface roughness effect on the erosion have been carried out at the linear plasma device PSI-2. Experiments show in the case of molybdenum a reduction of the net erosion by up to 40% (rel. to the smooth case) due to the surface roughness of Ra = 600 nm, which is in line with ERO2.0 predictions. For the case of the JET ITER-like wall divertor (W-coated tiles) model shows the reduction of the net erosion by the factor of 2 for the surface roughness of 10 mcm scale; increased deposition in shadowed from the plasma areas is observed.

P 6.3 Tue 11:55 b302

Determination of the energy distribution of sputtered atoms from polished metallic surfaces by high resolution spectroscopy — •Stephan Ertmer, Oleksandr Marchuk, Sven Dickheuer, Sebastijan Brezinsek, Philippe Mertens, Marcin Rasiński, and Arkadi Kreter — Forschungszentrum Jülich GmbH - Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany

Knowledge of the energy distribution of sputtered atoms for ions at low impact energies is essential for different applications. We modelled the distribution from the line shape emitted by sputtered aluminium (Al) and tungsten (W). Mirror-polished Al and W samples were exposed to an argon (Ar) plasma ($T_e = 3\,\mathrm{eV}$; $n_e = 3.5 \times 10^{18}\,\mathrm{m}^{-3}$) in the linear plasma device PSI-2. The plasma ions were accelerated to impact energies of 30 to 160 eV onto the target by biasing. The line of sight of a high resolution spectrometer (resolving power $\lambda/\Delta\lambda = 7 \times 10^5$) was directed parallel to the target normal. The energy distribution of the sputtered atoms was modelled from the detected line shape using the Doppler-shifted-emission model [1] with an extension considering instrumental broadening and Zeeman splitting. The results show good agreement with the Thompson energy distribution. For an increase in the impact energy of the Ar^+ ions, we observe an increase in the high energy tail of the sputtered atoms distribution function. Furthermore, the reflection of light at the targets surface was modelled from the line shape and the surface binding energies were determined.

[1] S. Dickheuer et al. *Phys. Plasmas* **26**, 073513 (2019)

P 6.4 Tue 12:10 b302

Ion-induced secondary electron emission coefficient of clean and dirty metal surfaces analysed in an ion beam experiment — •Rahel Buschhaus[1], Maik Budde[2], and Achim von Keudell[1] — [1]Experimentalphysik II, Ruhr-University Bochum — [2]Department of Applied Physics, TU Eindhoven

In glow discharges the generation of secondary electrons at surfaces play an important role for ignition and maintenance of a plasma. The ion-induced secondary electron emission coefficient (iSEEC) γ depends on the chemical state of the surfaces and is defined as number of released electrons per incident ion. Depending wether metal surfaces are clean or „dirty“, e.g. oxidized, the γ coefficient varies [1]. The elementary plasma processes on surfaces are mimicked by sending quantified beams of ions to metal foils in an ultra-high vacuum reactor. Different thin metal foils are exposed to an ion beam of argon or metal ions, which are extracted from an inductively coupled plasma discharge (ICP). This ion beam is mass and energy selected (2eV-5keV) before reaching the metal foil. The unique feature of the here presented experiment is the possibility of analysis of surface processes induced by single and multiple ionized argon and/or metal ions and their oxides within a broad energy and mass range. For determination of the iSEECs a collector system based on current measurements is used [2]. We will present γ of different clean and dirty metal surfaces. The emission of electrons will be induced by either argon or metal ions within a broad energy range. [1] A. V. Phelps *et al. Plasma Sources Sci. Technol.* **8** R21 (1999) [2] A. Marcak *et al.*, *Rev. Sci. Instrum.* **86**, 106102 (2015)

P 6.5 Tue 12:25 b302

Interaction of low-energy electrons with metallic walls — •Franz Xaver Bronold and Holger Fehske — Institut für Physik, Universität Greifswald, 17489 Greifswald,

The interaction of electrons with the walls of the discharge vessel is an important surface process in technological low-temperature plasmas. It affects, for instance, the operation modii of dielectric barrier discharges, Hall thrusters, and divertor plasmas in fusion devices. Little is however known quantitatively about the process because it occurs at energies below 50 eV which are hard to access experimentally. There are only a few attempts to measure probabilities for electron absorption, backscattering, or secondary emission in this energy range. A few years ago we presented therefore an approach for calculating the probabilities from a semi-empirical microscopic model and applied it to dielectric walls [1]. The approach is based on an invariant embedding principle for a function $Q(E\eta|E'\eta')$ summing up the backscattering trajectories arising from the interaction of the incoming electron with the excitations and imperfections of the wall. Now we apply the approach to a metallic wall where the dynamic interaction of the penetrating electron with the metal's Fermi sea and the scattering on imperfections determines the absorption, backscattering, and secondary emission probabilities. Numerical results for the electron absorption probability of a Cu surface are in good agreement with experimental data indicating that the semi-empirical modeling captures in this case the low-energy scattering physics also rather well. [1] F. X. Bronold and H. Fehske, Plasma Phys. Control. Fusion **59**, 014011 (2017)

P 6.6 Tue 12:40 b302

Deuterium Retention and Surface Modification of Tungsten Alloys produced by Powder Injection Moulding after Deuterium Plasma Exposure — •Robert Krug[1], Sören Möller[1], Steffen Antusch[2], Marcin Rasinsky[1], Arkadi Kreter[1], Marius Wirtz[1], and Bernhard Unterberg[1] — [1]Forschungszentrum Jülich, Institut für Energie- und Klimaforschung,52425 Jülich, Germany — [2]KarlsruheInstitute of Technology, Institute for Applied Materials, P.O. Box3640, 76021 Karlsruhe

In this work, we investigate the behaviour of the surface near region (first few μm) of different PIM produced tungsten alloys under deuterium plasma exposure. For this, the samples are exposed to a deuterium plasma with a total fluence of $\approx 5 \cdot 10^{25}\mathrm{m}^{-2}\mathrm{s}^{-1}$ at a temperature of 200°C in the linear plasma device PSI-2.

In preliminary studies it was determined, that especially preferential sputtering of the alloying particles and the plasma interaction with the carbon based binder have the most impact on the plasma behaviour of PIM alloy materials.

These surface modifications due to the plasma are investigated by Focussed Ion Beam and Scanning Electron Microscopy (FIB-SEM), the change in material composition by Secondary Ion Mass Spectrometry (SIMS) and the deuterium depth concentration in the first few μm by Nuclear Reaction Analysis (NRA).

P 7: Atmospheric-pressure plasma and applications 2

Time: Tuesday 11:00–13:00 Location: b305

Invited Talk P 7.1 Tue 11:00 b305

Simulation of microarcs: challenges and perspectives — •Margarita Baeva[1], Detlef Loffhagen[1], Markus M. Becker[1], Erwan Siewert[2], and Dirk Uhrlandt[1] — [1]Leibniz Institute for Plasma Science and Technology, 17489 Greifswald, Germany — [2]Linde AG, Geschäftsbereich Linde Gas, 85716 Unterschleissheim, Germany

Microarcs are generated on sub-millimetric scale. They are encountered in switching devices and are currently considered as promising tools in material processing. Experiments on microarcs are extremely difficult so that modelling can be seen as an alternative for their characterization. Studies on microarcs can greatly contribute to the overall arc plasma modelling. In particular, a unified numerical modelling of microarcs opens the opportunity to clarify questions of fundamental importance: to what extent do arc column and near-electrode regions interact with each other over different arc lengths; is the division of the arc plasma into sub-regions relevant to short-length arcs; what is the extension of the regions with considerable space-charge; how do the near-electrode regions change in space; do cathode and anode boundary regions merge when the arc length becomes minuscule. Results of a recent unified model of microarcs will be presented and discussed along with those obtained by means of a fully non-equilibrium approach, in which the space charge sheaths are so far unresolved.

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

P 7.2 Tue 11:30 b305

Vacuum ultraviolet spectroscopy of cold atmospheric pressure plasma jets — •Judith Golda[1], Beatrix Biskup[2], Vincent Layes[2], Tristan Winzer[1], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Experimental Physics II, Ruhr-University Bochum, Germany

Due to elevated pressure and thus high number of three-body collisions, cold atmospheric pressure plasmas generate excimer species that can emit highly energetic photons thus transferring energy inside the discharge and to treated substrates. However, they are difficult to assess as they are absorbed by air or window material.

Here, we present a method to measure vacuum ultraviolet (VUV) photons using a monochromator with an aerodynamic window. Emission spectra of an RF-excited atmospheric plasma jet (COST-Jet) [1] were analyzed for typical gas mixtures. The data suggest that helium excimers contribute notably to the excitation of molecular and atomic species. The emission intensities do not follow the densities of ground-state species, underlining the variety of excitation channels and the change of the electron energy distribution function under changing the gas composition.

[1] J. Golda et al., J. Phys. D: Appl. Phys. 49 084003, 2016.

P 7.3 Tue 11:45 b305

Verification of electric discharge modeling code developed in FEniCS — •Aleksandar P. Jovanovic, Detlef Loffhagen, and Markus M. Becker — Leibniz Institute for Plasma Science and Technology, Greifswald, Germany

The main goal of this work is to verify a newly developed fluid model code and to test its performance. The code is developed in FEniCS, open-source computing platform for solving partial differential equations by the finite element method. This platform is chosen due to support for symbolic representation of the weak form of partial differential equation, which simplifies problem definition significantly. In addition, it supports parallel processing by using MPI and provides various types of finite elements and numerical solvers. The code is verified by benchmarking and by the method of exact solution. Two benchmark studies, 1) modeling of an axisymmetric positive streamer in air, and 2) modeling of a low pressure glow discharge in argon are presented. The results are compared to the benchmark data in the first, and to the results obtained with a commercial software COMSOL Multiphysics® in the second study. In addition, the method of exact solution for a time of flight experiment is used for verification purpose. In all cases good agreement with the reference data is observed and a similar parallel performance as with COMSOL is achieved.

Funded by the Deutsche Forschungsgemeinschaft – project number 407462159.

P 7.4 Tue 12:00 b305

Atmospheric pressure RF plasma jets driven by tailored voltage waveforms in He/N_2 mixtures — •Ihor Korolov[1], Marc Leimkühler[1], Mark Böke[1], Zoltán Donkó[2], Volker Schulz-von der Gathen[1], Lena Bischoff[1], Gerrit Hübner[1], Péter Hartmann[2], Timo Gans[3], Yue Liu[4], Thomas Mussenbrock[4], and Julian Schulze[1,5] — [1]Ruhr-University Bochum, Germany — [2]Wigner Research Centre for Physics, Hungary — [3]University of York, United Kingdom — [4]Brandenburg University of Technology Cottbus-Senftenberg, Germany — [5]School of Physics, Dalian University of Technology, China

Micro atmospheric pressure plasma jets (μAPPJ) can efficiently generate different reactive species at the buffer gas temperatures which are close to the ambient temperature. These reactive species are suited for various applications: wound healing, sterilization, cancer treatment, surface modification, etc. In this work, we investigate the μAPPJ operated in mixtures of He and N_2 and driven by tailored voltage waveforms both experimentally by using tunable diode-laser absorption spectroscopy and via kinetic Particle-in-Cell/Monte Carlo simulations. We find an excellent agreement between the results of experiment and simulations over a wide range of conditions for the spatially resolved and averaged helium metastable density. The latter is found to be significantly enhanced by increasing the number of consecutive driving harmonics. The results show that voltage waveform tailoring allows one to enhance the control over the electron energy distribution function to optimize the excited species generation.

P 7.5 Tue 12:15 b305

Laser-induced fluorescence of magnetized plasma with magnetic sub-level resolution — •Roman Bergert, Slobodan Mitic, and Markus H. Thoma — I. Physikalisches Institut, Justus-Liebig Universität Gießen

The behaviour of a dielectric barrier discharge (DBD) jet influenced by an external constant magnetic field (0.3 T) at different pressures was investigated by tunable diode laser absorption spectroscopy (TDLAS) and laser-induced fluorescence (LIF) in perpendicular observation to

the magnetic field. TDLAS and LIF were done with magnetic sub-level resolution on π (linear) and σ (circular) polarized transitions of Argon $1s_4$ at 842.47 nm and $1s_5$ at 801.48 nm. Unpolarized laser light was used for the measurements. For LIF the 842 nm transitions were used for pumping.
The $1s_4$ magnetic sub-level densities were reconstructed from linear polarized transitions for different pressures. The densities were later used for modeling of the magnetic sub-level and polarization resolved fluorescence of 842 nm and 801 nm for different pressures. 'Forbidden' transitions were observed and could be explained with a model including level mixing of the $2p_8$ sub-level states through neutral collisions. A strong visible pressure dependence of LIF and the development of the 'forbidden' transition could be observed and modeled successfully.

P 7.6 Tue 12:30 b305

Ro-vibrational distribution measurements in transient atmospheric pressure plasmas by coherent anti-Stokes Raman scattering — •Jan Kuhfeld, Dirk Luggenhölscher, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, Germany

Ro-vibrational excited molecules govern the plasma wall interaction and the chemical reactions in atmospheric pressure plasmas. Excitation of a molecule can occur by an energetic electron or by collisional transfer from an already excited molecule. One of the key goals in discharge design is optimizing these excitation processes in order to achieve maximum energy efficiency in chemical conversion, e.g. CO_2 into CO. The experimental approach for investigating these processes introduced here is based on a particular coherent anti-Stokes Raman scattering (CARS) scheme. This single shot dual pump CARS scheme provides information on the ro-vibrational population of two molecular species simultaneously, here N_2 and CO_2. Additionally, one of the laser beams for the CARS technique is used to perform electric field measurements via E-FISH (electric field induced second harmonic generation). Excited molecules are created by two separate ns-pulsed APPJ with effluents intercepting. Space and time resolutions are determined by the interaction volume of the lasers and the pulse length respectively. Those are in the order of 100 μm and 10 ns. Here, first measurements of the electric field and the vibrational excitation of Nitrogen in a Helium-Nitrogen mixture are presented.

P 7.7 Tue 12:45 b305

Gliding arc plasmatron- plasma chemical reactor for methane conversion — Simon Böddeker, •Nikita Bibinov, and Peter Awakowicz — Institute for Electrical Engineering and Plasma Technology, Ruhr-University Bochum, 44801 Bochum, Germany

A gliding arc plasmatron (GAP) is applied as part of plasma chemical reactor for methane conversion and synthesis of carbon containing materials without associated carbon dioxide production. This plasma source can be operated in two different modes, namely gliding arc channel with diameter of 0.2-0.3 mm similar to conventional GA in vortex gas flow and plasma plume mode, with one (or several) hot and broad plasma object(s) with diameter 4-5mm incorporated into the gliding arc channel. Plasma conditions and efficiency of methane conversion in these two modes are very different. The first GAP mode is characterized by gas temperature of 2000K-2500K, electron density of about 10^{14} cm^{-3} and methane dissociation frequency of about 10 s^{-1}. Under these plasma conditions mainly formation of methyl radicals is expected. Plasma of plasma plume is very hot, 5500K-6000K, electron density amounts to about 10^{15} cm^{-3} and frequency of thermal methane dissociation is about 10^7 s^{-1}. Under these plasma conditions methane will be completely dissociated. In optimized GAP geometry, gas flow rate and electric current (200-300 mA) plasma plume has contact to the plasma reactor surface only via thin GA channels. At that material of electrodes is not thermal overloaded. Switching between modes is possible by variation of plasma reactor geometry and gas flow.

P 8: Low-temperature plasma and applications

Time: Tuesday 14:00–15:25 Location: b302

P 8.1 Tue 14:00 b302

Spoke-synchronized probe measurements in a high power impulse magnetron discharge — •Julian Held, Philipp Maass, Volker Schulz-von der Gathen, and Achim von Keudell — Experimental Physics II, Ruhr University Bochum, Germany

In high power impulse magnetron sputtering (HiPIMS) bright plasma spots are observed during the discharge pulses that rotate with velocities in the order of 10 km/s in front of the target surface. It has proven very difficult to perform any quantitative measurements on these so-called spokes, that emerge stochastically during the build-up of each plasma pulse. In this contribution, we present a new *time shift averaging* method to perform measurements integrating over many discharge pulses, but without phase averaging of the spoke location, thus preserving the information of the spoke structure. This method is then applied to perform Langmuir probe measurements, employing magnetized probe theory to determine the plasma parameters inside the magnetic trap region of the discharge. Spokes are found to have a higher plasma density, electron temperature and plasma potential than the surrounding plasma. The electron density slowly rises at the leading edge of the spoke to a maximum value of about $1 \cdot 10^{20}\,\mathrm{m}^{-3}$ and then drops sharply at the trailing edge to $4 \cdot 10^{19}\mathrm{m}^{-3}$. The electron temperature rises from 2.1 eV outside the spoke to 3.4 eV at the trailing end of the spoke. A reversal of the plasma potential from about -7 V outside the spoke to values just above 0 V in a spoke is observed, as has been proposed in the literature.

P 8.2 Tue 14:25 b302

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

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

In this work, optical emission spectroscopy (OES) and energy resolved ion mass spectrometry where used to gain further understanding of the above mentioned particle movement. While OES delivers information about the emitting particles inside the plasma the mass spectroscopy will see the particles which leave the plasma only. The measurements where done for a circular Ti-target with 50 mm diameter and 0.5 Pa Argon as working gas.

It could be shown that the maximum rotation velocity is in the range of 0.5 - 1.8 km/s depending on the measured species. Differences in the axial distribution of these velocities for Ar and Ti show an dependency on the axial movement of the particles. Furthermore power and time variations where performed showing no reasonable influence.

P 8.3 Tue 14:40 b302

Electric field measurements on the INCA discharge — Christian Lütke Stetzkamp, •Tsanko Vaskov Tsankov, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany

A periodically structured vortex electric field can lead to an efficient collisionless energy gain [1,2]. This theoretical concept was realized experimentally by the inductively coupled array (INCA) discharge and the first results reveal the great potential of the concept [2].

The exact structure of the electric field of this discharge is a vital part of the efficiency of the stochastic heating. Here results from measurements of the induced electric field in INCA with different diagnostics are shown and compared with theoretical predictions. In-situ measurements with RF modulation spectroscopy (RFMOS) and ex-situ B-dot measurements are used.

[1] U. Czarnetzki and Kh. Tarnev, *Phys. Plasmas* **21**, 123508 (2014)
[2] U. Czarnetzki, *Plasma Sources Sci. Technol.* **27**, 105011 (2018)
[3] Philipp Ahr *et al*, *Plasma Sources Sci. Technol.* *27*, 105010 (2018)

P 8.4 Tue 14:55 b302

Experimental benchmark of radiation transport calculations

in low pressure low temperature hydrogen discharges — •Stefan Briefi[1,2], Frederik Merk[1], Roland Friedl[2], Caecilia Fröhler[2], and Ursel Fantz[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [2]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg, Germany

In a discharge, the emissivity of the atomic hydrogen Lyman series is strongly affected by reabsorption of photons resulting in an underestimation of the population densities determined from VUV spectroscopy. This effect can be corrected via line escape factors. In general, the required correction increases with the atomic hydrogen density n_H. For $10^{18} < n_H < 10^{20}$ m^{-3} typical for low pressure plasmas, the correction can reach orders of magnitude making a careful benchmark inevitable.

Measurements have been carried out at a planar ICP at varying pressure (1 to 10 Pa) and RF power (700 to 1000 W) with an intensity-calibrated VUV spectrometer for determining the emissivity of the Lyman series up to L_ζ ($n = 7$). In addition, the population of the $n = 2$ state of atomic hydrogen was measured with tunable diode laser absorption spectroscopy on the Balmer-α line. Furthermore, the population of the higher lying states up to $n = 7$ is obtained from optical emission spectroscopy. The latter two diagnostics are not affected by reabsorption and hence the obtained population densities are used as reference values. They are matched very well when correcting the populations derived from VUV spectroscopy with line escape factors.

P 8.5 Tue 15:10 b302

Improved Analytic Response Function of the Planar Multipole Resonance Probe — •Michael Friedrichs[1], Dennis Pohle[2], Ilona Rolfes[2], and Jens Oberrath[1] — [1]Modeling and Simulation, Department of Electric Power Engineering, South Westphalia University of Applied Science, Soest, Germany — [2]Institute of Microwave Systems, Department of Electrical Engineering and Information Sciences, Ruhr University Bochum, Bochum, Germany

The planar multipole resonance probe (pMRP), which is mounted inside of the chamber wall, is a specific design of the Active Plasma Resonance Spectroscopy (APRS) and a promising candidate to monitor plasma processes without perturbing them. Based on the cold plasma model an analytic solution of the response function for the ideal pMRP could be derived, which allows to determine the resonance frequency of the probe plasma system. The geometry of the real pMRP is more complicated and requires a numerical model for full 3D electromagnetic simulation in CST. The calculated resonance frequencies of both models are qualitatively in agreement but differ in the exact position. This difference is dominated by the difference in the geometry, which cannot be considered directly in the analytic solution. Thus, a simulation of a more realistic geometry in electrostatic approximation will be presented in Comsol Multiphysics and a numerical adaption of the vacuum excitation in the analytic solution can be implemented in the analytic evaluation of the response function. This allows an improvement of the analytic solution and can be used to derive a more realistic formula for the resonance frequency.

P 9: Helmholtz Graduate School 2 and Magnetic confinement 2

Time: Tuesday 14:00–16:10 Location: b305

Invited Talk P 9.1 Tue 14:00 b305

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 connections lengths of typically several 100 m. 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, a strong poloidal plasma rotation along the islands' magnetic flux surfaces is observed, which is accompanied by rather flat or even hollow profiles of electron temperature and density across the islands, resulting in a large SOL width (∼5 cm). Outside the islands, the SOL reveals similarities (e.g. exponentially decaying profiles) and differences to a typical tokamak SOL. A particular focus is laid on blob-filaments, which are found to have much slower radial propagation velocities in W7-X than in tokamaks. The reasons for and implications of this observation will be discussed.

P 9.2 Tue 14:30 b305

SOLPS simulations for alternative divertor configurations in the future upper divertor in ASDEX Upgrade — •Ou Pan[1,2], Tilmann Lunt[1], Marco Wischmeier[1], David Coster[1], Ulrich Stroth[1,2], and The ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Physik-Department E28, Technische Universität München, 85748 Garching, Germany

High heat loads on the plasma facing components of tokamak divertors impose serious constraints on the achievable performance of future fusion reactors. ASDEX Upgrade (AUG) recently decided the upgrade of its upper divertor to study alternative divertor configurations (ADCs) which are currently discussed as a possible solution for the power exhaust problem. Validated by recent AUG experiments in upper single null (SN) configuration, the SOLPS code was applied to extrapolate the performance of the X-divertor and snowflake configurations in the future upper divertor. With the same heating, fueling and impurity seeding, as well as similar parameter profiles at the outer mid-plane, the simulations predict a much lower target power load in ADCs than that in SN configuration. This is explained by a larger radiation volume and an enhanced volumetric recombination rate in such ADCs. Simulations with drifts show a modified cross-field transport and the activation of a secondary strike point.

P 9.3 Tue 14:55 b305

Scrape-off layer (SOL) power width scaling and correlation between SOL and pedestal gradients across L, I and H-mode plasmas at ASDEX Upgrade — •Davide Silvagni[1,2], Thomas Eich[1], Michael Faitsch[1], Tim Happel[1], Bernhard Sieglin[1], Pierre David[1], Luis Gil[3], Ulrich Stroth[1,2], and the ASDEX Upgrade team[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [2]Physik-Department E28, Technische Universität München, James-Franck-Str. 1, 85748 Garching, Germany — [3]Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade Lisboa, PT

A cross-regime (L-mode, I-mode, inter-type-I-ELM H-mode and stationary ELM-free H-mode) database combining scrape-off layer (SOL) power decay length λ_q divertor measurements and upstream SOL electron pressure, temperature and density decay lengths has been assembled at ASDEX Upgrade. It is found that a cross-regime λ_q scaling is best described by a local edge quantity, such as the edge electron pressure evaluated at $\rho_{\mathrm{pol}} = 0.95$. Furthermore, λ_q exhibits a clear correlation with edge electron pressure gradient lengths, no matter if taken inside or outside the separatrix. In addition, the database reveals that SOL and pedestal electron pressure gradients are remarkably well correlated across all confinement regimes. Moreover, it is shown that the Spitzer-Härm electron conduction regime is a reasonable approximation to estimate λ_q across different confinement regimes. The main implication of these findings is that in these regimes a widening of λ_q is linked to a reduction of edge electron pressure gradients.

P 9.4 Tue 15:20 b305

Quantitative investigation of the neutron production in ASDEX Upgrade — •Monika Koleva[1,2], Giovanni Tardini[1], Hartmut Zohm[1], and The ASDEX Upgrade Team[1] — [1]Max-Planck-Institute for Plasma Physics, Garching bei München, Germany — [2]LMU, München, Germany

A detailed ASDEX Upgrade geometry has been implemented in the MonteCarlo neutron transport code Serpent, the reference for a new absolute calibration of the neutron counters. The code allows the description of 3D geometries imported from CAD.

The experimental technique consists of a toy train carrying a radioactive source at two radial positions inside the tokamak vessel on the equatorial plane, allowing a long calibration time.

The current simulation scenario uses a neutron point source and looks at the output of the Helium-3 neutron detector. This is a prior step to including a radioactive source with an energy distribution and aims to test as well the detector response. The energy of the source has been varied between 0.025 eV and 4 MeV. A convergence assessment with respect to the total number of neutrons run is shown, ranging from 10E4 to 10E7. Taking vessel components but no moderation into account the detector already calculates about 1 n/s which is close to the experimental result. Further clarification is still in progress. The next step is providing a moderator and simulating also the BF3 and scintillation detectors at ASDEX Upgrade.

In addition, preliminary results of the discrepancies between the experimental neutron rate and the one predicted by TRANSP are shown.

P 9.5 Tue 15:45 b305

Assessment of plasma edge transport in Neon seeded plasmas in disconnected double null configuration in EAST — •Dieter Boeyaert[1,3], Sven Wiesen[1], Marco Wischmeier[2], Wouter Dekeyser[3], Stefano Carli[3], Liang Wang[4], Fang Ding[4], Kedong Li[4], Yunfeng Liang[1,4], Martine Baelmans[3], and EAST -team[5] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching, Germany — [3]KU Leuven, Department of Mechanical Engineering, Celestijnenlaan 300, 3001 Leuven, Belgium — [4]Institute of Plasma Physics, Hefei 230031, China — [5]see appendix of Wan B.N. et al., Nucl. Fusion 2019

Power and particle exhaust are key for future nuclear fusion reactors [1]. Dissipation is determined by the amount of power, particle and momentum losses inside the Scrape-Off Layer (SOL). Under high power conditions in future all-metal fusion devices like ITER or DEMO, extrinsic impurity seeding is required to induce divertor detachment through impurity radiation [1].

This contribution analyzes Ne seeded and unseeded DDN deuterium discharges at EAST with decreasing separation between the separatrices, both with experimental data from EAST and SOLPS-ITER simulations [2]. Ne seeded discharges in H-mode from the 2019 EAST campaign are studied (heating power P_heat = 2.5 MW, plasma current I_p = 0.4MA, and toroidal field B_p = 2.4T). [1] M. Wischmeier et al., Nucl. Mater. 2015 [2] S. Wiesen et al., Nucl. Mat. 2015

P 10: Poster Session 2

Time: Tuesday 16:30–18:30 Location: Empore Lichthof

P 10.1 Tue 16:30 Empore Lichthof

High-pressure melting line of helium from ab initio calculations — Martin Preising and •Ronald Redmer — Institut für Physik, Universität Rostock, D-18051 Rostock

Knowledge of the high-pressure melting line of helium up to the TPa region is important to astrophysics, e.g., for the determination of the region of hydrogen-helium phase separation as predicted in the interior of gas giants like Saturn and Jupiter. We applied two-phase simulations to directly calculate the high-pressure melting line of helium from 425 to 10 000 K and from 15 GPa to 35 TPa by using molecular dynamics based on density-functional theory. The implementation of the two-phase simulation method and the relaxation of the simulation to an equilibrium state was studied in detail, as well as its convergence with respect to particle number. We performed extensive two-phase simulations with the Perdew, Burke and Ernzerhof (PBE) and the van der Waals density functional (vdW-DF) exchange-correlation functional and found almost identical results. The P(T) melting line shows a slight downward curvature at higher pressures but not as pronounced as predicted in earlier studies.

P 10.2 Tue 16:30 Empore Lichthof

Physics applications of the ASDEX Upgrade flight simulator Fenix — •Michael Englberger[1,2], Filip Janky[2], Emiliano Fable[2], Ralph Dux[2], Ondrej Kudlacek[2], Thomas Pütterich[2], Hartmut Zohm[2], and the ASDEX Upgrade Team[2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, D-80799 München — [2]Max-Planck-Institut für Plasmaphysik, D-85748 Garching b. München, Germany

Fenix, the ASDEX Upgrade (AUG) flight simulator, is a tool based on the ASTRA transport code, coupled with the 2-D equilibrium code SPIDER and a Simulink model of the actuators and the AUG control system. In this work Fenix was used to simulate existing AUG discharges in order to study and improve the models of Fenix. We focused on plasma discharges in which the loss of heating sources led to a disruption of the plasma. The relevant plasma and control system parameters already showed a realistic behavior, while some deviations require further analysis. Another aim of this work was to find a description of the tungsten influx into the vessel. Tungsten is the dominant radiation source in AUG, therefore, it is essential to include a tungsten influx model. An estimate of the tungsten influx was calculated from measurements for a set of typical H-mode plasma discharges. Using experimental data, a scaling for tungsten influx as a function of plasma parameters (e.g. electron temperature and density) was found. The implementation of the tungsten influx improved the behavior of the simulated plasma radiation, however, some remaining discrepancies showed the tungsten transport needs further improvement.

P 10.3 Tue 16:30 Empore Lichthof

Self-sustained divertor oscillations in ASDEX Upgrade — •Paul Heinrich[1,2], Peter Manz[2,1], Matthias Bernert[2], Gregor Birkenmeier[2,1], Dominik Brida[2], Marco Cavedon[2], Pierre David[2], Michael Griener[2], Tim Happel[2], Ulrike Plank[2], Felix Reimold[3], Ulrich Stroth[2,1], Marco Wischmeier[2], and Wei Zhang[2] — [1]Physik-Department E28, Technische Universität München, James-Franck-Str. 1, 85748 Garching, Germany — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [3]Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, 17491 Greifswald, Germany

Alternating radiation phenomena between the inner and outer divertor regions in the sub kHz range are investigated in the tokamak ASDEX Upgrade. While the inner divertor oscillates between the onset and fluctuating state of detachment, the outer divertor oscillates between conditions where it can maintain high recycling conditions or not. The detachment state of the inner divertor determines the magnitude of the neutral flux through the private flux region, thus sets the recycling conditions at the outer divertor. In return these recycling conditions determine the particle content in the divertor, hence the detachment state at the inner divertor.

P 10.4 Tue 16:30 Empore Lichthof

Observation of Alfvénic mode activity at the Wendelstein 7- X stellarator — •Kian Rahbarnia[1], Torsten Bluhm[1], Matthias Borchardt[1], Bernardo B Carvalho[2], Ralf Kleiber[1], Axel Könies[1], Sara Mendes[1], Jonathan Schilling[1], Christoph Slaby[1], Henning Thomsen[1], Manfred Zilker[1], and Wendelstein 7-X[1] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Instituto de Plasmas e Fusao Nuclear Instituto Superior Tecnico, Lisbon, Portugal

During the last divertor campaign at the Wendelstein 7-X stellarator (Greifswald, Germany) no dedicated experiments have been carried out to investigate the excitation mechanism of Alfvén eigenmodes (AE) in the plasma. Nevertheless fairly independent from magnetic configuration and heating scenario (electron cyclotron resonance heating and/or neutral beam injection) broadband fluctuations around 200 kHz have been observed by the Mirnov diagnostic. A complete amplitude and phase calibration of the in total 125 individual probes including all relevant data acquisition system components allows a detailed spectral and mode analysis, using damped multiple signal classification (DMUSIC) and stochastic system identification techniques (SSI). The results are compared with theoretically predicted Alfvén continua calculated with the 3D-MHD continuum code CONTI. The nature of these fluctuations is most likely associated with ellipticity-induced Alfvén eigenmodes in the outer regions of the plasma. The role of density and temperature profiles, as well as iota profiles and Doppler shift effects due to electric fields at the plasma edge are investigated.

P 10.5 Tue 16:30 Empore Lichthof

Tomographic inversion analysis of current-driven MHD collapses in Wendelstein 7-X stellarator plasmas — •Henning Thomsen, Christian Brandt, Yu Gao, Sara Mendes, Kian Rahbarnia, Jonathan Schilling, Torsten Stange, and Marco Zanini — MPI f. Plasmaphysik, Wendelsteinstr 1, 17491 Greifswald

The X-ray tomography system XMCTS has been operated in the recent campaign of Wendelstein 7-X stellarator. The diagnostic consists of 20 cameras inside the plasma vessel and enables tomographic image reconstruction from more than 300 lines of sight. Problems in the camera shutter setup were identified and are considered in the tomographic inversion procedures. Tomogram series of intervals with high time resolution are used to visualize fast internal MHD plasma events in order to understand the underlying instability mechanisms. One important data analysis tool for post-processing is the filtering of the spatio-temporal data with the singular value decomposition. This technique can be used to remove the background radiation distribution of the tomograms. We apply these methods to X-ray data recorded during experiment programs with toroidal electron cyclotron current drive, in which fast collapses of the central plasma temperature profile have been observed.

P 10.6 Tue 16:30 Empore Lichthof

Plasma beta effects on the island divertor of Wendelstein 7-X — •Alexander Knieps[1], Yunfeng Liang[1], Yasuhiro Suzuki[2], Carsten Killer[3], Olaf Grulke[3], Marcin Jakubowski[3], Holger Niemann[3], Yu Gao[3], Olaf Neubauer[1], Guruparan Satheeswaran[1], Philipp Drews[1], Dirk Nicolai[1], Joachim Geiger[3], Michael Endler[3], and W7-X Team[1,2,3] — [1]Forschungszentrum Jülich, Jülich, Germany — [2]National Institute for Fusion Science, Toki, Japan — [3]Institut für Plasmaphysik, Greifswald, Germany

The Wendelstein 7-X (W7-X) stellarator relies on an island divertor for heat- and particle-exhaust. It aims to demonstrate long-pulse operation in fusion relevant performance regimes, aiming at a plasma beta of around 5%. At such performance levels, pressure-gradient-driven currents can modify the structure of the edge magnetic field. W7-X is a multi-configuration machine, and there are strong differences between the individual configurations' responses to high plasma pressure. This work presents simulations of pressure-related magnetic field changes in multiple configurations, obtained using the HINT code. The beta-induced changes of the heat-fluxes onto the divertor targets are simulated using fieldline-diffusion and compared to experimental data obtained during the divertor campaigns of W7-X in 2017 and 2018.

P 10.7 Tue 16:30 Empore Lichthof

Conceptual design study of an Energy Recovery System for the DEMO NBI — •Giuseppe Starnella, Christian Hopf, and Niek den Harder — Max-Planck-Institut für Plasmaphysik, Garching, Germany

The commercial viability of a fusion power plant requires Neutral Beam Injectors with a high energy efficiency. The main limitation on the ITER NBI is represented by the gas neutralisation efficiency. In this regard, the plasma neutraliser is one of the promising new technologies that are under investigation for the DEMO NBI. As an alternative option, the concept of Energy Recovery makes the current technique of gas neutralisation still a viable choice. The idea is to recover the energy of the residual ions of the neutralisation process by decelerating them onto electrically biased collectors, after separating the negative and positive ions from the neutral beam in opposite directions. We present the CAD model of the conceptual design of an ERS and its integration into an NBI ITER-like beamline. A 3D ion optics code is used to simulate the ion trajectories. The ERS efficiency and the relative improvement of the NBI wall-plug efficiency are studied as functions of the residual ion deceleration energy. We show that a recovery energy of 50 keV allows the collection of all the ions. The impact of the beamline new configuration on the gas density profile is also investigated, especially in terms of neutral beam and residual ion losses.

P 10.8 Tue 16:30 Empore Lichthof

Adapting a hybrid kinetic/gyrokinetic semilagrangian code for the studying of fusion plasmas — •Aleksandr Mustonen[1], Karen Pommois[2], Felipe Nathan DeOliveira[3], Simon Lautenbach[4], Florian Allmann-Rahn[5], Rainer Grauer[6], and Daniel Told[7] — [1]Aleksandr.Mustonen@ipp.mpg.de — [2]Karen.Pommois@ipp.mpg.de — [3]Nathan.DeOliveira@ipp.mpg.de — [4]Simon.Lautenbach@ruhr-uni-bochum.de — [5]Florian.Allmann-Rahn@rub.de — [6]Grauer@tp1.ruhr-uni-bochum.de — [7]Daniel.Told@ipp.mpg.de

An investigation of many important fusion plasma phenomena, directly affecting the confinement and stability, is only possible through a kinetic modeling because of the underlying effects which have relatively small characteristic scales. Fully kinetic simulations providing all of the information about the particle distribution, however, have a major drawback of their high computational cost.

The usage of a hybrid models is one of the possible ways if one would like to circumvent this limitation and investigate the nature and the physics of the edge transport barrier. By using of a hybrid: a kinetic model for ions and a drift/gyrokinetic for electrons we can resolve all of the effects related to ions without any reduction while still retaining kinetic electron effects.

Basing on the "ssV" code by the computational plasma physics group at Ruhr-Universität Bochum, we are developing a new flux conservative model for the edge tokamak plasma with a flux-aligned coordinates. A delta-f version of code is under development, which is used for the code comparison for the modeling of Landau damping and ITG mode.

P 10.9 Tue 16:30 Empore Lichthof

Towards nonlinear simulations of mitigated disruptions in ASDEX Upgrade — •Fabian Wieschollek, Matthias Hölzl, and Sibylle Günter — Max Planck Institute for Plasma Physics, 85748 Garching bei München, Germany

Disruptions constitute a significant threat for large-scale tokamak devices due to associated massive heat loads and mechanical stresses. Hence, disruptions have to be studied extensively to improve detection, avoidance or mitigation schemes. One promising tool for disruption mitigation foreseen also for the ITER tokamak are shattered pellet injections (SPI), where pellets consisting of Deuterium or low-Z impurities like Neon or Argon are injected after shattering.

Simulations of mitigated disruptions in ASDEX Upgrade using the nonlinear MHD code JOREK are under preparation. We investigate SPI both into unperturbed plasmas and into configurations that exhibit disruption precursors, to understand the effectiveness of SPI depending on plasma dynamics. First results for deuterium SPI are shown. For realistic simulations of impurity-SPI, JOREK needs to be extended. We plan to trace each charge state of the impurities separately using a coronal model. First tests and further plans are shown.

P 10.10 Tue 16:30 Empore Lichthof

Implementation and testing of stellarator-capable models in JOREK — •Nikita Nikulsin[1], Matthias Hoelzl[1], Alessandro Zocco[2], Rohan Ramasamy[1], Karl Lackner[1], and Sibylle Günter[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Max Planck Institute for Plasma Physics, Greifswald, Germany

The JOREK nonlinear MHD code, which currently only supports tokamak simulations, is being extended to stellarators. This is a two-part process. First, a stellarator-capable model, i.e. a model that does not make any assumptions on the underlying geometry, needs to be implemented. The second step involves modifying the currently implemented axisymmetric flux-aligned grids to allow alignment to non-axisymmetric flux surfaces.

We have derived a hierarchy of stellarator-capable models which have better conservation properties than presently used models, but also a different and more complicated mathematical structure [1]. Here, we present our work on the implementation of these new models, first testing results and the peculiarities associated with the new models. A comprehensive benchmark of the new models against presently used models will be carried out in the tokamak limit before we proceed to stellarator simulations.

[1] N. Nikulsin et al, Phys. Plasmas 26, 102109 (2019).

P 10.11 Tue 16:30 Empore Lichthof

Self-consistent 2D fluid model for optimizing RF coupling at NNBI ion sources — •Dominikus Zielke[1,2], Stiliyan Lishev[3], Stefan Briefi[1,2], and Ursel Fantz[1,2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg, Germany — [3]Faculty of Physics, Sofia University, 1164 Sofia, Bulgaria

In Negative-ion based Neutral Beam Injection systems (NNBI) for fusion, a hydrogen plasma is generated via inductive RF coupling at a frequency of 1 MHz inside the ion source in cylindrical vessels, called drivers. At low gas pressures of 0.3 Pa, electron densities and temperatures of $10^{18}\,\mathrm{m}^{-3}$ and 10 eV are reached. Only a fraction η of the generator power of up to 100 kW per driver is absorbed by the plasma, the rest is lost via eddy currents in the RF network, the internal Faraday screen and the surrounding steel structure. Since at 100 kW, the RF components work close to their technological limits, it is desirable to use lower generator powers while increasing η.

To optimize the RF coupling with respect to e.g. RF frequency or geometry, a 2D cylindrically symmetric multi-species fluid model is used, which describes the coupling between the RF fields and the electrons in the stochastic heating regime self-consistently.

The model is successfully validated with electrical and Langmuir probe measurements from the BATMAN Upgrade ion source testbed, where η is measured to be around 70-80%. The model is then utilized to study the impact of the distances between RF coil windings, coil and discharge, Faraday screen and surrounding steel structure on η.

P 10.12 Tue 16:30 Empore Lichthof

Braginskii Transport Coefficients for the Gyrokinetic Sugama Collision Operator versus the full Landau Operator — •Mario Raeth and Klaus Hallatschek — Max Planck Institute of Plasma Physics, Garching, Germany

The ad-hoc model collision operator derived by Sugama et al. and implemented in a Eulerian gyrokinetic solver (CGYRO) is tested in detail against the multi-fluid transport equations for magnetised plasmas derived from the Landau collision operator by Braginskii . It has been shown that the anomalous transport levels in gyrokinetic turbulence simulations with this collision operator do not match Braginskii fluid levels in the presence of significant temperature fluctuations.

To further investigate the transport processes, scenarios are created which allow us to isolate the various transport processes described by the Braginskii fluid model. By this method, it is possible to see precisely which transport coefficients result from the Sugama operator. In addition to the deviation of the parallel transport processes of $\sim 20\%$, it is shown that the perpendicular heat flux is significantly larger (by $\sim 50\%$ for the ion heat conductivity) than the quantities derived from the Landau operator. The ion stress caused by a sheared perpendicular heat flux is ten times larger than expected and the ion viscosity deviates by $\sim 40\%$. This indicates that the Sugama operator is not sufficiently accurate to achieve a close agreement between fluid and kinetic models, especially in the case of temperature perturbations in the plasma. Furthermore, ongoing work on the comparison with a full 6D kinetic model implemented by Kormann et al. will be presented.

P 10.13 Tue 16:30 Empore Lichthof

Simulating turbulence and profile evolution in the tokamak periphery with GRILLIX — •Wladimir Zholobenko, Thomas Body, Andreas Stegmeir, David Coster, and Frank Jenko — Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany

To be economically viable, magnetic confinement nuclear fusion reactors must be big. This makes the construction of practice relevant experiments like ITER very costly, leaving little room for experimentation and none for failure. Therefore, theoretical understanding and predictive capability are vital. Most promising are first principle based plasma turbulence codes, such as GRILLIX.

GRILLIX' main feature is the simulation of turbulent flows in complex, experimentally relevant magnetic geometry. The physical model[1] - global drift-reduced Braginskii equations - has no splitting between background and fluctuations. This allows to not only simulate gradient driven turbulent transport, but also the profile evolution itself. The results depend only on magnetic geometry, plasma sources and initial conditions - yielding high predictive capability for the price of high computational expense.

The code and the physical model are yet under development, to increase performance, reliability and realism. However, first applications to today's tokamaks like ASDEX Upgrade are able to reproduce important qualitative features, such as the self-consistent electric field and its impact on turbulence and profiles.

[1] W. Zholobenko *et al.*, Thermal dynamics in the FCI turbulence code GRILLIX, 17th PET workshop, submitted to CtPP (2019).

P 10.14 Tue 16:30 Empore Lichthof

Hamiltonian emulators for charged particleorbits in magnetized plasmas — •Katharina Rath[1,2], Christopher G. Albert[1], Bernd Bischl[2], and Udo von Toussaint[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching, Germany — [2]Department of Statistics, Ludwig-Maximilians-University Munich, Ludwigstraße 33, 80539 Munich, Germany

Currently used full models to trace orbits inside 3D configurations of magnetic plasma confinement for low-collisional reactor-relevant plasmas require highly accurate tracing of thousands of particles over billions of time-steps, which is too time-consuming to be part of optimization routines. A fast structure-preserving model emulator for Hamiltonian systems is developed to significantly speed up the computation of fusion alpha particle orbits in 3D fields of perturbed tokamaks and stellarators. The model emulator is constructed via physics-informed machine learning methods, in particular kernel based statistical methods such as Gaussian processes combined with geometric numerical methods. The tailored kernel functions allow to preserve phase-space structure and conserve invariants of motion such as energy and momentum over long periods of time.

P 10.15 Tue 16:30 Empore Lichthof

Towards a Realistic Dimits Shift Prediction using Gyrokinetic Tertiary Instability Calculations — •Axel Hallenbert and Gabriel Plunk — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

A frequently observed feature in gyrokinetic simulations close to marginal stability is the quenching of transport by persistent, self-generated shearing zonal flows, resulting in a nonlinear upshift of the effective critical gradient known as the Dimits shift. Unfortunately a consistent way to predict the size of the Dimits shift has so far been lacking. In an attempt to remedy this, tertiary instability investigations together with full nonlinear simulations within the Dimits shift regime have been performed for various cases using GENE. Two main conclusions can be drawn, the first of which is that the tertiary instabilities corresponding to the simplified zonal flow profiles previously sufficient to predict the Dimits shift for the Terry-Horton system and the strongly driven gyrofluid limit of gyrokinetics are generally insufficient to explain the Dimits shift in full gyrokinetics. Secondly a further subdivision into two qualitatively different regimes is consistently observed whose separation seems linked with the evolution of the zonal flow profiles in the presence of small-amplitude drift waves.

P 10.16 Tue 16:30 Empore Lichthof

Self-similar hydrodynamics and pellet injection — •Alistair Arnold, Per Helander, and Pavel Aleynikov — IPP Greifswald, Stellarator Theory Department

Pellet injection is a kind of refuelling used in stellarators and tokamaks (in particular the Wendelstein 7-X stellarator[1]), and is associated with a large and rapid net exchange of energy between electrons and ions[2]. From a hydrodynamic perspective, assuming that pellet ions remain at zero temperature, the result of the cold pellet electrons being heated by a background of hot electrons is ambipolar expansion of the entire cloud, with the electrons 'dragging along' the cold ions. The early phase of the expansion is self-similar in nature, due to the lack of inherent length scale associated with the hydrodynamic problem. Approximately half of the heating power provided to the cold electrons is transferred to the cold ions in the form of flow velocity kinetic energy, which is eventually converted to heat by collisions with the background. The limits of the validity of the hydrodynamic approach are investigated as well as the microscopic collisional picture of pellet injection, in particular the role of energy transfer between cold ions and electrons, and the conversion of the pellet ions' parallel energy to heat on a collisional timescale that is slow compared to the cloud expansion.

[1] R C Wolf et al. Major results from the first plasma campaign of the wendelstein 7-x stellarator. Nuclear Fusion, 57(10):102020, 2017.

[2] A Aleynikov et al. Plasma ion heating by cryogenic pellet injection. Journal of Plasma Physics, 85(905850105), 2019.

P 10.17 Tue 16:30 Empore Lichthof

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

Two important requirements for a viable stellarator reactor are easy-to-build-coils and good confinement. Omnigenous configurations, 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. We analyze the space of solutions using NESCOIL to identify equilibria that can be constructed using simple planar coils.

[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 10.18 Tue 16:30 Empore Lichthof

CO2 conversion and energy efficiency of a microwave plasma torch — •Katharina Wiegers, Irina Kistner, Andreas Schulz, Matthias Walker, and Günter Tovar — Institute of Interfacial Process Engineering and Plasma Technology IGVP, University of Stuttgart, Stuttgart, Germany

Mankind nowadays is strongly affected by the ongoing climate change which is caused mainly by the increasing emission of carbon dioxide (CO2) from e.g. traffic, coal power plants and industry. An inherent problem of the energy production by renewable sources such as photovoltaics and wind mills is the often observed discrepancy between actual energy "production" and energy demand, due to their discontinuous availability. The so-called "excess" energy can be used to operate a microwave plasma torch at atmospheric pressure. The CO2 plasma leads to the formation of carbon monoxide (CO) and oxygen radicals (O). To avoid the thermodynamically forced recombination of both back to CO2, when leaving the plasma state an effective separation process is required. The separation is achieved by ceramic hollow fibers. The remaining CO can be used as an important chemical C1-building block, which can be further employed for creating molecules with a higher commercial value. This work is focused on the conversion and energy efficiency of the CO2 plasma by different process parameters like microwave power, gas flow and distance from inside the plasma to the afterglow. The efficiencies are determined via FT-IR and mass spectrometry.

P 10.19 Tue 16:30 Empore Lichthof

Ro-vibrational excitation measurement in transient ns-discharges by multiple optical diagnostics — •Yanjun Du, Dirk Luggenhölscher, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany

CO_2 conversion is of growing interest in the context of greenhouse gas abatement and renewable energy exploration. The non-thermal plasma is promising means for efficient conversion since the unique electron, vibrational, rotational and gas temperatures in these plasmas allow focusing the discharge energy to the desired channels instead of heating the gas. Specifically, the vibrational excitation can lower activation barriers for direct dissociation and, thus, improve the final energy efficiency. This project aims at a fundamental understanding of the vibrational-stimulated CO_2 conversion by providing detailed experimental data. ns-pulsed atmospheric pressure plasma jets will be used to achieve independent control of plasma generation and molecular excitation by separating the relevant time scales. The evolution of the ro-vibrational distribution of both symmetric and asymmetric vibrational modes in CO_2 can be monitored by TDLAS at 2285 cm^{-1}. The plasma condition can be examined by temporally and spatially resolved optical emission spectroscopy. Here results from these investigations will be presented and discussed. The investigations are supported by the Alexander von Humboldt Foundation and the DFG in the frame of the CRC 1316.

P 10.20 Tue 16:30 Empore Lichthof

Treatment of methylene blue solution with a cold atmospheric pressure plasma — •Nils Dose, Kerstin Sgonina, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

Methylene blue solutions have previously been treated with different plasma sources resulting in its degradation due to following reactions. The degradation mechanism has also been investigated using dielectric barrier discharge showing that methylene blue reacts with various forms of oxygen like O_3 and OH [1]. In addition, the effluent of a He/O_2-plasma ignited in the COST-Jet has already been analysed with mass spectrometry to determine the density of atomic oxygen and ozone. In this work, the reaction of methylene blue with atomic oxygen and ozone is investigated.

An aqueous methylene blue solution was treated with the effluent of the COST-Jet, using a He/O_2 gas mixture. By observing the degradation of methylene blue, the influence of different parameters was investigated. The O_2 admixture as well as the distance between the plasma and the liquid were varied to see how O and O_3 react with methylene blue while distinguishing both reactants. Additionally, the concentrations of methylene blue were used to observe the influence on the degradation.

[1] F. Huang *et al.*, Chemical Engineering Journal 162.1 (2010)

P 10.21 Tue 16:30 Empore Lichthof

Electric Field Measurements via EFISH in a CARS Setup — Jutta Püttman, Jan Kuhfeld, •Dirk Luggenhölscher, and Uwe Czarnetzki — Ruhr-University Bochum, Experimental Physics V, Germany

The electric field strength is a basic parameter of non-thermal plasmas since it determines the energy of the electrons which governs the discharge dynamics in high pressure plasmas. Further, if the electric field strength and its temporal development are known, this can be combined with additional diagnostics like voltage and current measurements to infer many other quantities of interest e.g. displacement and conduction current, dissipated power, and electron density. The electric field is measured by "Electric field induced second harmonic generation" (EFISH) [1] using the second harmonic of a pulsed Nd:YAG laser which is part of a more complex CARS setup for measuring the ro-vibrational distribution of N2 and CO2. The presence of an electric field induces an asymmetry in the polarizability of the gas which enables the otherwise forbidden generation of the second harmonic radiation. The method is species independent and allows for spatial and temporal resolved measurements in which the resolution is governed by the focal parameter and pulse duration of the laser. The method is characterized, calibrated and first measurements in an atmospheric pressure nanosecond pulsed discharge are presented.

[1] A. Dogariu, B. Goldberg, S. O'Byrne, and R. Miles, Phys. Rev. Appl. (2017) 024024

P 10.22 Tue 16:30 Empore Lichthof

2D Model Simulation for Single Filament Dielectric Barrier Discharge in Air — •Bahram Mahdavipour[1], Sebastian Dahle[2,3], and Jens Oberrath Oberrath[4] — [1]Institute of Product and Process Innovation, Leuphana University Lüneburg, Germany — [2]Clausthal Center for Material Technology, Clausthal University of Technology, Leibnizstr. 9, 38678 Clausthal-Zellerfeld, Germany — [3]Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, 1000 Ljubljana, Slovenia — [4]South Westphalia University of Applied Science, Department of Electric Power Engineering, Modeling and Simulation, Soest, Germany

Dielectric-barrier discharges (DBD) are devices that are being used in several applications such as surface modification, plasma chemical vapor deposition, plasma medicine, pollution control, gas, and air cleaning. Filamentary DBDs are created as a number of short time duration individual breakdown channels and are known as microdischarges. Most of the chemical reactions of DBDs take place in their microdischarges. The aim of this work is to study microdischarges at low temperatures and atmospheric pressure conditions in an air DBD to analyze their creation, the chemical reactions, and the physical mechanisms that occur. The microdischarge is simulated in a 2D fluid model in PLASIMO with simplified air (nitrogen-oxygen mixture) in a needle to needle geometry. At the powered and dielectrically insulated electrode, a sinusoidal voltage is applied and the counter electrode is grounded. Through the simulation, parameters like electron density, N2+, O2+, and ozone production can be studied.

P 10.23 Tue 16:30 Empore Lichthof

Influence of secondary electron emission and dielectric permittivity on argon dielectric barrier discharges — •Marjan Stankov, Markus M. Becker, Robert Bansemer, and Detlef Loffhagen — Leibniz Institute for Plasma Science and Technology (INP), 17489 Greifswald, Germany

In this contribution the behavior of dielectric barrier discharges (DBD) in argon at subatmospheric pressure with the variation of the secondary electron emission coefficient (γ) and dielectric permittivity (ε_r) of the dielectric layers is studied by means of fluid modeling. The investigated plasma source has a symmetric plane-parallel geometry with the electrodes covered by quartz dielectrics and a gap width of 3 mm. A time-dependent, spatially one-dimension fluid model comprising balance equations for particle number densities and the electron energy density coupled with Poisson's equation was employed for modeling of the DBD. Model calculations were carried out for different values of γ and ε_r of dielectric layers at pressures from 100 to 650 mbar. Very good agreement between modeling results and measured data for the discharge current and dissipated power was obtained over the complete pressure range. It was found that the increase of γ and ε_r leads to an earlier occurrence of gas breakdown and decreasing of the breakdown voltage. The analysis of the average dissipated power reveals that the variation of ε_r has a stronger influence on the modeling results in comparison with γ variation, especially at higher pressures.

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P 10.24 Tue 16:30 Empore Lichthof

Influence of oxygen on deuterium retention and release in self-damaged tungsten — •Maximilian Brucker[1,2], Kristof Kremer[1,3], and Thomas Schwarz-Selinger[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, D-85748 Garching, Germany — [2]Ulm University, Albert-Einstein-Allee 11, D-89081, Ulm, Germany — [3]Technische Universität München, James-Franck-Straße 1, D-85748, Garching, Germany

Understanding hydrogen isotope (HI) retention in first-wall materials is crucial to predict fuel loss in future fusion devices. The influence of oxygen is discussed controversly in literature. Since in almost all experiments tungsten (W) is exposed to air prior to and/or after loading with deuterium (D), a thin surface oxide layer is naturally present at W surfaces. The effect of such a tungsten oxide layer could play a role on the retention and release of HIs and is examined in ex-situ experiments. As samples, self-damaged W is used. Due to self-damaging of pure tungsten with 20 MeV W ions an about 2 μm thick defect-rich getter layer is created which can trap up to about 2 % HIs. In order to load the damaged tungsten with D, a low-temperature D plasma is used. To examine the effects of outgassing, the samples are first D loaded and then electro-chemically oxidized to oxide layer thicknesses of 25 nm to 100 nm. After oxidation, Rutherford Backscattering Spectroscopy, Nuclear Reaction Analysis and Thermal Desorption Spectroscopy are used to quantify the amount of oxygen, the depth profiles of the retained deuterium and the outgassing behavior. A quantitative discussion of the result will be presented.

P 10.25 Tue 16:30 Empore Lichthof

Investigating the deformation of drawn tungsten wires — •Maximilian Fuhr[1,2], Bailey Curzadd[1,2], Johann Riesch[1], Martin Balden[1], and Rudolf Neu[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching bei München — [2]Technische Universität München, Boltzmannstraße 15, 85748 Garching bei München

Drawn tungsten wires are used as reinforcement fibres in tungsten fibre-reinforced tungsten composites (W_f/W). These composites mitigate the embrittlement issue of tungsten materials used in nuclear fusion technology by utilising extrinsic toughening mechanisms.

Tungsten wires show both a high strength and ductility when deformed in a room temperature tensile test. After reaching the maximum stress, the stress-strain curve exhibits a plateau that is followed up by a sharp stress drop. Contradicting the current theories, the localisation of plastic deformation to a specific specimen region (necking) is clearly visible only after the stress drop has occurred. Several different deformation mechanisms have so far been discussed to explain this behaviour of tungsten wires.

Thus, the tensile stress-strain behaviour of drawn tungsten wires is investigated using interrupted tensile tests at room temperature. The microstructure of the deformed specimens is studied using SEM and EBSD techniques. Special focus is thereby directed to the characteristic grain structure consisting of highly elongated grains and the strong fibre texture.

P 10.26 Tue 16:30 Empore Lichthof

Zirconium oxide based layers investigated by the 3 omega method — •Vitali Bedarev[1], Philipp A. Maass[1], Marina Prenzel[2], Marc Böke[1,2], and Achim von Keudell[1,2] — [1]Institute for Experimental Physics II, Ruhr-University Bochum, Universitätsstr. 150, D-44780 Bochum,Germany — [2]Research Department Plasmas with Complex Interactions, Ruhr-University Bochum, Universitätsstr. 150, D-44780 Bochum,Germany

Aim of the project is to develop thin layers by using deposition techniques like CVD and later PECVD which can be used for galvanic isolation. First step will be the evaporation of a precursor (based on a zirconium oxide bond). The evaporated gas is guided into the main chamber by using nitrogen (with a flow of 25/50 sccm). Hence a zirconium oxide layer is expected to be synthesized. The main focus is to study thermal conductivity of thin layers in-situ, therefore, one can use the 3 omega method.

Furthermore, we will analyze the change of the thermal conductivity depending on the morphology of the layer. The layer growth rate is expected to be > 500 nm/h and the layer thickness < 30 microns.

P 10.27 Tue 16:30 Empore Lichthof

Spoke-synchronised optical emission spectroscopy in a high-power impulse magnetron discharge — •Philipp Maass, Julian Held, Volker Schulz-von der Gathen, and Achim von Keudell — Experimental Physics 2, Ruhr-University Bochum, Germany

High-power impulse magnetron sputtering (HiPIMS) is a physical vapour deposition technique in which a plasma is ignited in front of a target in order to sputter atoms from the target and coat a substrate. In such a plasma, inhomogeneities, which appear as localised light emissions - so-called spokes -, can be detected. They move in ExB-direction at a velocity of about 10 km/s.

Spokes appear in the magnetic trap region in front of the magnetron. In order to further investigate them, non-intrusive measurements are needed. Optical emission spectroscopy seems the best option, is however limited due to the stochasticity of the spokes' appearance in space and time. Therefore, a triggering system was developed that enables the recording and investigation of spoke-synchronised measurements.

The triggered OES measurements were performed using a CCD-camera and filters in a frontal and an orthogonal set-up aimed at the target. The spokes were found to have very complex internal structures indicated by the sequence of filtered emissions. The spread of the spokes was discovered to be large, extending to the last closed magnetic field line.

P 10.28 Tue 16:30 Empore Lichthof

Control of Spokes in HiPIMS Discharge — •Mathews George 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 produces plasmas of very high density of the order $10^{19}\mathrm{m}^{-3}$ 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[1] [3]. These so called spokes are assumed to play a role in the transport of particles and energy away from the target [2]. The primary objective is the control of spokes by using externally applied field on a Langmuir probe in HiPIMS. The major motive behind spoke control is to regulate the deposition rate and quality of the film. DCMS was chosen for the starting phase since the spokes in DC regime are more uniform compared to HiPIMS. Amplified sinusoidal voltage signals are applied on a Langmuir probe to draw electron current from the plasma at the highest gradients in the E x B direction. The variation of spoke frequency or any kind of influence on the spokes characteristics with respect to the applied frequency are detected by measuring the spoke frequency using a photomultiplier. [1] A Hecimovic, A von Keudell *J. Phys. D: Appl. Phys.* 51 (2018) 453001 (15pp) [2] N Brenning, *et al.* 2013 *J. Phys. D: Appl. Phys.* 46 084005 [3] Andre Anders, Yuchen Yang *Appl. Phys. Lett.111*, 064103 (2017)

P 10.29 Tue 16:30 Empore Lichthof

Wigner crystals in bunches with finite emittance in the bubble regime — •Lars Reichwein, Johannes Thomas, and Alexander Pukhov — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Düsseldorf

The influence of non-zero emittance onto the spatial structure of an equilibrium electron bunch in a quasi-static bubble model is studied. The full Liénard-Wiechert potentials are used to calculate the relativistic inter-particle interaction while the external force is described in the context of a simplified bubble model [1]. We introduce transverse momenta as a perturbation approach of the previous zero-emittance model [2]. For low emittances the crystalline structure of the bunch is preserved, while for higher emittances the observed symmetry is broken. In the region of this phase transition a widening of the structure and formation of various shells can be observed. These structural changes resemble those of the zero-emittance model when the parameters momentum, plasma wavelength and total particle number were varied.

[1] I. Kostyukov et al., Phys. Plasmas 11, 5256 (2004)
[2] L. Reichwein et al., arXiv:1903.04858 (2019)

P 10.30 Tue 16:30 Empore Lichthof

Analytical models for the Trojan Horse regime of underdense photocathode plasma wakefield acceleration — •Johannes Thomas and Alexander Pukhov — Heinrich Heine Universität Düsseldorf

Broken plasma wake fields in homogeneous plasmas provide a feasible path for high- gradient particle acceleration. Especially efficient is the so-called blow-out regime of particle wake field acceleration[1], where a short, highly dense particle bunch excites a distorted spherical cavity from which all electrons are banished. The blow-out moves with nearly the speed of light through the plasma and generates quasi-mono-energetic electron bunches. In the context of underdense photocathode plasma wakefield acceleration (also known as the Trojan Horse regime) it could be shown that a laser-controlled release of electrons directly into a blow-out allows the generation of electron bunches with ultra-low emittance and ultra-high brightness [2]. In our presented work we show:

(i) why known (semi-)analytical blow-out models have difficulties to correctly describe the acceleration of single electrons in the quasi-static fields of the Trojan Horse regime;

(ii) how a quasi-static model for the special parameter range of the Trojan Horse regime can be formulated;

(iii) that tailored plasma channels can stabilize the injection mechanism.

[1] P. Chen et. al, Phys. Rev. Lett 54, 693 (1985).
[2] B. Hidding et. al, AIP Conference Proceedings 1507, 570 (2012).

P 10.31 Tue 16:30 Empore Lichthof

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 investigated different models and compared them 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.

P 10.32 Tue 16:30 Empore Lichthof

Construction of a Pre-Pulse Generator for Few-Cycle Laser Pulses — •Jonah Book, Steffen Mittelmann, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Here we report the design, setup and characterization of a pre-pulse generator for high-intensity few-cycle pulses. The difficulty in contrast to longer pulse durations is keeping the dispersion low for both pulses and at the same time preserving their beam quality. A pre-pulse generator offers a variety of valuable uses in laser-plasma-physics. When splitting a laser pulse into two pulses with differing intensities, one can be used to ignite a surface plasma which constitutes a target with adjustable properties for the other, stronger pulse, such that certain aspects of the interaction can be optimized, like plasma temperature, ionization state or harmonic generation. We present our new design together with the characterization of both pulses, most of all pulse duration and focus quality, as well as their temporal and spatial overlap.

P 10.33 Tue 16:30 Empore Lichthof

Recent experiments on waves in a complex plasma in the PK-4 Laboratory under microgravity — •Mierk Schwabe, Mikhail Pustylnik, and Hubertus Thomas — Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt, Weßling, Deutschland

The PK-4 Laboratory is a Russian-European laboratory for studies on complex plasmas on board the International Space Station ISS. Its heart consists of a direct current plasma tube with 3 cm diameter and a total length of the working area of 20 cm. Microparticles of various sizes can be injected into the plasma. Microparticles can be trapped in the discharge by, for example, quickly switching the discharge polarity, or by applying a longitudinal thermal gradient. The polarity switching causes the ions and electrons of the plasma to stream around the microparticles, and the ions form wakes in downstream direction of the microparticles, which in turn attract other microparticles and lead to the formation of microparticle strings. Here, we report on recent experiments on waves that form in a cloud of trapped microparticles with a special emphasis on the influence of string formation on wave propagation.

P 10.34 Tue 16:30 Empore Lichthof

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 10.35 Tue 16:30 Empore Lichthof

Two dimensional absolute density distributions of Nitric Oxide (NO) in the effluent of the "COST Reference Microplasma Jet" — •Patrick Preissing[1], Ihor Korolov[2], Volker Schulz-von der Gathen[1], and Marc Böke[1] — [1]Experimental Physics II, Ruhr-University Bochum, Bochum — [2]Institute for Electrical Engineering and Plasma Technology, Ruhr-University Bochum, Bochum

In cold atmospheric pressure plasmas (CAPs) the heavy particles remain cold (i.e. near room temperature), while the electrons can be effectively heated. This leads to a high temperature chemistry with low thermal stress for the sample. Therefore, CAPs provide great properties for applications, such as for biomedical ones. In this context a robust, stable micro RF reference jet was developed with a high degree of reproducibility (COST reference jet). Owing to the non-equilibrium character various types of dissociation products are created. Species as for example Nitric Oxide or Ozone typically have longer lifetimes and are therefore likely candidates to interact with the treated sample. While at larger concentrations NO was found to be extremely harmful to the human body, at lower concentrations the molecule triggers many important biological processes as intercellular messenger and diffuses rapidly through most tissues which makes it an important component for tissue and wound treatments. In this work we present two dimensional, time averaged, absolute density distributions of NO in the effluent of the COST-Jet measured by means of Laser Induced Fluorescence (LIF). The measurements are performed within the framework of the SFB1316.

P 11: Laser plasma and laser applications 1

Time: Wednesday 11:00–13:00 Location: b302

Invited Talk P 11.1 Wed 11:00 b302

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 11.2 Wed 11:30 b302

Imaging of low-electron-density plasma using short-wave Infrared (SWIR) and mid-infrared (MIR) pulses — •Yinyu Zhang[1,2], Mingzhuo Li[2], Matthias Kübel-Schwarz[1,2], Carola Zepter[1,2], Yu Zhao[1,2], Alexander Sävert[1,2], Malte C. Kaluza[1,2], and Gerhard G. Paulus[1,2] — [1]Helmholtz Insitute, Jena, Germany — [2]Institute of Optics and Quantum Electronics, Jena, Germany

Laser-driven plasma-based accelerators (LPA) are of great interest as they are able to efficiently accelerate charged particles to hundreds of MeV, or even to the multi-GeV energy range [1, 2] on a table-top scale. For a LPA, a low electron density is preferred as it allows for a longer acceleration distance and thus higher particle energies [3]. However, the diagnostic of the plasma using transverse shadowgraphy becomes challenging because the refractive index variation for the imaging decreases due to the low electron density. In order to increase the contrast of plasma shadowgraphs, the wavelength of the probe pulses should be increased. Here, we present the imaging of low electron density plasmas at 1.8 μm and 3.6 μm. [1] E. Esarey, et. al., Rev. Mod. Phys. 81 (2009) [2] S. M. Hooker, et. al., Nat. Phy. 7 (2013) [3] W. Lu, et. al., Phys. Rev. ST Accel. Beams 10 (2007).

P 11.3 Wed 11:45 b302

Laser Harmonic Generation on a Plasma Blister on the Surface of a Solid — •Bastian Hagmeister and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

The interaction of an intense femtosecond laser pulse (10^{17} W/cm^2) with solids is well understood but there are still new effects to explore. The nonlinear process of harmonic generation depends strongly on the conditions of the pre-plasma and the laser pulse contrast. Typically, the pedestal of an intense laser pulse disturbs this process, however, in some cases it transforms the setting.

In the following, we show that harmonics can be generated on the surface of a plasma blister with high efficiency. This plasma blister is generated by the amplified spontaneous emission (ASE) accompanying the laser pulse. The ASE hits the surface of the solid a few nanoseconds before the laser pulse and generates the plasma blister. By adjusting the delay between the laser pulse and the ASE, the blister size can be modified. Due to this expansion, the harmonics, which arise on the blister surface, have a different direction from harmonics generated on the target surface.

P 11.4 Wed 12:00 b302

Ion Spectroscopy of Single-Digit-fs Laser Pulse Plasmas with respect to different Laser Parameters — •Jan Riedlinger, Bastian Hagmeister, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

The exposure of solids to high intensity sub-10-fs laser pulses creates an extremely transient high temperature plasma, of which many properties are not fully predictable today, in contrast to plasmas created with longer laser pulses. One example is the achieved ionization state as well as the energy distribution of the emitted ions. We performed measurements to characterise the ion emission of such plasmas. We present here experimental results for a set of varied laser parameters, such as intensity, pulse energy and duration as well as different solids as target materials, to attain a better understanding of plasma formation and the subsequent dynamics. Most of all, the peak intensity has been examined over multiple orders of magnitude by means of our new attenuator up to maximum values of 10^{18} W/cm^2 at the shortest pulse durations of about 8 fs.

P 11.5 Wed 12:15 b302

Multi-Parameter-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 simulations with different ionization models are in good agreement with the gained experimental results which allows a precise prediction of laser-gas interactions. The setup will be used to realize the Trojan Horse Injection model at the FLASHForward facility at DESY in Hamburg.

P 11.6 Wed 12:30 b302

Pump-probe experiments with 10 fs resolution for revealing the early phase of laser plasma evolution — •Maximilian Münzberg, Michael Stumpf, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

We present the results of an experiment in which the onset of plasma expansion has been investigated. Ultrashort laser-pulses (8 fs) with intensities of $2 \cdot 10^{17}$ W/cm^2 are focused onto flat metallic surfaces. A synchronized ultrashort probe beam was reflected at the developing plasma at various delays with a time resolution close to 10 fs. The wave front deformation of the probe pulse was investigated by a Mach-Zehnder interferometer. In total, we determined the temporal evolution of the electron distribution at the solid-vacuum interface. We present the results for different target geometries, e.g. a bulk metal target and target with surface layers and discuss them together with PIC simulations, which show and explain a high dependence in the early expansion stage of the surface structure of the different targets.

P 11.7 Wed 12:45 b302

Wigner crystals in bunches with finite emittance in the bubble regime — •Lars Reichwein, Johannes Thomas, and Alexander Pukhov — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Düsseldorf

The influence of non-zero emittance onto the spatial structure of an equilibrium electron bunch in a quasi-static bubble model is studied. The full Liénard-Wiechert potentials are used to calculate the relativistic inter-particle interaction while the external force is described in the context of a simplified bubble model [1]. We introduce transverse momenta as a perturbation approach of the previous zero-emittance model [2]. For low emittances the crystalline structure of the bunch is preserved, while for higher emittances the observed symmetry is broken. In the region of this phase transition a widening of the structure and formation of various shells can be observed. These structural changes resemble those of the zero-emittance model when the parameters momentum, plasma wavelength and total particle number were varied.

[1] I. Kostyukov et al., Phys. Plasmas 11, 5256 (2004)
[2] L. Reichwein et al., arXiv:1903.04858 (2019)

P 12: Atmospheric-pressure plasma and applications 3

Time: Wednesday 11:00–12:45 Location: b305

Invited Talk P 12.1 Wed 11:00 b305

Surface modification with atmospheric-pressure plasmas - applications and challenges — •Claus-Peter Klages, Lars Bröcker, Andreas Czerny, Stefan Kotula, Meret Leonie Lehner, Andris Martinovs, and Vitaly Raev — Institute for Surface Technology, Technische Universität Braunschweig, Braunschweig, Germany

Since the early 1990, soon after demonstration of stable uniform dielectric-barrier discharges by a group at Sophia University in Tokyo, the number of scientific papers concerning applications of atmospheric-pressure plasmas for surface treatment has been increasing rapidly up to between 150 and 200 per year in the recent decade. In the industry, so-called *corona treatment* was introduced much earlier - already around 1950 to render polymer surfaces wettable or, in the 1960, to degrease aluminum surfaces. In spite of a long and successful technical history of applications, fundamental mechanisms of the interactions between discharges and organic or inorganic surfaces and products of these interactions are to a large extent still unknown. The lecture will give an account of recent work at Fraunhofer IST or at IOT/TUBS on applications of barrier discharges for treatment of inorganic surfaces such as silicon, silica, aluminum or silver, and on recent studies on the plasma-nitrogenation of polymer surfaces and low-molecular-weight model compounds, utilizing flowing post-discharges as well as single-filament discharges in nitrogen. Results of infrared-spectroscopic investigations of plasma-nitrogenated samples are compared with densities of reactive nitrogen species in the gas phase.

P 12.2 Wed 11:30 b305

Experimental Investigation of a Plasma Electrolytic Polishing Process for the Pretreatment of Cemented Carbide — •Sehoon An[1], Rüdiger Foest[1], Katja Fricke[1], Luka Hansen[2], Thorben Kewitz[1], Hendrik Riemer[3], Maik Fröhlich[4], Holger Kersten[2], and Klaus-Dieter Weltmann[1] — [1]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany — [2]Institute of Experimental and Applied Physics, CAU, Kiel, Germany — [3]Technical University, Berlin, Germany — [4]University of Applied Sciences, Zwickau, Germany

Plasma electrolytic polishing (PEP) has gained much attention owing to the significant improvement of surface properties within short time, but also because of its ecological benefits. We report on PEP processes for the pretreatment (cleaning) of cemented carbide, a typical material for tools. Depending on electrolyte temperature, concentration and process voltage, optimum operating conditions could be identified. Beneficial conditions for cleaning are between 100 V and 150 V for current densities in the range of 0.2 to 0.8 A/cm2. Investigations on the energy flux towards the workpiece were conducted by employing a thermocouple and monitoring the temperature. Distinct heating phases are observed and discussed in relation to different contributing factors to the total energy flux. In addition, the surface status of the cemented carbide after PEP was examined using SEM and AFM. For tribological assessment, the samples were coated with an AlTiSiN layer. Tool lifetimes comparable to conventional pre-treatment could be achieved but with less consumption of harmful chemicals.

P 12.3 Wed 11:45 b305

Electric field behaviour of a micro cavity plasma array measured by Stark shift of helium — •Sebastian Dzikowski[1], Sylvain Iseni[2], Marc Böke[1], and Volker Schulz-von der Gathen[1] — [1]Ruhr-University, Bochum, Germany — [2]GREMI, Orleans, France

Micro-structured array devices get more and more interest for gas reformation and plasma catalysis. In case of devices where cavities are integrated in the dielectric the applied electric field can strongly influence the interaction between plasma and catalyst.

Here we present a metal-grid array device consisting of a powered metal-grid, a dielectric foil and a grounded magnet. The grid contains uniformly arranged cavities with dimensions in the one hundred micrometer scale. This sandwich-like structure allows disassembling and exchange of the dielectric foil with catalytic properties. Typically, the metal-grid array operates close to the atmospheric pressure and is applied with a bipolar triangular voltage waveform with an amplitude up to 800 V at 15 kHz.

To measure the internal electric field, we use the 492.19 nm helium line that gets split in an allowed and forbidden counterpart. The distance between the two components is proportional to the electric field.

We present and discuss time-averaged and time resolved measurements depending on typical operation parameters such as applied voltage, cavity diameter and frequency.

P 12.4 Wed 12:00 b305

The spatial distribution of HO2 in a cold atmospheric pressure plasma jet investigated by cw cavity ring-down spectroscopy — •S.-J. Klose[1], M. Gianella[2], K. Manfred[2], H. Norman[2], G. A. D. Ritchie[2], and J. H. van Helden[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, D — [2]Department of Chemistry (PTCL), University of Oxford, UK

In order to tailor the impact of cold atmospheric pressure plasma sources on biomedical or semiconductor targets, a profound understanding of the chemical reaction network is pivotal. One big open question in the field of plasma-liquid interaction is still, where the reactive species come from: Are they produced in the gas phase and diffuse into the liquid or are they formed via secondary reactions inside the liquid? We investigate the gas phase reactions of the cold atmospheric pressure plasma jet kINPen, already used for wound healing and in cancer research, in order to understand the reaction kinetics of H2O2, which is a key species in the plasma to cell interaction. The small diameter of these plasma jets, which is usually in the order of mm's, makes diagnostics challenging. A common approach to obtain absolute species densities are absorption spectroscopy techniques. To increase the absorption path length, cavity-enhanced spectroscopy methods can be applied. However, with these techniques often line-of-sight densities without any spatial information are obtained. Nevertheless, with cw cavity ring-down spectroscopy, we were able to determine the spatial distribution of the HO2 radical that is involved in the formation and destruction of H2O2.

P 12.5 Wed 12:15 b305

Loss processes of plasma-generated atomic oxygen in phenol solutions — •Kerstin Sgonina[1], Giuliana Bruno[2], 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. 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 [2]. 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 should reveal the up-to-now unknown absolute reaction rates of atomic oxygen in liquid phase and at the liquid surface.

[1] J. Benedikt *et al.*, Phys. Chem. Chem. Phys. 20 12037, 2018.
[2] G. Willems *et al.*, New J. Phys. 21 059501, 2019.

P 12.6 Wed 12:30 b305

Plasma Medical Investigations for Disinfection of Different Surfaces and Their Modifications Caused by Cold Atmospheric Plasma Treatment — •Sandra Moritz[1], Alisa Schmidt[1], Joachim Sann[2], and Markus Thoma[1] — [1]1. Physikalisches Institut, Justus-Liebig University, Gießen, Germany — [2]Physikalische Chemie, Justus-Liebig University, Gießen, Germany

Inactivation of microorganism on sensitive surfaces by cold atmospheric plasma is one major application in the field of plasma medicine, because it provides a simple way to sterilize heat-sensitive materials. Therfore, one has to know whether plasma treatment affects treated surfaces. In this contribution, the effect of cold atmospheric surface micro-discharge (SMD) plasma on plasma-treated surfaces was investigated. Hence, different material samples (stainless steel, different polymers and glass) were plasma-treated for 16 hours using an SMD plasma device. Furthermore, the device was used to investigate the behaviour of Bacillus atrophaeus inoculated on the material samples at different treatment times. Afterwards, the material probes were analysed using surface analysis methods such as laser microscopy, contact angle measurements and X-ray photoelectron spectroscopy. The results show in case of the treated bacteria that a log reduction in bacterial number between 3.0 and 6.0 can be achieved within only 15 min of plasma treatment. In accordance to this results, surface analysis revealed, that there were three different types of reactions the probed materials showed to plasma treatment, ranging from no changes to shifts of the materials' free surface energies and oxidation.

P 13: Lunch talk: German Research Foundation (DFG) (joint session A/K/P/MO/MS/Q)

Time: Wednesday 13:10–13:55 Location: f303

Lunch Talk P 13.1 Wed 13:10 f303

Funding by the German Research Foundation (DFG) – a brief overview — •Andreas Deschner — Deutsche Forschungsgemeinschaft (DFG), Kennedyallee 40, 53175 Bonn, Germany

During the last 100 years, the German Research Foundation (DFG) and its predecessors have been funding research in Germany. Today, the DFG is the central third party funding organization for basic research in Germany. It offers a broad spectrum of funding opportunities from individual grants to larger coordinated programs.

This talk will give a brief outline of the financial framework, the decision-making processes and the funding portfolio of the DFG. I will mostly focus on the different programs that offer support to early career scientists, e.g. the new Walter Benjamin for postdoctoral positions and the Emmy Noether program for junior research groups.

P 14: Codes and modelling

Time: Wednesday 14:00–15:55 Location: b302

P 14.1 Wed 14:00 b302

Quantum hydrodynamics for plasmas – quo vadis? — •Michael Bonitz[1], Zhandos Moldabekov[2], Hanno Kählert[1], and Shen Zhang[1] — [1]Institut für Theoretische Physik und Astrophysik, Universität Kiel, Leibnizstr. 15 — [2]Al Farabi University, Almaty, Kazakhstan

Quantum hydrodynamics (QHD) has become popular for modeling quantum plasmas and warm dense matter, following Ref. 1. While QHD is quite successful for describing Bose-Einstein condensates and plasmonic excitations in metallic nanoparticles, the application of the model of Ref. [1] to dense plasmas has lead to oversimplified fluid equations. These equations neither reproduce the correct plasmon dispersion (except for 1D models) nor the screened potential of an ion in a quantum degenerate plasma [2, 3] and have led to astonishing predictions that have been controversially discussed. Here we present a systematic derivation, starting from quantum statistical theory, that leads to microscopic QHD equations that are in agreement with time-dependent DFT and quantum kinetic theory and which serve as a basis for deriving improved QHD models for plasmas [3].

[1] G. Manfredi and F. Haas, Phys. Rev. B **74**, 075316 (2001)
[2] Zh. Moldabekov, M. Bonitz, and T. Ramazanov, Phys. Plasmas **25**, 031903 (2018)
[3] M. Bonitz, Zh. Moldabekov, and T. Ramazanov, Phys. Plasmas **26**, 090601 (2019)

P 14.2 Wed 14:25 b302

Ionization in high-density plasmas: an ab initio study for carbon at Gbar pressures — Mandy Bethkenhagen[1], Bastian B. L. Witte[1,2], Gerd Röpke[1], Tilo Döppner[3], Dominik Kraus[4,5], Siegfried H. Glenzer[2], and •Ronald Redmer[1] — [1]Institut für Physik, Universität Rostock, 18051 Rostock — [2]SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, CA 94025 USA — [3]LLNL, Livermore, CA 94550, USA — [4]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden — [5]Institute of Solid State and Materials Physics, TU Dresden, 01069 Dresden

We apply density functional theory molecular dynamics (DFT-MD) simulations to calculate the ionization degree of plasmas in the warm dense matter regime. Standard descriptions of the ionization potential depression (IPD) have been challenged recently by experiments approaching unprecedentedly high densities indicating that improved IPD models are required to describe warm dense matter. We propose a novel ab initio method to calculate the ionization degree directly from the dynamic electrical conductivity using an exact sum rule. This approach is demonstrated for carbon at a temperature of 100 eV and pressures in the Gbar range. We find substantial deviations from widely applied IPD models like Stewart-Pyatt and Ecker-Kröll implying that condensed matter and quantum effects like band structure and Pauli blocking need to be included explicitly in ionization models. Our results will help to precisely model matter under conditions occurring, e.g., during inertial confined fusion implosions or inside astrophysical objects such as brown dwarfs and low-mass stars.

P 14.3 Wed 14:40 b302

***Ab initio* simulation results for the dynamic properties of warm dense matter** — •Michael Bonitz[1], Paul Hamann[1], Tobias Dornheim[2], and Alexey Filinov[1] — [1]Institut für Theoretische Physik und Astrophysik, Universität Kiel, Leibnizstr. 15 — [2]Center for Advanced Systems Understanding (CASUS), Görlitz, Germany

Warm dense matter (WDM) – an exotic state where electrons are quantum degenerate and ions may be strongly correlated – is ubiquitous in astrophysics and highly compressed laboratory plasmas. We have recently obtained *ab initio* thermodynamic results for the electron component in WDM based on novel quantum Monte Carlo (QMC) simulations [1, 2] including the first *ab initio* parametrization of the exchange-correlation free energy F_xc [2, 3]. Moreover, recently the first exact QMC results for the dynamic local field correction and the dynamic structure factor could be obtained [4]. An interesting result is the prediction of a negative plasmon dispersion – an effect that should be observable in dense hydrogen.

[1] T. Dornheim, S. Groth, T. Sjostrom, F.D. Malone, W.M.C. Foulkes, and M. Bonitz, Phys. Rev. Lett. **117**, 156403 (2016)
[2] S. Groth, T. Dornheim, T. Sjostrom, F.D. Malone, W.M.C. Foulkes, and M. Bonitz, Phys. Rev. Lett. **119**, 135001 (2017)
[3] T. Dornheim, S. Groth, and M. Bonitz, Phys. Reports **744**, 1-86 (2018)
[4] T. Dornheim, S. Groth, J. Vorberger, and M. Bonitz, Phys. Rev. Lett. **121**, 255001 (2018)

P 14.4 Wed 14:55 b302

Molecular dynamics study of non-equilibrium dense plasmas with ionization potential depression — •Rui Jin[1,2], Malik Muhammad Abdullah[1,3,4], Zoltan Jurek[1,3], Sang-Kil Son[1,3], and Robin Santra[1,3,4] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Department of Physics and Astronomy, Shanghai Jiaotong University, Shanghai, China — [3]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [4]Department of Physics, Universität Hamburg, Hamburg, Germany

High energy density matter exists extensively in the universe, from hot dense plasmas such as supernova and stellar interiors to warm dense matter such as planetary interiors. Creating and analyzing hot and warm dense plasmas under such extreme conditions in the laboratory is critical to understand their unique properties. The advent of x-ray free-electron laser (XFEL), which provides intense femtosecond pulses, enables us to quickly heat bulk materials, creating dense plasmas under non-local thermal equilibrium (NLTE). In the dense plasma, ionization potential depression (IPD) effect emergies, but theoretical IPD models have been considered at local thermal equilibrium. In this study, we employ XMDYN, a Monte-Carlo (MC) and molecular-dynamic (MD) -based computational tool, to simulate the dense materials interacting with intense XFEL pulses. In order to include the IPD for NLTE plasma environment, we propose a numerical method based on ab initio calculation of atomic energy shifts due to the micro-field obtained directly from MD simulations. We demonstrate the the IPD effects in MD simulations of solid-density aluminum plasma formation.

P 14.5 Wed 15:10 b302

PICLS: a gyrokinetic full-f particle-in-cell code for open field line simulations — •Mathias Boesl, Andreas Bergmann, Alberto Bottino, David Coster, and Frank Jenko — Max Planck Institut für Plasmaphysik, D-85748 Garching, Germany

While in recent years, gyrokinetic simulations have become the workhorse for theoretical turbulence and transport studies in the plasma core, their application to the edge and scrape-off layer (SOL) region presents significant challenges. The “full-f” code PICLS has been developed, to in particular study the SOL region with its steep density and temperature gradients as well as large fluctuation amplitudes. PICLS is based on an electrostatic full-f model with a linearized field equation and uses kinetic electrons. The electrostatic potential is calculated via the polarization equation, with the help of B-spline finite-elements for the charge deposition and the field solver. In this talk, we will introduce the PICLS model and show our results of applying it to the well-studied 1D parallel transport problem during an edge-localized mode (ELM) for the non-collisional and collisional case. Our current progress on extending PICLS towards three spatial domains, will be presented and key features for the 3D extension, such as field solver and particle pusher, will be shown.

P 14.6 Wed 15:25 b302

Particle in Cell Simulations for the KATRIN Experiment — •Jonas Kellerer, Christian Reiling, and KATRIN Collaboration — Karlsruhe Institute of Technology (KIT), ETP, Postfach 3640, 76021 Karlsruhe

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 an highly magnetized, partly collisional, multi-species, non-thermal (with thermal components), bound plasma. The combination of these properties make an analytical description impossible. Thus we decided on a two folded 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. These results will be used by the well tested ACRONYM Particle in Cell code to resolve the fast electron-field interactions. The derived fields are in turn used as input for the KARL code. To accommodate for the special experimental conditions we implemented curve-shaped boundaries in the conformal FDTD algorithm, following the Dey-Mittra algorithm. Hereby we took extra care on the electron-wall interactions. Supplementary we added electromagnetic background fields mimicking the use external power supplies.

P 14.7 Wed 15:40 b302

Dynamic structure factor of Yukawa liquids: molecular dynamics simulations and memory function approach — •Hanno Kählert — ITAP, Christian-Albrechts-Universität zu Kiel

Molecular dynamics simulations are used to compute the dynamic structure factor (DSF) of a strongly coupled Yukawa liquid over a wide range of coupling strengths. Despite its simplicity, the Yukawa model is of relevance for a variety of systems, including dense plasmas or strongly coupled dusty plasmas. The results for the DSF are compared with a theoretical approach based on the memory function formalism. In particular, a memory function incorporating viscoelastic effects [1] is applied to model the collective behavior of the Yukawa liquid at long wavelengths and low frequencies. Fitting the model to the simulation data allows one to estimate transport coefficients such as the viscosity. In addition, the fluctuation-dissipation theorem and the Kramers-Kronig relations are used to compute the complex density response function, which makes it possible to obtain the memory function directly from the simulation data.

[1] U. Bafile, E. Guarini, and F. Barocchi, Phys. Rev. E **73**, 061203 (2006).

P 15: Helmholtz Graduate School 3 and Magnetic confinement 3

Time: Wednesday 14:00–16:05 Location: b305

Invited Talk P 15.1 Wed 14:00 b305

How turbulence sets boundaries for fusion plasma operation — •Peter Manz, Thomas Eich, and the ASDEX Upgrade Team — Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany

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 (the H-mode density limit) and also trigger a sequence of 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. In the electrostatic limit relevant for L-mode their relative strength depends on the collisionality only. In H-mode also electromagnetic effects are important. In order to develop a more physics based understanding of the operation boundaries turbulence control parameters have been measured at the separatrix in ASDEX Upgrade. Taking into account over a hundred discharges, different confinement regimes are mapped into a phase space of normalized collisionality and plasma beta. Thereby confinement regimes can be assigned to different regimes of plasma edge turbulence. The density limit occurs around the transition from drift-dominated to interchange dominated turbulence, the transition to improved confinement regimes is around the transition to finite-beta turbulence.

P 15.2 Wed 14:30 b305

Geometry and Kinetics of Astrophysical Plasmas: A gyrokinetic approach — •Felipe Nathan de Oliveira Lopes[1,2], Karen Pommois[1,2], Aleksander Mustonen[1,2], Rainer Grauer[2], and Daniel Told[1,2] — [1]Max Planck Institute for Plasma Physics — [2]Ruhr-University Bochum

In the context of astrophysical plasmas, various methods are used in order to study problems such as dissipation of turbulent energy and magnetic reconnection[1][2][3]. The use of fluid models allow us to understand macroscopic phenomena[4], but lacks the dynamics of kinetic physics[5]. On another hand, kinetic models[6] usually consume an enormous amount of computing time. The use of reduced models such as gyrokinetics are foreseen to bridge the gap between the fluid and kinetic approaches[7].

In the present work, we aim to investigate the use of gyrokinetics in two different scenarios. Firstly we are going to consistently derive a hybrid hamiltonian field theoretical system[8, 9, 10], based on the lagragian formulation of a symplectic two-form[11]. In this system, ions are treated fully kinetically, and electrons gyrokinetically. With this model, we wish to develop a cost effective kinetic computational framework. The second aspect of the present work addresses a well known problem in space physics, namely magnetic reconnection with guide field[12]. We start with a gyrokinetic analysis using the code GENE[13]. Firstly we analyze the dynamics of the parallel electric field and reconnection rate on the X point, and proceed with benchmarking GENE with a fully kinetic PIC code.

P 15.3 Wed 14:55 b305

Carbon distribution and transport in ECRH and NBI heated plasmas with Charge Exchange Spectroscopy on W7-X — •Lilla Vanó, Oliver P. Ford, and Robert C. Wolf — Max-Planck-Institute for Plasma Physics, Greifswald, Germany

Impurity transport plays a crucial role in the optimization of fusion plasmas, as impurities affect the plasma radiation and can cause power losses. If neoclassical effects dominate the transport, strong impurity accumulation is predicted in the plasma core. According to simulations, neoclassically dominated impurity transport is a possibility in the optimized stellarator Wendelstein 7-X (W7-X) plasma.

To quantify impurity confinement in W7-X, carbon concentration profiles are investigated and used with the impurity transport modeling code STRAHL to determine the transport coefficients (diffusivity and radial convective velocity). The results are compared with neoclassical predictions in order to assess the anomalous contribution.

The profiles are derived from the Charge Exchange Recombination Spectroscopy (CXRS) diagnostic that observes the Neutral Beam Injection (NBI) which is well-suited for determining spatially resolved profiles of fully-stripped low-Z impurities. This work concentrates on carbon, the main intrinsic impurity in W7-X.

Different configurations, densities and heating scenarios with different NBI and ECRH power ratios are explored. Of particular interest are discharges with pure NBI heating phases or with very low ECRH power, where indications of unusually high impurity confinement times have been observed.

P 15.4 Wed 15:20 b305

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 Energéticas, Medioambientales y Tecnológicas

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. Comparing the temporal dynamics of the shell ablation with a neutral gas shielding model gives good agreement. As seen from fast frame camera images of the shell ablation cloud, the TESPEL trajectory through the plasma does not suffer any deflections. This permits localizing the deposited tracer in the plasma by a simple time-of-flight attempt. The temporal evolution of the line emissions by tracer impurity ions of various charge states, observed by vacuum ultraviolet spectroscopy (HEXOS) and high resolution X-ray imaging spectrometry (HR-XIS) shows 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.

P 15.5 Wed 15:35 b305

Spectroscopic characterization of the boronization impact on the impurity sources in Wendelstein 7-X — •Stepan Sereda[1], Sebastijan Brezinsek[1], Erhui Wang[1], Tullio Barbui[2], Rudolf Brakel[3], Birger Buttenschön[3], Peter Drewelow[3], Andrei Goriaev[4], Ralf König[3], Maciej Krychowiak[3], Yunfeng Liang[1], Dirk Naujoks[3], Andrea Pavone[3], Marcin Rasinski[1], Lukas Rudischhauser[3], Holger Viebke[3], Tom Wauters[4], Victoria Winters[3], and the W7-X team[3] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), Jülich, Germany — [2]Princeton Plasma Physics Laboratory, Princeton, NJ 08540, United States of America — [3]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [4]Laboratory for Plasma Physics, LPP-ERM/KMS, B-1000 Brussels, Belgium, Trilateral Euregio Cluster (TEC) Partner

In the last experimental campaign of Wendelstein 7-X the passively cooled test divertor unit made of carbon and the stainless steel wall were the main sources of low-Z impurities oxygen and carbon. To tackle this problem three boronizations were performed which significantly decreased the impurity levels (more than factor of 10 for oxygen and 4 for carbon). These changes are characterized by the emission spectroscopy focused at the impurity sources. The ion flux change for the second and the third boronizations is deduced from the divertor Langmuir probes data. The change of hydrogen recycling after the boronization is studied employing filter cameras for hydrogen line radiation observing the complete divertor module.

P 15.6 Wed 15:50 b305

Reynolds stress formation of ZF drive under imposed shear flows at the stellarator TJ-K — •Til Ullmann[1], Bernhard Schmid[1], Peter Manz[2], and Mirko Ramisch[1] — [1]IGVP Universität Stuttgart, Germany — [2]IPP, Max-Planck Institut, Garching

Shear flows in magnetized fusion plasmas are considered to have a major impact on the non-linear dynamics. In drift-wave (DW) turbulence, shear flows tilt and stretch turbulent eddies, resulting in the generation of large structures such as zonal flows (ZF). ZFs tap energy from the DW turbulence and, hence, are supposed to be involved in the formation of transport barriers at the transition into the high confinement regime. ZFs are themselves shear flows and react upon the turbulence. The stellarator TJ-K confines low-temperature plasmas, which allow for measurements of potential fluctuations with Langmuir probes inside the confinement region. In order to identify ZFs and to calculate the Reynolds stress (RS), which indicates the tilt of stretched eddies, 128 probes are poloidally positioned on four neighbouring flux surfaces. The background $E \times B$ flow as imposed by external plasma biasing is calculated from radial profiles of the plasma potential, measured by an emissive probe. The influence of stationary $E \times B$ flow shears on the tilt of turbulent eddies, the RS drive of ZFs and the energy transfer process into the ZFs are investigated experimentally.

P 16: Poster Session 3

Time: Wednesday 16:30–18:30 Location: Empore Lichthof

P 16.1 Wed 16:30 Empore Lichthof

The electric field of an electron in a electron-hole plasma with degenerate electrons. Possibility of formation of a superconductivity state — •Saltanat P. Sadykova[1] and Anri A. Rukhadze[2] — [1]Forschungszentrum Jülich (Julum.), Jülich, Germany — [2]Prokhorov General Physics Institute, Russian Academy of Sciences, Vavilov Str. 38., Moscow, 119991, Russia

We consider the possibility of formation of a superconductivity state either in a semiconductor or in a electronhole plasma with the degenerate electrons due to the attractive forces between the electrons as a result of the exchange effects through the electron-hole sound wave [1] by analogy to the phonon waves in a solid state. We have determined the view of an interaction potential between two electrons in a degenerate electron-hole plasma [2]. The potential appears to be attractive at distances large than the Debye radius and decreases as $1/r^3$. We discuss the conditions at which the bound electron state - so called “Cooper Pair” in a such field can be formed.

[1] A.F. Alexandrov, L.S. Bogdankevich, A.A. Rukhadze, Principles of Plasma Electrodynamics (Springer, Heidelberg,1984), pp. 167-170.
[2] S.P. Sadykova, A.A: Rukhadtze, Contributions to Plasma Physics. 2019, 1-7

P 16.2 Wed 16:30 Empore Lichthof

Interaction of runaway populations and instabilities — •Andrej Lier[1], Gergely Papp[1], Philipp Lauber[1], Ola Embreus[2], and George Wilkie[3] — [1]Institute for Plasmaphysics, Garching, Germany — [2]Chalmers University, Gothemburg, Sweden — [3]PPPL, Princeton, NJ, USA

Fusion-born alpha particles in ITER disruption simulations are investigated as a possible drive of Alfvenic instabilities, whose ability to expel runaway electron (RE) seed particles is explored in the pursuit of a passive, inherent RE mitigation system. Utilizing a linearized Fokker-Planck solver, the distribution functions of the highly energetic alpha population during a disruption are computed. A linear gyrokinetic magnetohydrodynamic (MHD) code calculates the Alfven spectrum supported by the plasma which is connected to the previously obtained distribution functions through a self-consistent nonlinear wave-particle interaction tool in order to evaluate the MHD-mode drive. The disruptions themselves are simulated as an exponential temperature drop with iterations taking place over the exponential decay time and final temperature. Focusing on fast thermal quenches and on the spatial density gradient of the suprathermal ion population, we found it capable of exciting weakly damped Alfven Eigenmodes present in the cold post-disruptive plasma in spatial and temporal regimes correlated with runaway electron formation.

P 16.3 Wed 16:30 Empore Lichthof

Non-linear MHD Assessments of Stellarator-like Tokamaks — •Rohan Ramasamy[1,2], Matthias Hoelzl[1], Erika Strumberger[1], Qingquan Yu[1], Javier Artola[3], Karl Lackner[1], and Sibylle Günter[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Max Planck/Princeton Research Centre for Plasma Physics — [3]ITER Organization, Route de Vinon sur Verdon, 13067 St Paul Lez Durance Cedex, France

Quasi-axisymmetric stellarators (QAS) have been proposed as a hybrid approach to plasma confinement, offering both the desirable magnetohydrodynamic (MHD) stability of stellarators, as well as the favourable energy transport properties of tokamaks. The non-linear MHD code JOREK is currently being extended in order to assess these devices. A 3D MHD model and non-axisymmetric grid, appropriate for stellarator simulations are being developed, as well as improvements to the current numerical solver.

In the short term, previous linear studies have shown that axisymmetric approximations to QAS devices can preserve the stability structure observed in 3D simulations. It has therefore been proposed to assess the non-linear evolution of QAS equilibria using such an approximation. This contribution presents simulation results of large scale instabilities in stellarator-like devices, validating against other MHD codes, and analytic solutions, to provide an intuition for the non-linear dynamics of stellarators.

P 16.4 Wed 16:30 Empore Lichthof

Machine Learning Methods as Surrogate Models for the Power Exhaust in Tokamaks — •Martin Brenzke[1], Sven Wiesen[1], Matthias Bernert[2], David Coster[2], Jenia Jitsev[3], Udo von Toussaint[2], EUROfusion MST1 Team[4], and the ASDEX Upgrade Team[5] — [1]Forschungszentrum Jülich, Institut für Energie- und Klimaforschung, 52425 Jülich, Germany — [2]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [3]Jülich Supercomputing Center (JSC), Institute for Advanced Simulation (IAS), Research Center Jülich, 52425 Jülich, Germany — [4]See the author list of B. Labit et al. 2019 Nucl. Fusion 59 086020 — [5]See the author list of H. Meyer et al. 2019 Nucl. Fusion 59 112014

One of the main challenges in the design of an economically viable fusion reactor are the thermal loads experienced by the targets in a divertor-based design. These thermal loads cause degradation of the target material and limit the lifetime of a divertor. Modeling these thermal loads is one of the most important points in determining the operating scenarios for future fusion devices and remains a challenging yet crucial task. In light of current developments and successes in the field of machine learning techniques, data-driven modeling is an interesting option for this problem. We present results for a machine learning-based modeling approach using experimental data from the ASDEX Upgrade experiment. We focus on a comparison of the performances of several machine learning approaches.

P 16.5 Wed 16:30 Empore Lichthof

Developments towards an electron-positron plasma in a magnetic dipole trap — •J. Horn-Stanja[1], A. Deller[1], U. Hergenhahn[1], S. Nissl[1], E. V. Stenson[1], M. R. Stoneking[1], T. Sunn Pedersen[1], H. Saitoh[2], C. Hugenschmidt[3], M. Singer[3], J. R. Danielson[4], and C. M. Surko[4] — [1]Max Planck Institute for Plasma Physics, Germany — [2]The University of Tokyo, Japan — [3]Technische Universität München, Germany — [4]University of California San Diego, USA

The electron-positron many-body system in the plasma state is distinguished by the mass equality of the constituents, leading to stability and wave-physics properties fundamentally different from those of conventional plasmas. The creation of such "pair plasma" in the magnetic field of a levitated dipole is the goal of the APEX/PAX collaboration.

Although lossless injection and second-long trapping of positrons has been demonstrated in experiments with a supported dipole at the first-class positron source NEPOMUC, the number of available positrons remains a key challenge. While a small positron Debye length in the pair plasma eventually requires the use of a multicell storage trap, current single-particle experiments will benefit from the recent development of the intense NEPOMUC primary beam at lower energies or the upcoming installation of a buffer gas trap at NEPOMUC which will provide dense positron pulses. First experiments using electrons and positrons simultaneously in a dipole trap are one such example.

In this contribution, we discuss recent and upcoming developments within the scope of the APEX project.

P 16.6 Wed 16:30 Empore Lichthof

Electron Bernstein wave heating at harmonics of the electron cyclotron resonance frequency — •Alf Köhn-Seemann and Eberhard Holzhauer — IGVP, Universität Stuttgart, Germany

Electron Bernstein waves (EBWs) provide a method to transfer energy to a plasma whose density exceeds the corresponding cut-off density of an injected microwave. No high-density cut-off exists for EBWs and they are very well absorbed at harmonics of the electron cyclotron resonance frequency. In addition, they can also drive significant toroidal net currents with current drive efficiencies exceeding those normally achieved by standard electron cyclotron resonance heating. EBWs are, however, electrostatic waves and need thus be coupled to externally injected electromagnetic waves. We discuss the different coupling mechanisms and how their efficiency depends on the plasma parameters. We will use both, full-wave simulations and ray-tracing calculations to illustrate the effect of increasing harmonics number by decreasing magnetic field strength. It will be shown how going to higher harmonics will change the propagation paths and the coupling efficiencies. The results obtained from numerics will be compared with experimental results obtained from the TJ-K stellarator with its density gradient lengths comparable to the wavelength of the injected microwave.

P 16.7 Wed 16:30 Empore Lichthof

The GIRAFFE experiment: in situ tensile tests of irradiated tungsten fibers — •Bailey Curzadd[1,2], Johann Riesch[1], Till Höschen[1], Alexander Feichtmayer[1,2], and Rudolf Neu[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Deutschland — [2]Technische Universität München, München, Deutschland

Although its low erosion rate and low retention of tritium make tungsten (W) the preferred plasma-facing material for future fusion reactors, its low-temperature brittleness is a potentially critical vulnerability that could lead to the premature failure of plasma-facing components. The degradation of essential material properties by the fusion environment - especially by neutron irradiation and gas atoms (H/He) trapped in the microstructure - greatly increases the likelihood of component failure. However, the degradation of W in the fusion environment is poorly characterized. For this reason, a novel experiment to better understand the mechanisms by which the mechanical properties of W are worsened by radiation damage and trapped impurities is in development. A principal research goal is the investigation of synergistic interactions between the factors that lead to material deterioration. Displacement damage will be produced by bombardment of samples with protons or heavy ions. Samples will be subsequently or simultaneously loaded with impurity gases, and the mechanical properties determined via in situ tensile testing. Due to the low penetration depth of protons and heavy ions in W, thin fibers and foils ($\approx 5\ \mu$m) are foreseen as samples. The fine microstructure of these samples enables the simulation of bulk material behavior.

P 16.8 Wed 16:30 Empore Lichthof

Characterization of lanthanum-hexaboride electron emitters as cathodes in pressure gauges for strong magnetic fields — •Bartholomaeus Jagielski, Uwe Wenzel, Mirko Marquardt, Jiawu Zhu, Thomas Sunn Petersen, and the W7-X Team — Max Planck Institute for Plasma Physics, Greifswald, Germany

In order to evaluate the particle exhaust rate on the pumping ducts 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) pressure recordings took place with ASDEX Pressure Gauges (APG) and with newly developed Crystal Cathode Pressure Gauges (CCPG). While the cathodes from thoriated tungsten of the APGs regularly bent under the influence of the magnetic field (2,1T) and the resulting Lorentz forces, the CCPGs, equipped with an emitter made of lanthanum hexaboride, functioned largely without problems [1]. The simple cylindrical geometry, relatively high resilience to cathode poisoning, low workfunction (2.5eV) etc., makes the LaB6-emitter a promising candidate for future, precise manometers in a range between 1mbar to 10^{-6} mbar and for a successful application in future fusion plants (ITER, DEMO). For the next campaign of W7-X (OP 2.0) the LaB6-cathodes are being tested in different experimental environments and characterized with recent ANSYS simulations. The design, preliminary results of the investigations, with and without external magnetic field, and the latest optimization as well as future plans of/for the CCPGs are presented. [1] U. Wenzel et al, J. Instrum.12(09), C09008 (2017).

P 16.9 Wed 16:30 Empore Lichthof

Statistical analysis of ballooning effect for sawtooth crashes in ASDEX Upgrade — •Oleg Samoylov, Valentin Igochine, Branka Vanovac, Matthias Willensdorfer, Hartmut Zohm, and ASDEX Upgrade Team — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

Sawtooth oscillations are nonlinear periodic relaxations of core plasma density and temperature in tokamaks. While the oscillations are often observed and known for decades, the process by which the periodic collapse of the core plasma temperature occurs is still only partially understood. There is no final model that could fully describe all experimental measurements. Some of the proposed sawtooth models predict a higher rate of the crashes at the low field side due to the ballooning effect. To prove the hypothesis, we statistically study the occurrence of the crashes at the low field side in ASDEX Upgrade. The main diagnostic for this study was 2D electron cyclotron emission (ECE) diagnostic, which measured temperature perturbations at the q=1 magnetic surface at the low field side. 200 sawtooth crashes were analyzed. 39 % of the sawtooth crashes were observed in the 2D ECE window, whereas in case of symmetrical occurrence only 23.6 % crashes were expected. This shows weak ballooning effect for the crashes used in the studies.

P 16.10 Wed 16:30 Empore Lichthof

First Steps towards TALIF Measurements of the H Atom Velocity Distribution Function and Density in Negative Ion Sources — •Frederik Merk, Christian Wimmer, Stefan Briefi, Emile Carbone, Ursel Fantz, and the NNBI-Team — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

H^- (and D^-) ion sources are required for neutral beam injection on the ITER fusion device. The test facility BATMAN Upgrade (BUG) is used to investigate the physics of these sources. H^- ions are produced in a low-temperature, low-pressure plasma environment by surface-conversion of H or H_x^+ at a (caesiated) low work function surface. As the dominant process is the H atom conversion, the H^- conversion yield depends on the flux of H atoms onto the surface. This flux is determined by the H atom velocity distribution function and the corresponding density. In order to determine reliable values for both parameters a TALIF (two-photon absorption laser induced fluorescence) system will be installed at the test facility. For the installation of the diagnostic under the harsh environment of the ion source (100 kW rf power, 45 kV high voltage), a stepwise approach is chosen. First, the TALIF implementation scheme and calibration is tested for O atoms in a small plasma torch. Then, a TALIF system for H is installed in a controlled environment on a small H_2 ICP experiment. Finally, the optimized diagnostic system is transferred to BUG, which will be the first time that such a system is installed at a H^- ion source. The design and the current status of the TALIF system is presented.

P 16.11 Wed 16:30 Empore Lichthof

Effects of oxide layers on deuterium uptake, retention and release in self-damaged tungsten — •Kristof Kremer[1,2], Maximilian Brucker[1,3], and Thomas Schwarz-Selinger[1] — [1]MPI for Plasma Physics, Boltzmanstraße 2, D-85748 Garching, Germany — [2]TUM, James-Franck-Straße 1, D-85748 Garching, Germany — [3]Ulm University, Albert-Einstein-Allee 11, D-89081 Ulm, Germany

Understanding hydrogen isotope (HI) retention in first-wall materials is crucial to predict fuel loss in future fusion devices, but the influence of surface oxides is discussed controversially in literature.

We examine the effect of thick (25–100 nm) tungsten-oxide layers on uptake, retention and release of HI in tungsten (W) by oxidizing the sample and then exposing it to a deuterium (D) plasma at low ion energy (< 5eV/D) and low temperature (370 K) to minimized erosion of the oxide. As samples, self-damaged W is used. Damaging with 20 MeV W ions creates a $\sim 2\,\mu$m thick, defect-rich getter layer that retains HIs. Nuclear reaction analysis, Rutherford back scattering and Thermal Desorption Spectroscopy (TDS) are used to quantify the amount of oxygen, the depth profiles of the retained D and the outgassing behavior. A strong influence of surface oxide layers on D uptake is observed, i.e., oxide layers strongly suppress D uptake. The oxide layer itself is only partially reduced by plasma exposure and only partially evaporated during TDS up to 1000 K. The role of thin (~ 2 nm), natural oxide layers are subject of future investigations. In this regard, we are setting up an in-situ experiment to examine HI uptake, retention and release on oxide-free W surfaces.

P 16.12 Wed 16:30 Empore Lichthof

Investigations of the peaking of ion temperature profiles in non-inductive high-beta advanced scenarios — •Maximilian Reisner[1], Emiliano Fable[1], Jörg Stober[1], Alexander Bock[1], Alejandro Bañon Navarro[1], Alessandro Di Sienna[1], Rainer Fischer[1], Rachael McDermott[1], and The ASDEX Upgrade team[2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching bei München, Germany — [2]See the author list of H. Meyer et al. 2019 Nucl. Fusion 59 112014

Non-inductive advanced Tokamak scenarios are a possible way for future nuclear fusion power plants to run in non-pulsed operation. In these scenarios, the ohmic current is replaced by externally driven current and a substantial bootstrap-current. Since the bootstrap current is produced in the presence of pressure gradients, internal transport barriers (ITBs) or regions of reduced transport are favorable to such scenarios. There are several mechanisms that are thought to be connected to the reduction of turbulence in the plasma core, in particular the ExB-shear and electromagnetic fast ion effects. In this contribution, the results of experiments conducted in the tokamak ASDEX Upgrade will be presented that aim to study these mechanisms in more detail. Furthermore, a new heuristic model to more accurately describe the reduction of turbulence in such high-beta non-inductive scenarios in the quasi-linear transport-code TGLF will be presented. This new model is calibrated on experimental results and simulations of the gyrokinetic code GENE.

P 16.13 Wed 16:30 Empore Lichthof

Supercapacitors-Based Power Supply for ASDEX Upgrade Tokamak — •Antonio Magnanimo[1], Markus Teschke[1], Gerd Griepentrog[2], and ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching Bei München, Germany — [2]Technische Universität Darmstadt, 64283 Darmstadt, Germany

ASDEX Upgrade (AUG) electrical power is provided by three Flywheel Generators (FG) that are charged up before the start of a plasma pulse with up to 15 MW for several minutes. The energy stored is then used to satisfy the high power needs during a plasma pulse of up to 450 MW. The biggest FG (EZ2) in case of a major fault could not be replaced by any other FG of such size, so an alternative power supply is needed. Supercapacitors are well known for their very high specific power, due to their internal structure. Combining this technology with a proper power converter topology such as the Modular Multilevel Converter (MMC), it would be possible to feed the coils of future Tokamaks with higher performances and reliability. The MMC topology, indeed, allows a discrete-leveled output voltage and, thanks to its high cells number, it can operate continuously even in case of fault of some cells, while a FG could not. In this poster the concept of a Supercapacitors-based power supply for Toroidal Field Coils of AUG is presented, highlighting the main advantages and challenges that this project requires. Furthermore, a charger concept able to optimize the available time between consecutive shots and an overview of the present experimental setup are given, showing some of the components to be tested for the first small-scale prototype.

P 16.14 Wed 16:30 Empore Lichthof

The Edge Density Profile in Tokamaks — •Christian Schuster[1,2], Elisabeth Wolfrum[1], Ulrich Stroth[1,2], and ASDEX Upgrade Team[1] — [1]MPI für Plasmaphysik, Garching — [2]Physik-Department E28, Technische Universität München

To obtain sufficient fusion power in a future reactor, the plasma in the core has to be hot and dense. Combined with the low plasma density at the wall of current tokamaks, this necessitates maintaining a density gradient. In H-mode the increase in density occurs mainly at the edge of the plasma, in a region known as the pedestal. But also in L-mode there is a steep increase in density at the same position. To extrapolate to future reactors, knowledge about the underlying processes that determine the shape of the density profile is needed.

There are several effects that are responsible for this large density gradient at the edge. We approximate all transport processes in the plasma with an effective diffusivity and mean flow. In H-mode the diffusivity is lowered drastically in the pedestal compared to the core, but the presence of a mean radial flow, called pinch, is unclear [M Willensdorfer, NF 2013]. On the other hand, it was shown that the density profile at the edge often also depends strongly on the source, i.e. neutral atoms entering the edge region [RJ Groebner, PoP 2002].

In steady state it is not possible to disentangle these effects. Modulation experiments were used previously for the analysis of transport in the plasma core. In this contribution we prepare the extension of this technique to the pedestal region, using new diagnostic possibilities and modeling of the tokamak edge.

P 16.15 Wed 16:30 Empore Lichthof

Scale-Resolved Multi-Field Experimental Investigation of Turbulence for the Validation of Gyrokinetic Simulations — •Klara Höfler[1,2], Tim Happel[2], Pascale Hennequin[3], Pedro Molina Cabrera[4], Tobias Görler[2], Elisee Trier[2], Ulrich Stroth[1,2], and the ASDEX Upgrade Team[2] — [1]Physik Department TUM, E28, Garching, Germany — [2]Max Planck Institut für Plasmaphysik, Garching, Germany — [3]Laboratoire de Physique des Plasmas, Ecole Polytechnique, Palaiseau, France — [4]MIT Plasma Science and Fusion Center, Cambridge, Massachusets, USA

Turbulence directly deteriorates the performance of fusion plasmas by causing significant particle and heat transport. The corresponding density and temperature fluctuations are measured on the ASDEX Upgrade tokamak via Doppler reflectometry, poloidal correlation reflectometry and a correlation electron cyclotron emission diagnostic. A long history of gyrokinetic validations showed a good agreement between individual experimental quantities and simulations. This contribution presents a plasma scenario designed for measurements of a large variety of turbulence quantitites at the same radial position and provides a powerful foundation for validation of codes. Detailed studies of density fluctuations such as wavenumber spectra, correlation lenghts radial and perpendicular to the confining magnetic field, turbulence decay times, the perpendicular velocity and spectra of perpendicular plasma flows are shown together with simulations done with the gyrokinetic code GENE. Particular emphasis is put on poloidally resolved perpendicular velocity measurements done with Doppler reflectometry.

P 16.16 Wed 16:30 Empore Lichthof

Excitation and dissociation of CO_2 heavily diluted in noble gas atmospheric pressure plasmas — •Christoph Stewig, Theresa Urbanietz, Steffen Schüttler, Volker Schulz-von-der-Gathen, Marc Böke, and Achim von Keudell — Experimental Physics II, RUB, Bochum, Germany

The storage of renewable energies into chemical fuels due to the dissociation of CO_2 has been an inspiring idea for years. Hereby, non-equilibrium plasmas may be a promising candidate, as they allow dissociation reactions without the necessity of high temperatures. The vibrational pumping of the CO_2 due to repeated collisions with energetic plasma compounds is one of the discussed reaction channels.

Utilizing an atmospheric RF driven plasma jet, the dissociation efficiency of CO_2 has been investigated. Helium, argon and different helium-argon admixtures where used as carrier gases for the discharge. As expected, argon leads to a much higher conversion efficiency and lower specific energy inputs (SEI) for dissociation. However, only a small admixture of argon to a helium plasma changes the conversion characteristics of said plasma to an argon-like behaviour, whereas the vibrational temperatures of CO_2 remain unchanged. This points towards a direct dissociation process instead of vibrational pumping prior to dissociation.

P 16.17 Wed 16:30 Empore Lichthof

Plasma Sterilization for Space Applications — •Alisa Schmidt[1], Meike Müller[2], Markus Thoma[1], Hubertus Thomas[2], and Petra Rettberg[3] — [1]I. Physikalisches Institut, Justus-Liebig-Universität, Gießen, Germany — [2]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt e.V., Weßling, Germany — [3]Institut für Luft- und Raumfahrtmedizin, Deutsches Zentrum für Luft- und Raumfahrt e.V., Köln, 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 $60min$. 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 16.18 Wed 16:30 Empore Lichthof

Power measurement and balance of an rf-driven dielectric barrier atmospheric pressure plasma jet — •Tristan Winzer, Natascha Blosczyk, Judith Golda, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Germany

Atmospheric pressure plasmas have received increasing attention in recent years due to their potential applications in industrial processes and in plasma medicine. Their non-equilibrium characteristics enable treatment of surfaces which are sensitive to heat. For all plasma processes, the power dissipated in the plasma is a key value. Its measurement is a requirement for comparison between different plasma sources, operating conditions and of experimental results with numerical models.

However, the accurate measurement of voltage, current and the phase shift between them is challenging in particular at rf-driven sources due to high frequencies. We therefore designed an experimental setup allowing us to measure these values with high stability and reproducibility. Using an oscilloscope and custom-designed software, we were able to monitor the power dissipated in an rf-driven dielectric barrier discharge operating at atmospheric pressure. The dependence on applied voltage and gas-mixture and a power balance will be presented.

P 16.19 Wed 16:30 Empore Lichthof

Actinometric measurements of an RF-driven atmospheric pressure plasma including calibration of a spectrometer via a tungsten-band lamp — •Natascha Blosczyk, Judith Golda, Tristan Winzer, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Germany

Atmospheric pressure plasmas have a wide range of usage in surface modification or medicine, because they generate active species such as atomic oxygen. The densities of these species depend on different parameters including gas composition and residence time in the plasma, therefore the influence of those parameters has to be examined. However, the determination of these dependencies is challenging, because many diagnostic methods interfere with the plasma.

In this contribution, an optical spectroscopy measurement of an RF-driven atmospheric pressure plasma jet operated in helium with admixture of oxygen and argon, taking an actinometric approach to measure the atomic oxygen density, is presented. The dependency of the results on total gas flow, position in jet and oxygen admixture is determined using a simplified actinometric approach. Further, the results are compared to those of an improved actinometric calculation taking in consideration additional effects influencing generation and depletion of atomic oxygen.

P 16.20 Wed 16:30 Empore Lichthof

Simulation of pressure increase in HVDC relays during plasma arcing — •Crispin Masahudu Ewuntomah[1] and Jens Oberrath[2] — [1]Institute of Product and Process Innovation, Leuphana University Lüneburg, Germany — [2]Modeling and Simulation, Department of Electric Power Engineering, South Westphalia University of Applied Science, Soest, Germany

During short circuit situations in high voltage direct current (HVDC) relays, plasma arcs are formed. The arcs extremely vaporize the contact spots of the relays such that, significant pressure is built up in the enclosed chambers of the relays. The pressure buildups may lead to explosions. To quantify such buildups, a Panasonic AEV14012 relay is being investigated, using short circuit experimental results and a numerical model established in COMSOL. The thermal plasma parameters derived from the numerical model are used to simulate the time dependent increase of pressure within the enclosed chamber of the relay. The results show the plasma arc formation, time dependent arc evolution, and pressure increase. It is established from the results that; the excessive vaporization of the contacts increases the pressure in the enclosed chamber significantly, which is quantified by the numerical model.

P 16.21 Wed 16:30 Empore Lichthof

Diagnostic of magnetron sputtering deposition in process plasma using thermal probes — •Felix Schlichting, Julia Cipo, and Holger Kersten — Institute of Experimental and Ap-

plied Physics, University of Kiel, Germany

In recent studies the intrinsic properties, determined by the I-V characteristics of magnetised films deposited by magnetron sputtering, were correlated with the plasma parameters obtained by passive thermal probe (ptp) measurements [1]. By measuring the energy flux coming from the target and plasma in a magnetron sputtering source, the functional dependence between deposition properties and film properties can be analysed. This knowledge is important in developing memristive devices, used in neuromorphic engineering or image processing algorithms, and for understanding the signal-to-noise ratio in magnetic field sensors. The ptp can simultaneously be used for energy flux measurements and as a planar Langmuir probe, yielding also the electrical properties of the plasma. The parameters have been determined in radial position across the substrate region.

[1] F. Zahari et al., Journal of Vacuum Science & Technology B 37, 061203 (2019)

P 16.22 Wed 16:30 Empore Lichthof

Measurements with a Diagnostic Package for Electric Propulsion Satellite Platforms — •Tony Krüger, Thomas Trottenberg, Alexander Spethmann, and Holger Kersten — Institute of Experimental and Applied Physics, University of Kiel, Germany

To measure the plasma environment of electrically propelled satellites, a novel electric propulsion diagnostic package (EPDP) is currently being developed. Spacecrafts often carry sensitive instruments and other subsystems which might be disturbed or degraded due to the unintended backflow from applied plasma thrusters [1]. With their exhaust plume and its resultant surface-modification effects, these thrusters significantly influence the spacecraft's environment. To gain control of these effects, the EPDP contains a retarding potential analyzer, a planar Langmuir probe, and an erosion sensor to measure relevant plasma parameters [2]. In the course of the Heinrich Hertz (H2Sat) telecommunication satellite financed by the DLR, the EPDP system is currently being developed for its maiden flight on H2Sat, which is scheduled for launch in 2022. This contribution shows up-to-date measurements with the EPDP performed in our ion beam chamber. [1] Trottenberg et al., Development of a Flight Electric Propulsion Diagnostic Package (EPDP) for EP Satellite Platforms, IEPC-2019-345, 36th International Electric Propulsion Conference University of Vienna, Austria, September 15-20, 2019, [2] Wang et al., Deep Space One Investigations of Ion Propulsion Plasma Environment, J. Spacecr. Rockets, vol. 37, pp. 545-555, 2000

P 16.23 Wed 16:30 Empore Lichthof

Combination of a quartz crystal microbalance and a force probe as a diagnostic tool for an ion beam experiment — •Manuel Maas, Mathis Klette, and Holger Kersten — Institute of Experimental and Applied Physics, University of Kiel, Germany

Many properties of a solid surface can be modified by a thin deposited film. One way to deposit thin films is via energetic ions. This method of physical vapor deposition is called sputtering. In order to monitor and optimize this process, different diagnostics are needed. Especially, angular resolved measurements are highly demanded.

A commonly used diagnostic for the deposition process is the quartz crystal microbalance [1]. It is a shear mode resonator which can be used to determine the deposited mass loading. Another diagnostic for sputtering is a force probe [2]. This diagnostic developed in our group uses the deflection of a rod to obtain the applied force. In particular, the deflection is determined by interferometric measurements.

The quartz crystal microbalance and the combined probe are tested in an ion beam experiment by sputtering aluminium and aluminiumoxide. The angular distribution of the sputtered/reflected atoms is measured. To evaluate the obtained data, a simulation based on the software TRIM is used [3].

[1]G. Sauerbrey, Zeitschrift für Physik 155, 206-222 (1959).

[2]Spethmann, A., Trottenberg, T., Kersten, H., Phys. Plasmas 24(2017), 093501.

[3]J. Biersack and L. Haggmark, Nucl. Instrum. Methods 174, 257 (1980).

P 16.24 Wed 16:30 Empore Lichthof

Formation of Zn Nanostructures using Low Energy Ion Beam Sputtering — Alexander Prediger, •Mathis Klette, Thomas Trottenberg, and Holger Kersten — Institute of Experimental and Applied Physics, University of Kiel, Germany

The formation of dune, ripple or dot-like nanostructures on surfaces by low energy ion beam sputtering has been subject to intensive study in the past few decades [1][2]. Most of the research focused on the creation of nanostructures on single crystalline semiconductor materials, such as GaSb, InP, and Si. Only a few studies were performed for metals or amorphous materials.

In this work, we present nanostructures synthesized by an ion beam directed onto amorphous zinc targets. The zinc targets were treated by a 1200 eV argon ion beam for up to 60 minutes under different angles of incidence. The properties and morphology of the samples were studied with contact angle measurements, scanning electron microscopy (SEM) and X-ray photoelectron spectroscopy (XPS). The SEM images show surfaces covered in a grid of tilted needle-like structures. Under certain conditions, samples show spherical clusters at the tip of the needle, likely caused by strong electric fields. The experiment allows to study the influence of ion species, target materials, pressure, ion beam energy, and processing time on these needle-like structures.

[1] R. Gago, et al., Nanotechnology **13**, 304-308 (2002)

[2] F. Frost, A. Schindler, and F. Bigl, Phys. Rev. Lett. **85**, 4116-4119 (2000).

P 16.25 Wed 16:30 Empore Lichthof

On the status of the investigation of the INCA discharge — •Christian Lütke Stetzkamp, Tsanko Vaskov Tsankov, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany

Recently a novel concept for collisionless electron heating and plasma generation at low pressures was theoretically proposed [1]. It is based on periodically structured vortex fields, which produce certain electron resonances in velocity space. The concept was experimentally realized by the inductively coupled array (INCA) discharge and first experimental results in atomic gas plasmas were presented in [2].

Here, an overview of the recent advances in the analysis of the discharge are given. Experimental results regarding the discharge operation in molecular gases as well as investigation of an alternative electric field configuration proposed in [1] are presented. The future challenges and possibilities of the concept are discussed.

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

[2] Philipp Ahr et al, Plasma Sources Sci. Technol. 27, 105010 (2018)

P 16.26 Wed 16:30 Empore Lichthof

Dynamical and static structure factor of non-ideal ions in quantum plasmas — Zhandos Moldabekov[1,2], •Hanno Kählert[2], Tobias Dornheim[3,2], and Michael Bonitz[2] — [1]Institute for Experimental and Theoretical Physics, Al-Farabi Kazakh National University, Almaty, Kazakhstan — [2]ITAP, Christian-Albrechts-Universität zu Kiel — [3]Center for Advanced Systems Understanding (CASUS), Görlitz

Advances on dense plasma diagnostics [1] should make it possible to probe ion acoustic modes at warm dense matter and dense plasma conditions. This motivates a theoretical investigation of the ionic dynamical structure factor (DSF). We have computed the DSF employing a linearly screened ion potential in molecular dynamics simulations. Electronic correlations were taken into account using local-field corrections in the STLS approximation [2,3]. The range of plasma parameters at which the STLS approximation is applicable for the description of the screening has been defined in Ref. [4]. The impact of electronic correlations on the ionic DSF is elucidated by comparing the STLS based results to MD data with a screened ion potential in the random phase approximation. Finally, the applicability of the Yukawa model for the description of the ionic DSF in dense plasmas is discussed [5].

[1] E. E. McBride *et al.*, Rev. Sci. Instrum. **89**, 10F104 (2018).

[2] K. S. Singwi *et al.*, Phys. Rev. **176**, 589 (1968).

[3] S. Tanaka and S. Ichimaru, J. Phys. Soc. Jpn. **55**, 2278 (1986).

[4] Zh. Moldabekov *et al.*, Phys. Rev. E **98**, 023207 (2018).

[5] Zh. Moldabekov *et al.*, Phys. Rev. E **99**, 053203 (2019).

P 16.27 Wed 16:30 Empore Lichthof

Metadata schemas and ontologies for plasma technology — •Markus M. Becker[1], Steffen Franke[1], Fabian Hoppe[2], Jessica Laufer[1], Lucian Paulet[1], Harald Sack[2], Volker Skwarek[3], Tabea Tietz[2], and Simon Tschirner[3] — [1]INP Greifswald — [2]FIZ Karlsruhe — [3]HAW Hamburg

The necessity and potential of systematic archiving and publication of digital research data is increasingly seen in the scientific landscape. Transparency of research, validation of research results, and the creation of a basis for data-driven science are among the benefits. However, proper labelling of the research data provided and uniform quality criteria are essential factors for the interdisciplinary reuse of data. Recently, a first metadata schema for documentation of research data in the field of applied plasma physics and plasma medicine has been introduced (arXiv:1907.07744). The present contribution discusses planned extensions to this core schema for specific applications and introduces activities aiming at enabling and permanently supporting data-driven research and knowledge transfer in the field of plasma technology. These activities include the development of a plasma ontology for semantic linking of metadata schema elements and objects on the basis of collaborative systems available to the plasma physics community. Furthermore, blockchain technology is used for automated quality checks, transparent data publications, and monitoring of scientific reputation.

The German Federal Ministry of Education and Research (BMBF) funded this work under grant marks 16QK03A, 16QK03B, 16QK03C.

P 16.28 Wed 16:30 Empore Lichthof

Beschleunigung und Fortbewegung von ultrahochenergetischen kosmischen Strahlen — •Jonas Graw, Martin Weidl und Frank Jenko — Max-Planck-Institut für Plasmaphysik

Ultrahochenergetische kosmische Strahlen sind elektrisch geladene Teilchen, die sich mit Energien größer als 10^{18} eV im Kosmos bewegen. Es ist nicht bekannt, wie diese Teilchen zu solch hohen Energien kommen und stellt eines der größten Rätsel der Astrophysik dar. Daher wollen wir die Beschleunigungsmechanismen von kosmischer Strahlung in unserer Forschung analysieren.

Als Quellen ultrahochenergetischer kosmischer Strahlung gelten aktive Galaxienkerne. Diese stoßen Gas parallel zur Rotationsachse mit sehr hohen Energien und Beschleunigungsraten aus. Den emittierten Teilchenstrahl bezeichnet man als Jet. Im Jet werden Schockwellen ausgebildet, in welchen einige Teilchen zu extrem hohen Energien beschleunigt werden. In unserer Forschung verwenden wir astrophysikalische Plasmen mit mehreren Ionenspezies in hochenergetischen Umgebungen. Derzeit untersuchen wir den Phasenraum aus Wellenvektor $\mathbf{k}$ und Kreisfrequenz ω. Dabei analysieren wir die unterschiedlichen Moden, die sich aus analytischen Überlegungen und Simulationen ergeben. Besonders interessant sind dabei die Moden, die nicht im Elektronen-Protonen-Plasma existieren.

Die Beschleunigung von ultrahochenergetischen kosmischen Strahlen hängt dabei maßgeblich mit der Welle-Teilchen-Interaktion mit dem Plasma zusammen. Mit der Analyse des Plasmas wollen wir somit unser Verständnis über die Beschleunigungsmechanismen intensivieren.

P 16.29 Wed 16:30 Empore Lichthof

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

JAC [1], the Jena Atomic Calculator, has been developed for performing (relativistic) atomic structure calculations of different kind and complexity. In particular, this code has been designed and worked out to compute not only atomic state functions and properties but also cross sections, rates, angular distributions for a quite large number of atomic processes, including photo ionization and recombination, electron-impact processes and many others. JAC automatically generates self-consistent fields and, hence, is suitable for mass production of atomic data as they are frequently needed in plasma and astro physics. Moreover, further work will support atoms within different plasma models in order to better understand atomic behavior within different environments, from thin to very dense plasma.

[1] S. Fritzsche, Comp. Phys. Commun. 240 (2019) 1.

P 16.30 Wed 16:30 Empore Lichthof

Scattering and absorption diagnostics for nanodusty plasmas — •Harald Krüger and André Melzer — Institute of Physics, University Greifswald

Dusty plasmas with nanoparticles have drawn increased attention in the last few years. Beside the existing experimental setups with nanoparticles grown in the rf discharge, we present the insertion of industrial, nanoscaled dust with a gas jet injection setup.

The confined particles are investigated in terms of size and density distribution by a Mie scattering and absorption spectroscopy setup.

For the determination of the size the angular resolved scattering intensity for perpendicular und parallel polarized incident laser light is recorded. Two different approaches to calculate the resulting size of the particles and their challenges will be discussed.

Simultaneous to the size measurement, particle density measurements have been carried out. Here, the absorption of a broadband light source in the visible spectrum is recorded. Using an Abel inversion algorithm, the spatially resolved particle density distribution can be calculated.

P 16.31 Wed 16:30 Empore Lichthof

Dust Clusters and Dust-Density Waves in Magnetized Dusty Plasmas — •Andre Melzer, Harald Krüger, and Stefan Schütt — Institute of Physics, University Greifswald

The effects of magnetic fields on dusty plasmas have attracted high interest, recently, due to the availability of superconductive magnets for such experiments. Dusty plasmas consist of charged dust particles immersed in a discharge plasma with electrons, ions and neutrals. We now have performed experiments on dusty plasmas under strong magnetic fields.

On the one hand, dust clusters trapped in the sheath of an rf discharge have been Studied for different magnetic field strengths ranging from a few milliteslas to 5.8 T. The dynamics of the dust clusters are analyzed in terms of their normal modes. From that various dust properties such as the kinetic temperature, the dust charge and the screening length are derived.

On the other hand, different dust clouds of micron-sized dust particles are trapped in the sheath of the discharge and the self-excited dust density waves were studied for various magnetic field strengths meranging from 0 mT to about 2 T. From the comparison of the measured wave properties and a model dispersion relation the ion density and the dust charge are extracted.

P 16.32 Wed 16:30 Empore Lichthof

Particle charge determination from configurational temperature — •Michael Himpel and Andre Melzer — Institute of Physics, Greifswald University

The configurational temperature can be used to determine the temperature of a particle crystal from its positions rather than its velocities. This method has been found to yield the same results as the kinetic temperature measured with particle velocities. If both, the positions as well as the velocities, are measured with reasonable accuracy it is possible to extract the underlying particle charge. This poster will show the concept of the configurational temperature and present the application to dusty plasma experiments with the possibility to determine the individual charges of the particles in a two-dimensional cluster.

P 16.33 Wed 16:30 Empore Lichthof

The apokamp: Transient luminous event in physical laboratory — •Vasily Kozhevnikov, Andrey Kozyrev, Aleksandr Kokovin, Alexey Sitnikov, Eduard Sosnin, Victor Panarin, Victor Skakun, and Victor Tarasenko — Institute of High Current Electronics, Tomsk, Russian Federation

In 2016 the group of experimentalists led by Eduard Sosnin has been discovered a novel phenomenon in low-temperature plasma physics: an extended plasma jet developing perpendicular to the bending point of the pulsed arc discharge channel between two electrodes. The discharge has been entitled an apokamp. It was shown experimentally that the apokamp in low-pressure air represents an exact tiny analogue of large-scale stratospheric transient luminous events, e.g. blue jets or sprites depending on the operating pressure. Here we give first theoretical backgrounds for the apokamp phenomenon in terms of deterministic DC-discharge theory. We use so-called two-moment model of a multicomponent discharge plasma to describe a self-sustained periodic discharge in pure oxygen both in the inter-electrode gap and in the surrounding space above the electrodes.

P 17: Mitgliederversammlung

Time: Wednesday 18:30–20:00 Location: b305

Mitgliederversammlung

P 18: Complex plasma and Low-temperature plasma and applications 2

Time: Thursday 11:00–13:10 Location: b302

Invited Talk P 18.1 Thu 11:00 b302

Experiments on Binary Dust Mixtures — •Frank Wieben and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

A solid or fluid can drastically change its properties if an additional species of atoms or molecules is added. In the field of strongly coupled systems, colloidal dispersions were the first using polydisperse mixtures and observed phenomena like e.g. highly ordered alternating lattices. Naturally, the presence of a second species was expected to also impact closely related complex (dusty) plasmas, where solid as well as fluid states are accessible. The charged dust particles form two- or three-dimensional systems which are virtually undamped and allow for dynamical processes to emerge. Monodisperse systems proved to follow a One Component Plasma (OCP) description very well, thus serving as an ideal model experiment. Early microgravity experiments using two particle sizes revealed a demixing of the species, but recently the transition from demixed to mixed or even highly ordered binary complex plasmas was reported. This opened a completely new field and granted access to structural as well as (thermo-) dynamical properties of these systems. In this contribution an overview of the recent progresses in binary complex plasmas is given.

Invited Talk P 18.2 Thu 11:30 b302

Structure and transport in magnetized gas discharges related to dusty plasmas — •Peter Hartmann[1] and Marlene Rosenberg[2] — [1]Wigner Research Centre for Physics, Budapest, Hungary — [2]University of California San Diego, La Jolla, California, USA

Motivated by recent magnetized dusty plasma experiments at Auburn University and the University of Greifswald we have applied our GPU accelerated electrostatic cylindrical 2D Particle-in-Cell with Monte Carlo Collision simulations to describe charged particle transport in capacitively coupled RF discharges in an axisymmetric homogeneous magnetic field of up to a few Tesla magnitude. Microscopic details of the observed phenomena, like filamentation, imposed dust structure formation and light emission profiles have been computed and compared to the experiments.

P 18.3 Thu 12:00 b302

Experimental Studies of Phase Separation in Binary Dusty Plasmas under Microgravity — •Stefan Schütt and André Melzer — University Greifswald, Germany

Dusty plasma experiments under microgravity conditions allow to study the dynamics of individual particles in three-dimensionally extended systems. Such dusty plasmas typically contain one species of monodisperse dust particles. Adding a second species of monodisperse particles of different size allows to study phase separation processes. Those binary systems exhibit phase separation even for small relative size disparities of about 3%. Particles marked with a fluorecscent dye are used for one of the species. This makes it possible to distinguish between the species despite their small size disparity using a two-camera video microscopy setup and appropriate filters. The availability of high-resolution, high-speed cameras allows to track single particles during the separation process. As the particle number density as well as the flux are available, diffusion coefficients can be determined. Additionally, a method is presented that does not rely on particle tracking and therefore is much faster. A systematic study of phase separation at different size disparities made possible by this method is shown. This work was supported by DLR under grant no. 50WM1638.

P 18.4 Thu 12:25 b302

FTIR monitoring of nanoparticles synthesized in a capacitively coupled low-pressure plasma — •Oguz Han Asnaz, Franko Greiner, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Germany

Due to their unique physical, mechanical, electrical, and optical properties, in the last decades, nanoparticles have found a wide range of applications ranging from drug carriers in biomedicine over catalysts to batteries and solar cells. In all of these, fine control of the particle's surface properties as well as the bulk crystallinity is required.

Here, we present results of in situ analysis of Ar/C2H2-plasma-generated a-C:H nanoparticles by means of time-resolved multi-pass FTIR spectroscopy in parallel to optical light scattering techniques during operation. While the scattering techniques work well for larger particles, the absorption spectroscopy can be operated with particles with sizes even in the nanometer range, depending only on the density of absorbing features (chemical bonds on or in particles), i.e., independent of particle size. The a-C:H particles serve as a first model system to compare both measurement methods. In the future, surface modifications of silicon, metal or metal-oxide nanoparticles generated in external plasma sources will be studied, which will allow insight into the dynamics of surface oxidation, passivation, and thin-film deposition.

P 18.5 Thu 12:40 b302

Complex plasma experiments in microgravity with the Zyflex chamber — •Christina A. Knapek, Daniel P. Mohr, Peter Huber, and Mierk Schwabe — Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Materialphysik im Weltraum, Wessling, Germany

Complex plasmas consist of highly charged micrometer-sized grains injected into a low temperature noble gas discharge. The particles interact with each other via a screened Coulomb potential, and can form gaseous, liquid or solid states. On ground, gravity compresses the system and prevents the generation of larger, three-dimensional particle clouds. To study those systems, research in microgravity conditions, e.g. on parabolic flights, sounding rockets or the International Space Station (ISS), is essential.

In this talk, some of the latest results of experiments performed during parabolic flights with the Zyflex plasma chamber – a large, cylindrical radio-frequency (rf) discharge with adaptive internal geometry and a special electrode system – will be presented.

In microgravity, complex plasmas generated in a parallel-plate rf discharge usually exhibit a void in the central region of the plasma chamber, due to the ion drag force pushing particles out of the bulk plasma. The performed experiments include the successful generation of large, homogeneous 3D particle clouds without central void, and the observation of fluid phenomena at the void boundary.

This work is funded by DLR/BMWi (FKZ 50WM1441).

P 18.6 Thu 12:55 b302

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, DOI: 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 19: Helmholtz Graduate School 4 and Magnetic confinement 4

Time: Thursday 11:00–13:10 Location: b305

P 19.1 Thu 11:00 b305

CO_2 Dissociation from low to high pressure in plasma torch and surfaguide — •Federico Antonio D'Isa, Clemént Brochet, Ante Hecimovic, Emile Carbone, and Ursel Fantz — Max-Planck-institut für Plasmaphysik, BoltzmannStr. 2, 85748 Garching

The power to gas technology aims to store excess energy into gas by conversion of CO_2 into chemical fuels to reduce the CO_2 produced from the transportation sector. One step of the green-fuels production process consists in the dissociation of CO_2 into CO. In this work the dissociation of CO_2 into CO is investigated in a 2.45 GHz microwave plasma torch and a 2.45 GHz surfaguide. The two plasma sources are studied in the pressure range from 5-1000 mbar (surfaguide 5-60 mbar, plasma torch 60-1000 mbar). The gas temperature is found to increase from 1400 K to 3000 K with pressure in the range between 5-60 mbar and no significand differences are found between the two setups. The CO_2 conversion is found to be comparable in the two setups when the same power, pressure and input flow are used. In the plasma torch, above circa 120 mbar, a sudden transition from a radially di*use to a contracted plasma regime is reported. The latter is accompanied by a sharp increase of gas temperature from 3000 K to 6000 K in the plasma core. The CO_2 dissociation is strongly influenced by the discharge parameters, exhibiting peak values in the 100-200 mbar range, and usually increase with power. The measured CO_2 conversion and energy efficiency are compared to the conversion expected for a hot CO_2 gas at thermal equilibrium.

P 19.2 Thu 11:25 b305

Influence of the magnetic filter field on the source and beam performance at the large negative ion source ELISE — •Isabella Mario, Dirk Wünderlich, Federica Bonomo, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik, Garching, Germany

The neutral beam injection (NBI) system for ITER is based on RF sources for production of negative ions. The ELISE test facility (1/2 ITER source, 1m × 1m beam) plays a key role in demonstrating the scalability of the source performance between the prototype source (1/8 ITER source) to the full size ITER NBI source. Ion source requirements have to be combined with beam power uniformity (> 90% for ITER) to ensure an adequate beam transmission through the beamline. To minimize the destruction of negative ions by electron collisions in the plasma, the electron density and temperature close to the extraction area are reduced by a horizontal magnetic filter field. This, combined with electric fields and pressure gradients, gives rise to plasma drifts in the vertical direction, which affect the plasma properties and the beam profile. In this work the effect of the filter field on the plasma properties close to the extraction system and on the vertical beam profile at the ELISE test facility is presented. The aim is to study the global effect of the filter field on the source performance and beam uniformity. Plasma parameters such as positive and negative ion density and plasma potential are monitored 2 cm from the extraction apertures; several beam diagnostic tools provide accelerated beam current and divergences with a vertical spatial resolution of 4 to 5 cm.

P 19.3 Thu 11:50 b305

Hybrid driftkinetic-kinetic implementations and simulations for uniform magnetized space plasma. — •Karen Pommois[1], Simon Lautenbach[2], Florian Allmann-Rahn[2], Aleksandr Mustonen[1], Felippe Nathan De Oliveira[1], Rainer Grauer[2], and Daniel Told[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstrasse 2, 85748 Garching — [2]Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum

Kinetic numerical simulations, applied to study local heating in the solar wind, are computationally expensive due to the different evolution scales involved in the dynamics. Therefore, simplified models, such as hybrid fluid-kinetic and gyrokinetic, are widely employed. Gyrokinetics is missing waves with frequencies above the cyclotron frequencies of the species involved and can be applied only to cases of strong magnetization and where the magnetic moment is conserved. Instead, the hybrid-fluid model is missing electron kinetic effects, important even at ion scales. Consequently, we are working on a new computationally lighter hybrid model, composed of kinetic ions and driftkinetic electrons in an uniform magnetic field. The distribution functions are evolved through semilagrangian schemes separately for ions and electrons and coupled through the field, evolved using a domain decomposition method and an iterative scheduled relaxation method. In particular, we are interested in studying the stochastic heating at low beta, where the non conservation of the magnetic moment of ions breaks the gyrokinetic description for ions while electron landau damping do not ensure the validity of fluid description for electrons.

P 19.4 Thu 12:15 b305

Radiation cooling in strongly anisotropic electron-positron plasmas — •Daniel Kennedy and Per Helander — Max-Planck-Institut für plasmaphysik

Electron-positron plasmas have been found to possess "remarkable stability properties" [Helander, 2014] due to the mass symmetry of the two species. As such, it is thought that electron-positron plasmas confined in the magnetic field generated by a circular current- carrying coil ought to enjoy excellent confinement. In previous studies, it has been assumed that the equilibrium distribution function of such a plasma, ought to be an isotropic Maxwellian.

However, we have recently found that electron-positron plasmas under expected laboratory conditions are optically thin to cyclotron radiation. This radiative cooling is an extremely efficient way for the plasma to dissipate perpendicular energy on timescales which are typically much faster than the collision time. The presence of cyclotron cooling results in a strongly anisotropic equilibrium distribution function due to the different distributions of perpendicular and parallel velocities.

In this talk, I discuss these findings and show how cyclotron cooling can be incorporated into kinetic models for electron-positron plasmas. In particular I discuss how the presence of radiation cooling can impact the energy of the plasma and the ramifications this might have in terms of plasma stability.

P 19.5 Thu 12:40 b305

Development of a levitated dipole trap to study positron-electron plasma — •Matthew Stoneking[1,2], Juliane Horn-Stanja[1], Haruhiko Saitoh[3], Eve Stenson[1], Stefan Nissl[1,4], Thomas Sunn Pedersen[1,5], Alexander Card[1], Christoph Hugenschmidt[4], Markus Singer[4], James Danielson[6], Clifford Surko[6], and Uwe Hergenhahn[1] — [1]Max Planck Institute for Plasma Physics, Garching and Greifswald, Germany — [2]Lawrence University, Appleton, USA — [3]University of Tokyo, Japan — [4]Technische Universität München, Garching, Germany — [5]University of Greifswald, Germany — [6]University of California, San Diego, USA

A Positron-Electron eXperiment (APEX) is a project that aims to produce and study magnetically confined short Debye-length positron-electron plasma. We present design plans for a levitated dipole experiment to realize this goal. The design uses a floating coil constructed with high temperature superconducting tape (average radius 7.5 cm, current 30-50 kA-turns) to produce magnetic fields of order 0.1 - 1.0 T. Current is induced in the floating coil by inductive charging using a second superconducting coil (70-140 kA-turns). Two (~100 W) cryocoolers cool the superconducting coils (to 20K) and a copper radiation shield (to 80 K). Laser rangefinders provide position and attitude signals to feedback on the lifting coil (water-cooled, ~5 kA-turns) power supply. Positrons and electrons are injected into the dipole field using pulsed electric fields to produce ExB drifts that carry particles across the field. Scintillation detectors employed in pairwise coincident configurations detect annihilation gamma rays to diagnose positron losses.

P 19.6 Thu 12:55 b305

An Intense Pulsed Positron Source (IPPS) — •Stephan König[1], Martin Singer[2], Lutz Schweikhard[1], and Thomas Sunn Pedersen[2] — [1]Institut für Physik, Universität Greifswald — [2]Max-Planck-Institut für Plasma Physik

In a typical plasma the mass difference between the electrons and ions leads to instabilities and wave phenomena. It is predicted that in a positron-electron plasma due to the mass equality many of these phenomena will vanish. The APEX (A Positron Electron eXperiment) collaboration aims for the production of the first electron-positron plasma. One part of this collaboration is the Intense Pulsed Positron Source (IPPS), for the accumulation and storage of large numbers ($\sim 10^{11}$) of positrons in multiple Penning traps. From those devices the positrons will be guided to a levitated dipole for the intended electron-positron experiments. In this contribution first measurements with only one Penning trap in a 3.1T superconducting magnet are presented. This includes basic measurements like trap alignment, control of diocotron motion and plasma compression by rotating-wall application.

P 20: Laser plasma and laser applications 2

Time: Thursday 14:00–16:00 Location: b302

Invited Talk P 20.1 Thu 14:00 b302

The interaction of lasers with material using pulse durations from fs to ns — •Georg Pretzler[1], Steffen Mittelmann[1], Jannis Oelmann[2], Julian Wegner[1], and Sebastijan Brezinsek[2] — [1]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf — [2]Forschungszentrum Jülich, Institut für Energie- und Klimaforschung – Plasmaphysik

We compare the interaction of lasers with different pulse durations with solid matter and focus on the effects induced in the target, like ionization, ablation, and crater formation. Experiments were performed with lasers of fs-, ps-, and ns-durations, yielding strongly differing results concerning plasma temperature, interaction depth, particle ejection and spectral line emission. The effects were analysed by the help of various types of simulations, and different energy transfer mechanisms proved to be dominant, dependent on the laser pulse duration. This allows connecting the well-known results with longer pulses to the ultra-short high-intensity regime, which might help for selecting the right laser parameters for applications. One example is discussed in the talk, namely laser induced breakdown spectroscopy (LIBS) for the diagnostics of the first wall in fusion devices, for which a series of experiments is presented using lasers with different pulse durations.

P 20.2 Thu 14:30 b302

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], Dongye Zhao[2], Ding Wu[3], Arkadi Kreter[2], Sebastijan Brezinsek[2], Hongbin Ding[3], and Georg Pretzler[1] — [1]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf — [2]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik — [3]Key Laboratory of Material Modification by Laser, Ion and Electron Beams, Dalian University of Technology

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) with possible in-situ application is used. This widely applied technique is executed by lasers with different pulse durations. In our institute we are operating a sub 10 fs Ti:Sa-laser that big advantage 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 our laser system can be compared to ns- and ps-LIBS signals, 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 20.3 Thu 14:45 b302

Characterisation of plasma-facing surfaces by double-pulse LIBS with picosecond pulses — •Erik Wüst[1], Jannis Oelmann[1], Sebastijan Brezinsek[1], Christian Linsmeier[1], and Claus Schneider[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung, 52425 Jülich — [2]Forschungszentrum Jülich GmbH, Peter-Grünberg-Institut, 52425 Jülich

Depth-resolved information about fuel retention and material mixing on plasma-facing components surfaces made out of Tungsten (W), Beryllium (Be) or Graphite (C) are required in order to understand plasma-surface interaction processes in long pulse plasma devices like ITER or W7-X. Laser-induced breakdown spectroscopy (LIBS) is here a promising candidate for the detection of hydrogen (H) isotopes, such as tritium which is critical from the point of safety.
The selection of W as plasma-facing material induces challenges regarding the detection of residual plasma fuel in the component due to overall low H isotope retention by implantation. One way to adapt to this by improving the detection limit of the technique is double-pulse LIBS (DP-LIBS) which uses a second laser pulse to further excite released H atoms in the plasma induced by the first pulse. This amplifies the H_α line intensity, which is used for H determination.
The perspective of DP-LIBS as a technique for H retention measurement is discussed and our approach to implement DP-LIBS with short pulses of a Nd:YAG laser ($\tau = 35$ ps, with wavelengths 1064 nm, 532 nm and 355 nm available simultaneously) is presented.

P 20.4 Thu 15:00 b302

Two-dimensional simulations of a water-confined ns-laser shock peening — •Vasily Pozdnyakov[1] and Jens Oberrath[2] — [1]Institute of Product and Process Innovation, Leuphana University Lüneburg, Germany — [2]South Westphalia University of Applied Science, Department of Electric Power Engineering, Modeling and Simulation, Soest, Germany

Due to continuously rising demands in microelectronics, aerospace and automotive productions, new surface improvement methods are required. Laser shock peening (LSP) is one of such enhancement techniques, which is considered to be a potential substitute to a conventional shot peening process due to a better performance and a wider application range. LSP deals with laser pulses with high intensities (over 1 GW/cm2) and short durations (ns-range), so all occurring physical phenomena are difficult to measure experimentally. Therefore, computer simulations of plasma formation and shock wave generation are required in order to optimize the process for industrial applications.

In this work, a two-dimensional simulation of a water-confined laser shock peening of aluminium with a circular laser focus is done. The radiation-hydrodynamics code MULTI2D [1] is used, which allows to identify temporal evolution of plasma and shock wave spatial distributions. The occurring processes are analyzed and compared for different peening parameters to get a physical insight into a pulsed laser-matter interaction. The results can be used for LSP optimization.

[1] R. Ramis, J. Meyer-ter-Vehn, and J. Ramírez, Comput. Phys. Commun. 180, 977-994 (2009)

P 20.5 Thu 15:15 b302

Efficiency of bi-circular High Harmonic Generation with a kHz Laser — •Zahra Chitgar[1], Roman Adam[2], and Paul Gibbon[1,3] — [1]Jülich Supercomputing Centre, Forschungszentrum Jülich, Germany — [2]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich GmbH, Germany — [3]Centre for Mathematical Plasma Astrophysics, KU Leuven, Belgium

Circularly-polarized (CP) extreme UV- and X-ray radiation is an essential tool for analyzing the magnetic properties of materials. Recently, CP high harmonic generation (HHG) has been demonstrated experimentally by focusing bi-chromatic (800 + 400nm wavelength), counter-rotating CP laser pulses into gas targets [Kfir, O. et al, Nat. Phot. (2015)], thus overcoming a long-standing limitation of HHG being only possible with linearly polarized light. The efficiency and brightness of such gas-based harmonics is ultimately restricted by the need to keep laser intensities below the ionization threshold, a limitation that can be overcome by using plasmas. Theoretical [Sharma, P. et al, Phys Plasmas (2018)] and numerical [Chen, Z. Phys Rev E (2018)] analysis have shown that a bi-circular laser driver can also work in under- and over dense plasmas with apparently the same selection rules as in gases, i.e. every third harmonic is suppressed and adjacent harmonics have opposite helicity. Here we demonstrate using both fluid and kinetic (PIC) modelling that bi-circular HHG has a comparable efficiency to the HHG source driven by linearly polarized laser light reflected from or transmitted through a thin ionized foil target with JuSPARC-VEGA laser parameters (40mJ, 25fs, 1kHz).

P 20.6 Thu 15:30 b302

Ultrafast Polarization of an Electron Beam in Intense Bi-chromatic Laser Pulses — •Daniel Seipt[1,2], Dario Del Sorbo[3], Christopher P. Ridgers[4], and Alec G. R. Thomas[2]

— [1]Helmholtz-Institut Jena, Fröbelstieg 3, D-07743 Jena, Germany — [2]The Gérard Mourou Center for Ultrafast Optical Science, University of Michigan, Ann Arbor, MI-48109, USA — [3]High Energy Density Science Division, SLAC National Accelerator Laboratory, Menlo Park, CA-94025, USA — [4]York Plasma Institute, Department of Physics, University of York, York YO10 5DD, UK

Recent high-intensity laser-plasma experiments provided evidence for quantum radiation reaction effects due to hard photon emission. In this talk I will discuss the radiative spin-polarization of the electrons as a manifestation of quantum radiation reaction affecting the spin-dynamics. It is demonstrated that radiative polarization of high-energy electron beams can be achieved in collisions with PW class bichromatic laser pulses. We employ both a Boltzmann kinetic approach and a Monte-Carlo algorithm within the quasi-classical approximation of intense field QED to simulate the interaction. Aspects of spin dependent radiation reaction are addressed, where spin polarization leads to a measurable splitting of the energies of spin-up and spin-down electrons. Immediate consequences for extreme-intensity laser plasmas are discussed.

P 20.7 Thu 15:45 b302

X-ray assisted nuclear excitation by electron capture in plasmas generated by optical lasers — •Yuanbin Wu, Christoph H. Keitel, and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1,D-69117 Heidelberg, Germany

Nuclear excitation by electron capture (NEEC) is a resonant process in which electron recombination into an ion occurs with the simultaneous excitation of the nucleus. In this work we investigate theoretically x-ray assisted NEEC into inner-shell atomic holes in plasmas generated by strong optical lasers. This scenario involves intense x-ray radiation from an x-ray free electron laser (XFEL) to additionally produce inner-shell holes in the plasma ions, into which NEEC may occur. As a case study we consider the 4.85-keV transition starting from the 2.4 MeV ^{93m}Mo isomer that can release the stored excitation energy.

We find that, already at few hundred eV plasma temperature, the generation of inner-shell holes can allow optimal conditions for NEEC, otherwise reached for plasmas in thermodynamical equilibrium only at few keV [1]. The combination of XFELs and optical lasers is also advantageous as NEEC rates can be maximized at plasma temperatures where the photoexcitation rate remains low. Considering the combination of mJ-class optical laser and XFEL, the NEEC excitation number can reach ~ 1 depleted isomer per second and is competitive with scenarios recently envisaged at petawatt-class lasers [2].

[1] Y. Wu, C. H. Keitel, and A. Pálffy, arXiv:1910.05326.
[2] Y. Wu, J. Gunst, C. H. Keitel, and A. Pálffy, Phys. Rev. Lett. 120, 052504 (2018).

P 21: Helmholtz Graduate School 5

Time: Thursday 14:00–16:00 Location: b305

Invited Talk P 21.1 Thu 14:00 b305

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

For the investigation of turbulence activity in the shear- and scrape-off layer (SOL) of W7-X different diagnostics are used. Probe heads yield information on density- and temperature profiles and on turbulence rotation and radial electric field. Deeply in the SOL and the plasma edge correlation reflectometry measures turbulence spectra and the poloidal correlation length of dominant low k-turbulence.

The presentation intends to give an overview on turbulence phenomena at W7-X as there are e.g. quasi coherent modes which are observed close to the shear layer in the plasma edge. A decomposition of the coherence spectra allows to characterize them by a few turbulence components, only. Broad band turbulence extracted from those spectra is strongly suppressed in the vicinity of the shear layer supporting that low k-turbulence is torn apart in the shear region.

Furthermore, transient high frequency events in the range of 800 kHz - 1000 kHz are observed for certain magnetic configurations in the coherence spectra. They correlate with the observation of spikes in the diamagnetic energy and the plasma current.

P 21.2 Thu 14:30 b305

MHD simulations of ELM cycles in ASDEX Upgrade — •Andres Cathey Cevallos[1], Matthias Hoelzl[1], Michael Dunne[1], Guido Huijsmanns[2,3], and Sibylle Guenter[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]CEA, IRFM, Saint-Paul-Lez-Durance, France — [3]Eindhoven University of Technology, Eindhoven, The Netherlands

Edge Localized Modes (ELMs) in tokamaks cause severe concern for future devices like ITER. Large ELMs lead to an expulsion of hot plasma from the edge of the confined region to the tokamak plasma facing components in 0.1–1 milliseconds repetitively every 10–100 milliseconds.

Simulations of single ELM crashes with the non-linear 3D magnetohydrodynamic (MHD) code JOREK [GTA Huysmans and O Czarny, NF 47 7 2007] have been validated qualitatively and quantitatively showing good agreement against experimentally observed ELM crashes. Such simulations start with unstable plasma equilibria. To become predictive the entire ELM cycle needs to be simulated. Here, we present simulations of ELM cycles in ASDEX Upgrade and thorough comparisons against experimental measurements. The difficulties related to simulating ELM cycles, how they were overcome with JOREK, and further steps necessary for a better and more comprehensive understanding of ELM dynamics will be discussed at length.

P 21.3 Thu 14:55 b305

Gyrokinetic investigation of the ASDEX Upgrade I-mode pedestal — •Karl Stimmel, Alejandro Banon Navarro, Tim Happel, Daniel Told, Tobias Goerler, Elisabeth Wolfrum, James Peter Martin Collar, Rainer Fischer, Phillip A. Schneider, Frank Jenko, and The ASDEX Upgrade Team — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

Characterizing pedestal turbulence in the tokamak I-mode is a crucial step in understanding how particle and heat transport decouple during I-mode operation. This work models an ASDEX Upgrade I-mode discharge for the first time via linear and nonlinear gyrokinetic simulations with the GENE code. L-mode and I-mode regimes at two different pedestal locations are investigated. A microtearing mode which is not apparent in initial value linear L-mode simulations is found to dominate in I-mode simulations at both radial positions, and ion-scale instabilities are characterized for all four scenarios linearly. Computed nonlinear heat flux values approach experimental measurements with nominal input parameters in three of the four cases, and heat transport is found to be dominated by ion-scale electrostatic turbulence. Electrostatic potential oscillation frequencies, as well as potential-temperature and potential-density crossphases are compared linearly and nonlinearly, and agreement is found at wavenumber ranges corresponding with peaks in the simulated heat flux spectra at one radial position for L-mode and I-mode.

P 21.4 Thu 15:20 b305

Classification of tokamak plasma confinement states with convolutional recurrent neural networks — •Francisco Matos[1], Vlado Menkovski[2], Federico Felici[3], Alessandro Pau[3], Frank Jenko[1], The TCV Team[4], and The Eurofusion MST1 Team[5] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Eindhoven University of Technology, Eindhoven, Netherlands — [3]Ecole Polytechnique Federale de Laussane, Swiss Plasma Center, Switzerland — [4]See author list of S. Coda et al 2019 Nucl. Fusion 59 112023 — [5]See author list of B. Labit et al., 2019 Nucl. Fusion 59 086020

During a tokamak discharge, the plasma can vary between different confinement regimes: Low (L), High (H) and, in some cases, a temporary (intermediate state), called Dithering (D). In addition, while the plasma is in H mode, Edge Localized Modes (ELMs) can occur. The automatic detection of changes between these states, and of ELMs, is important for tokamak operation. Motivated by this, and by recent developments in Deep Learning (DL), we developed and compared two methods for automatic detection of the occurrence of L-D-H transitions and ELMs, applied on data from the TCV tokamak. These methods consist in a Convolutional Neural Network (CNN) and a Convolutional Long Short Term Memory Neural Network (Conv-LSTM). We measured our results with regards to ELMs using ROC curves and Youden's score index, and regarding state detection using Cohen's Kappa Index.

P 21.5 Thu 15:45 b305

Dynamically assisted nuclear fusion — •Ralf Schützhold[1,2,3] and Friedemann Queisser[1,2,3] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — [2]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — [3]Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, Duisburg 47057, Germany

We consider deuterium-tritium fusion as a generic example for general fusion reactions. For initial kinetic energies in the keV regime, the reaction rate is exponentially suppressed due to the Coulomb barrier between the nuclei, which is overcome by tunneling. Here, we study whether the tunneling probability could be enhanced by an additional electromagnetic field, such as an x-ray free electron laser (XFEL). We find that the XFEL frequencies and field strengths required for this dynamical assistance mechanism should come within reach of present-day or near-future technology.

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