Plasma Physics Division
Fachverband Plasmaphysik (P)

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Overview of Invited Talks and Sessions

(Lecture rooms b302 and b305; Poster Empore Lichthof)

Invited Talks

P 2.1	Mon	11:00–11:30	b305	**Mid-infrared cavity enhanced absorption spectroscopy of gas and surface species** — •Jean-Pierre van Helden, Norbert Lang, Andy Nave, Jürgen Röpcke
P 3.1	Mon	14:30–15:00	b302	**Advances in Laser Manipulation of Dusty Plasmas** — •Jan Schablinski, Frank Wieben, Dietmar Block
P 4.1	Mon	14:30–15:00	b305	**Impact of electron attachment processes on nonthermal plasmas** — •Jürgen Meichsner, Sebastian Nemschokmichal, Robert Tschiersch, Thomas Wegner
P 6.1	Tue	11:00–11:30	b302	**ns-Pulsed Micro-Plasmas at Atmospheric Pressures** — •Uwe Czarnetzki
P 7.1	Tue	11:00–11:30	b305	**Erste Ergebnisse an Wendelstein 7-X** — •Hans-Stephan Bosch, W7-X Team
P 8.1	Tue	14:30–15:00	b302	**Nanometer-scale characterization of laser-driven plasmas, compression, shocks and phase transitions, by coherent small angle x-ray scattering** — •Thomas Kluge, Melanie Rödel, Alexander Pelka, Emma McBride, Luke Fletcher, Christian Rödel, Siegfried Glenzer, Michael Bussmann, Ulrich Schramm, Thomas Cowan
P 9.1	Tue	14:30–15:00	b305	**Computer simulations of correlated fermions–from quantum plasmas to ultracold atoms and plasma-surface interaction** — •Michael Bonitz
P 13.1	Wed	11:00–11:30	b302	**Power exhaust by impurity seeding in fusion reactors** — •Matthias Bernert, Felix Reimold, Arne Kallenbach, Bruce Lipschultz, Ralph Dux, Marco Wischmeier, the ASDEX Upgrade team, the EUROfusion MST1 Team
P 17.1	Wed	14:30–15:00	b305	**Plasma measurement and control: challenges and recent advances** — •Timo Gans
P 21.1	Thu	11:00–11:30	b302	**The behavior of helium in fusion plasmas** — •Athina Kappatou, Rachael M. McDermott, Clemente Angioni, Thomas Pütterich, Ralph Dux, Michael G. Dunne, Rudolf Neu, Alexander Lebschy, Eleonora Viezzer, Marco Cavedon, the EUROfusion MST1 Team, the ASDEX Upgrade Team
P 21.2	Thu	11:30–12:00	b302	**Energy and Particle Core Transport in Tokamaks and Stellarators compared** — •Marc Beurskens, Clemente Angioni, Craig Beidler, Andreas Dinklage, Golo Fuchert, Matthias Hirsch, Thomas Puetterich, Robert Wolf
P 22.1	Thu	11:00–11:30	b305	**Fluid-kinetisches Hybrid Modell für Plasmarandtransport in He-Plasma am Stellarator Wendelstein 7-X** — •Michael Rack, Detlev Reiter, Felix Hasenbeck, Yuhe Feng, Petra Börner
P 24.1	Thu	14:30–15:00	b305	**Design and characteristics of the COST Reference Microplasma Jet for bio-medicine** — •Judith Golda, Julian Held, Volker Schulz-von der Gathen

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	**Artificial gauge fields and topology with ultracold atoms in optical lattices** — •Monika Aidelsburger
SYAD 1.2	Tue	11:30–12:00	e415	**Many-body physics with impurities in ultracold quantum gases** — •Fabian Grusdt
SYAD 1.3	Tue	12:00–12:30	e415	**How to determine the handedness of single molecules** — •Martin Pitzer
SYAD 1.4	Tue	12:30–13:00	e415	**Quantum systems under gravitational time dilation** — •Magdalena Zych

Sessions

P 1.1–1.5	Mon	11:00–13:05	b302	**Helmholtz Graduate School for Plasma Physices I**
P 2.1–2.7	Mon	11:00–13:10	b305	**Plasma Diagnostics I**
P 3.1–3.5	Mon	14:30–16:10	b302	**Dusty Plasmas I**
P 4.1–4.6	Mon	14:30–16:35	b305	**Plasma Technology**
P 5.1–5.32	Mon	16:30–19:00	Empore Lichthof	**Poster Session- Helmholtz Graduate School for Plasma Physics**
P 6.1–6.6	Tue	11:00–12:55	b302	**Low temperature plasmas I**
P 7.1–7.6	Tue	11:00–12:55	b305	**Magnetic Confinement I**
P 8.1–8.9	Tue	14:30–17:00	b302	**Laser Plasmas I**
P 9.1–9.7	Tue	14:30–16:40	b305	**Theory and Modelling I**
P 10.1–10.13	Tue	16:30–19:00	Empore Lichthof	**Poster Session- Dusty Plasmas**
P 11.1–11.3	Tue	16:30–19:00	Empore Lichthof	**Poster Session- Plasma Wall Interaction**
P 12.1–12.10	Tue	16:30–19:00	Empore Lichthof	**Poster Session: Magnetic Confinement**
P 13.1–13.4	Wed	11:00–12:15	b302	**Plasma Wall Interactions**
P 14.1–14.5	Wed	11:00–12:25	b305	**Dusty Plasmas II**
P 15	Wed	12:30–13:30	b305	**Mitgliederversammlung Fachverband Plasmaphysik**
P 16.1–16.9	Wed	14:30–16:55	b302	**Theory and Modelling II**
P 17.1–17.6	Wed	14:30–16:35	b305	**Plasma Diagnostics II**
P 18.1–18.4	Wed	16:30–19:00	Empore Lichthof	**Poster Session- Plasma Technology**
P 19.1–19.6	Wed	16:30–19:00	Empore Lichthof	**Poster Session- Laser Plasmas**
P 20.1–20.28	Wed	16:30–19:00	Empore Lichthof	**Poster Session- Low Temperature Plasmas**
P 21.1–21.5	Thu	11:00–12:55	b302	**Magnetic Confinement II**
P 22.1–22.7	Thu	11:00–13:10	b305	**Theory and Modelling III**
P 23.1–23.5	Thu	14:30–16:25	b302	**Helmholtz Graduate School for Plasma II**
P 24.1–24.6	Thu	14:30–16:25	b305	**Low Temperature Plasmas II**
P 25.1–25.18	Thu	16:30–19:00	Empore Lichthof	**Poster Session- Theory and Modelling**
P 26.1–26.21	Thu	16:30–19:00	Empore Lichthof	**Poster Session-Plasma Diagnostics**
P 27.1–27.7	Fri	11:00–12:45	b305	**Low Temperature Plasmas III**

Annual General Meeting of the Plasma Physics Division

Wednesday 12:30–13:30 b305

- Bericht
- Wahl
- Verschiedenes

P 1: Helmholtz Graduate School for Plasma Physices I

Time: Monday 11:00–13:05 Location: b302

Fachvortrag P 1.1 Mon 11:00 b302

Non-linear simulations of ELMs in ASDEX Upgrade — •Alexander Lessig[1], Matthias Hoelzl[1], François Orain[1], Sibylle Guenter[1], Marina Becoulet[2], Guido Huysmans[2], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstrasse 2, 85748 Garching, Germany — [2]CEA-IRFM, Cadarache, 13108 Saint-Paul-Lez-Durance, France

Large edge localized modes (ELMs) are a severe concern for the operation of future tokamak devices like ITER or DEMO due to the high transient heat loads induced on divertor targets and wall structures. It is therefore important to study ELMs both theoretically and experimentally in order to obtain a comprehensive understanding of the underlying mechanisms which is necessary for the prediction of ELM properties and the design of ELM mitigation systems.

Using the non-linear MHD code JOREK, we have performed first simulations of full ELM crashes in ASDEX Upgrade, taking into account a large number of toroidal Fourier harmonics. The evolution of the toroidal mode spectrum has been investigated. In particular, we confirm the previously observed non-linear drive of linearly subdominant low-n components in the early non-linear phase of the ELM crash. Preliminary comparisons of the simulations with experimental observations regarding heat and particle losses, pedestal evolution and heat deposition patterns are shown. On the long run we aim at code validation as well as an improved understanding of the ELM dynamics and possibly a better characterization of different ELM types.

Fachvortrag P 1.2 Mon 11:25 b302

Study of TEM-ITG turbulence transitions using Poloidal Correlation Reflectometry at AUG — •Dmitrii Prisiazhniuk[1,2], Andreas Krämer-Flecken[3], Garrard Conway[1], Peter Manz[1], Tim Happel[1], Ulrich Stroth[1,2], and The ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching, Germany — [2]Physik-Department E28, Technische Universität München, 85748 Garching,Germany — [3]Institut für Energieforschung - Plasmaphysik,Forschungszentrum Jülich, Association EURATOM-FZJ, 52425 Jülich, Germany

In several tokamaks a linear increase of the energy confinement time of Ohmic plasmas with the line averaged electron density has been reported. However, above a critical density the energy confinement time saturates. The corresponding regimes are named LOC and SOC, respectively. One hypothesis for the transition from LOC to SOC is a change in the dominant drive of the turbulence, from the trapped electron mode (TEM) to the ion temperature gradient (ITG). The main plasma parameters responsible for the change of the transport behaviour are still not identified. The recently upgraded Poloidal Correlation Reflectometer system in ASDEX Upgrade has been used to study the TEM-ITG transition. The system allows the study of turbulence characteristics (perpendicular & radial correlation length as well as the decorrelation time) and its interaction with the mean flow for a wide range of densities. The change of these parameters during the transition from TEM to ITG turbulence will be presented and the role of quasi-coherent structures will be discussed.

Fachvortrag P 1.3 Mon 11:50 b302

Deuterium Implantation into Tungsten at Low Temperature — •Johannes Bauer[1,2], Thomas Schwarz-Selinger[1], Martin Balden[1], and Klaus Schmid[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, D-85748 Garching — [2]Physik-Department E28, Technische Universität München, James-Franck-Str. 1, D-85748 Garching

To study the interaction of hydrogen isotopes with tungsten many experiments are conducted in linear plasma devices, which provide high enough hydrogen fluxes to supersaturate the tungsten sample and create defects such as blister. Here an alternative approach is presented. Instead of achieving a high deuterium concentration via high flux exposure, the sample temperature is reduced and the implantation energy of deuterium into tungsten is increased. The lower temperature associated with a reduction in diffusivity as well as the deeper implantation of deuterium lead to an increase of deuterium concentration within the implantation zone. Deuterium is stepwise implanted into polycrystalline tungsten up to a fluence of 1×10^{22} D/m^2 with an energy of 3.0 keV/D at a sample temperature of 134 K. The retained deuterium is measured in-situ by nuclear reaction analysis. For low fluence approximately 100 % of the implanted deuterium is retained, while for higher fluence the retention saturates. Close to the surface deuterium concentrations up to 64 % are reached. This leads to massive grain orientation dependent blistering with blister sizes between $100 - 1000$ nm at depths between $30 - 150$ nm. Besides the characterization of the blisters their influence on deuterium transport is studied.

Fachvortrag P 1.4 Mon 12:15 b302

High frequency magnetic fluctuations correlated with the inter-ELM pedestal recovery — •Florian M. Laggner[1], Elisabeth Wolfrum[2], Felician Mink[2], Marco Cavedon[2], Mike G. Dunne[2], Gregor Birkenmeier[2], Friedrich Aumayr[1], the ASDEX Upgrade Team[2], and the EUROfusion MST1 Team[2] — [1]Institute of Applied Physics, TU Wien, Fusion@ÖAW, Wiedner Hauptstr. 8-10, 1040 Vienna, Austria — [2]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

In H-mode plasmas, the maximum achievable pressure gradient at the plasma edge (pedestal) is usually set by an ideal MHD limit (peeling-ballooning), which if exceeded is leading to edge localised modes (ELMs), that relax the pedestal. However, the mechanisms setting the final pedestal shape (height and width) are not fully understood. This contribution focuses on the temporal evolution of the pedestal density and temperature profiles. After the maximum pre-ELM pedestal gradients are established a phase that is accompanied by the sharp onset of radial magnetic fluctuations with frequencies larger than 200 kHz is identified. During their presence the gradients of the edge electron density and temperature are clamped. The observed fluctuation frequencies scale with the minimum E × B velocity at the edge, that is estimated from neoclassical theory, indicating that the underlying modes are located in the steep gradient region. The toroidal mode number (n) of approximately 10 as well as the detection of the fluctuations on the high field side points in the direction of a MHD-type instability with low/high field side symmetric amplitude.

Fachvortrag P 1.5 Mon 12:40 b302

Experimental study of turbulence with the Ultra-fast swept Reflectometer in ASDEX Upgrade — •Anna Medvedeva[1,2,3,4], Christine Bottereau[3], Marco Cavedon[1], Frederic Clairet[3], Garrard D. Conway[1], Stephane Heureaux[2], Diego Molina[3], Antonio Silva[5], Ulrich Stroth[1,4], and AUG Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, D-85748 Garching — [2]Université de Lorraine, Nancy, France — [3]CEA, IRFM, St-Paul-Lez-Durance, France — [4]Physik-Department E28, Technische Universität München, Garching, Germany — [5]IST, Lisbon, Portugal

The experimental documentation of density fluctuations and their dependence on plasma parameters provides insights in the nature of turbulence and its driving parameters. In this contribution we will present measurements on the ASDEX Upgrade tokamak of the turbulence characteristics provided by an ultra-fast swept reflectometer with a time resolution as low as 1 μs. The focus will be on the dynamics in the transition from the Low (L) to the High (H) confinement mode which goes through an intermediate (I) phase where turbulence and shear flows strongly interact. I-phases for various plasma conditions are documented and the density gradient evolution is compared with the turbulence level. This investigation is carried out to discriminate between turbulence-driven zonal flows and neoclassically driven shear flows. In addition we present results on high frequency coherent modes appearing at the plasma edge during the H-mode and their link to MHD events (ELMs). The fast density profile dynamics during the ELM cycle is studied in relation to the local turbulence behavior.

P 2: Plasma Diagnostics I

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

Invited Talk P 2.1 Mon 11:00 b305

Mid-infrared cavity enhanced absorption spectroscopy of gas and surface species — •Jean-Pierre van Helden, Norbert Lang, Andy Nave, and Jürgen Röpcke — Leibniz Institute for Plasma Science and Technology (INP Greifswald), Greifswald

Understanding how plasmas interact with solid and liquid surfaces is of central importance in many fields such as microelectronics, materials and surface processing and in environmental and biomedical technologies. Improving process efficiency requires a comprehensive understanding of the kinetics of the transient intermediates involved at the plasma-substrate interface. The experimental approaches currently available provide an incomplete picture of plasma-surface interactions due to relatively low sensitivity. A further increase in sensitivity to detection limits of ppm down to ppt levels can be achieved by combining quantum and interband cascade lasers (QCLs and ICLs) with cavity-enhanced techniques based on optical cavities. The surface species can be detected by combining EC-QCLs with evanescent-wave attenuated-total-reflection (EW-ATR) spectroscopy. Cavity enhanced absorption spectroscopy can also be combined with ATR measurements. It was recognized early on in the development of cavity enhanced spectroscopies that if the internal reflection element in which the evanescent-wave is generated in ATR is included in the cavity it would greatly enhance ATR sensitivity. Here, the latest results in the development and applications to plasmas of mid-infrared cavity enhanced absorption spectroscopy of gas and surface species will be presented.

Fachvortrag P 2.2 Mon 11:30 b305

Charge-exchange from fast atoms in X-ray spectra — •Tobias Schlummer[1], Oleksandr Marchuk[1], Dave Schultz[2], Günter Bertschinger[1], Wolfgang Biel[1], and Detlev Reiter[1] — [1]Institut für Energie- und Klimaforschung, Plasmaphysik, Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Department of Physics, University of North Texas, Denton, TX 76203, USA

Charge exchange recombination (CX) is an important atomic process in astrophysical and laboratory plasmas. It describes the capture of a bound electron from an atom A by an ion X^z: $[X^z + A^q \rightarrow X^{z-1} + A^{q+1}]$. The newly formed ion X^{z-1} is preferentially in a highly exited state causing subsequent line emission. This line emission strongly depends on the final-state-resolved CX cross sections. However, the available theoretical data sets diverge significantly restricting the accuracy of spectroscopic measurements. Recently, a first experimental testing of the high energy final-state-resolved CX cross sections was performed at the TEXTOR tokamak using X-ray spectroscopy. The Rydberg series and the K_α spectrum of He-like argon were measured in the beam path of a 50 keV neutral hydrogen injector. The observed line enhancement caused by the interaction of H-like argon ions with the fast neutrals shows good agreement with the theoretical expectation based on one set of CX cross sections. The CX contributions from H($n = 1$) and H($n \geq 1$) atoms are clearly separable in the spectra. It is shown that the number of beam excited states is limited to principal quantum numbers $n \approx 10$ confirming recent models for fast atoms in fusion plasmas using parabolic quantum states.

P 2.3 Mon 11:55 b305

Dual frequency multichannel boxcar THz time domain spectroscopy measurements for the determination of the temporal evolution of the plasma density in pulsed low-pressure plasmas — •Steffen Marius Meier, Tsanko Vaskov Tsankov, Dirk Luggenhölscher, and Uwe Czarnetzki — Institut für Experimentalphysik V, Ruhr-Universität Bochum, 44780 Germany

THz time domain spectroscopy (THz TDS) is a non-invasive diagnostic method that allows the determination of the electron density and even the collision frequency. In contrast to microwave interferometry, THz TDS combines the advantages of a pico-second radiation pulse with a broad spectral width in the THz range ensuring better resistance to noise and vibrations. For the purpose of time-resolved measurements a standard THz TDS system was upgraded to improve the signal to noise ratio and the detection threshold. To achieve this, the detection method had to be changed. The lock-in frequency was increased from 7.6 kHz to 38 MHz to allow integration over more pulses within a shorter time. Additionally, a high performance lock-in amplifier is used that allows dual frequency multichannel boxcar measurements. Now measurements with less than 200 ps resolution are possible. The detection threshold was lowered to about $1 \cdot 10^{11}$ cm^{-3} or more precisely $1 \cdot 10^{12}$ cm^{-2} line integrated.

The current status of the project as well as results from temporally resolved plasma density measurements in inductively coupled magnetic multi-cusp argon and neon low-pressure discharges are presented.

P 2.4 Mon 12:10 b305

Laser four-wave mixing electric field strength measurements of filamentary DBDs — •Patrick Böhm[1], Manfred Kettlitz[2], Ronny Brandenburg[2], Hans Höft[2], and Uwe Czarnetzki[1] — [1]Institute for Plasma and Atomic Physics, Ruhr-University Bochum, 44801 Bochum, Deutschland — [2]INP Greifswald, 17489 Greifswald, Germany

In this contribution a four wave mixing technique based on Coherent anti-Stokes Raman spectroscopy (CARS) is used to measure electric field strengths in filamentary DBD discharges. The discharges are operated with a pulsed DC voltage in nitrogen at atmospheric pressure. For the investigation of the electric field an admixture of 5% - 10% of hydrogen is added as a tracer gas to ensure measurable signal intensities. The obtained measurement threshold is below the ignition field strength. Calibrating the system results in the determination of the absolute electric field strength in the measurements and also gives the breakdown voltage of the setup simultaneously. Current and voltage measurements ensure that the technique does not influence the discharges, i.e. that it is non-invasive. Alteration of the electric field has been observed during the internal polarity reversal and the breakdown process. In this case the major advantage over emission based methods is that this technique can be used independently from emission, e.g. in the pre-phase and in between two consecutive, opposite discharge pulses where no emission occurs at all. Therefore the CARS-based method could contribute to a better understanding of surface charge build-up, compensation and relaxation phenomena.

P 2.5 Mon 12:25 b305

Design, Setup, and Calibration of a Two-Wavelength Imaging Interferometer for the Diagnostics of Switching Arcs — •Jan Carstensen, Patrick Stoller, Sandor Simon, Philipp Jabs, and René Salzmann — ABB Corporate Research, Baden-Daettwil, 5405, Switzerland

Interferometric, schlieren and shadowgraphy methods, which are sensitive to the refractive index of a gas, are well established flow visualization techniques and have been applied to the diagnostics of electric arcs in high-voltage switching equipment, among many other things. In the vicinity of the arc the interpretation of the results is not straightforward, because the Gladstone-Dale relation, which connects the gas density with the measured refractive index, is not valid for temperatures above 2000 K, and ionization and dissociation processes have to be taken into account. This is a problem in particular during the zero crossing of the current –the moment when the current can be interrupted– since the hot arcing channel is in a non-equilibrium state, greatly complicating the modeling of the gas composition. One promising approach to tackle this problem is to introduce a second wavelength that allows a direct measurement of the electron density (see Refs. [1,2]). In this contribution we will present our design of a compact and flexible two-color imaging interferometer. The accuracy of the systems is proven using appropriate reference objects and first measurements of an electric arc embedded in a transonic gas flow are presented.

[1] K. Muraoka, et al., Jap. J. Appl. Phys., 19, L293 (1980)
[2] Y. Inada, et al., J. Phys. D, 47, 175201 (2014)

P 2.6 Mon 12:40 b305

investigation of gas parameters at high electrical field strength and under atmospheric gas pressure — •xingming fan, lothar naumann, mathias siebold, marcus kaspar, jörn dreyer, burkhard kämpfer, roland kotte, alejandro laso garcía, markus löser, ulrich schramm, and daniel stach — Helmhotz-Zentrum Dresden-Rossendorf

The laser test facility of the Helmholtz-Zentrum Dresden-Rossendorf for more precise measurements of different gas parameters in micro-

gap geometries with high electrical field up to 100kV/cm and at normal pressure will be presented. The light of 257nm is focused into the gas to initialize primary electrons by multiphoton ionization. The diameter of the focus is less than 20μm and the length is lesser than 500*m. The Townsend coefficient and electron drift velocity are presented for several gas mixtures. Simulations with the Garfield++ framework were performed for comparable geometries, gas mixtures and electrical fields. Experimental and simulation results will be discussed.

P 2.7 Mon 12:55 b305

Messung und Simulation des Kraftvektors auf Festkörperoberflächen beim Sputtern im Ionenstrahl — •Alexander Spethmann, Thomas Trottenberg und Holger Kersten — Institut für Experimentelle und Angewandte Physik der CAU zu Kiel

Der Sputter-Effekt wird üblicherweise durch die Sputterausbeute (Sputtering Yield), d.h. zerstäubte Teilchen pro einfallendes Teilchen, quantifiziert. Die experimentelle Bestimmung der Sputterausbeute kann üblicherweise durch Messung der Massenänderung des Sputtertargets, Änderung seiner Schichtdicke, Detektion der gesputterten Teilchen mit spektroskopischen Methoden oder durch dessen Einfang mittels Kollektorflächen erfolgen.

In diesem Beitrag hingegen werden Messungen der Kraft auf ein ebenes Messtarget mit einer neuartigen interferometrischen Sonde im Ionenstrahl einer Breitstrahlquelle vorgestellt. Teilchen aus dem Strahl, gesputterte Targetteilchen und reflektierte Teilchen führen zu einem auf das Messtarget wirkenden Kraftvektor. Das Messtarget ist am freien Ende eines einseitig eingespannten Biegebalkens fixiert, wobei durch Messung seiner Verbiegung mit zwei zueinander orthogonal angeordneten interferometrischen Sensoren der Kraftvektor zweidimensional und durch Drehung der Sonde im Strahl auch einfallswinkelabhängig bestimmt werden kann.

Die ermittelten Kraftvektoren werden mit denen durch einer auf SRIM basierten Simulation generierten verglichen. SRIM ist ein populärer Code zur Berechnung von atomaren Zweierstoßkaskaden.

P 3: Dusty Plasmas I

Time: Monday 14:30–16:10 Location: b302

Invited Talk P 3.1 Mon 14:30 b302

Advances in Laser Manipulation of Dusty Plasmas — •Jan Schablinski, Frank Wieben, and Dietmar Block — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Leibnizstraße 19, 24098 Kiel

Dusty plasmas allow to study fundamental processes of strongly coupled systems on a kinetic level. Besides the observation of self-excited processes, dust particles in a plasma can be effectively manipulated by several manipulation techniques. Laser manipulation is probably the most versatile tool to excite dynamical processes in dusty plasmas with negligible influence on the plasma conditions. The radiation pressure of intense laser beams was used in several experiments to excite lattice waves, oscillations of single particles or to study mach-cones, shear-waves and shear-flows in dusty plasmas [1] and thus contributed significantly to explore and explain the physics of dusty plasmas. Recently, optical traps for single particles were realized [2,3]. These traps are similar to well-known laser tweezers in colloidal suspensions [4] but have to overcome specific technical limitations in plasma experiments. This talk gives an overview of current laser manipulation tools and discusses their prospects and limitations for dusty plasma research.

[1] H. Thomsen, P. Ludwig, M. Bonitz, J. Schablinski, D. Block, A. Schella, and A. Melzer, J. Phys. D. Appl. Phys. 47, 383001 (2014). [2] V. Schneider and H. Kersten, Probl. At. Sci. Technol. 1, 164 (2013). [3] J. Schablinski, F. Wieben, and D. Block, Phys. Plasmas 22, 043703 (2015). [4] D.G. Grier, Nature 424, 810 (2003).

Fachvortrag P 3.2 Mon 15:00 b302

Phasenseparation in binären Staubgemischen — •Carsten Killer[1], Michael Himpel[1], André Melzer[1], Tim Bockwoldt[2], Stefan Schütt[2] und Alexander Piel[2] — [1]Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald — [2]IEAP, Christian-Albrechts-Universität zu Kiel

Experimente an staubigen Plasmen beschränken sich üblicherweise auf eine Sorte monodisperser Staubpartikel. Sind hingegen verschiedene Staubspezies vorhanden, können zusätzliche Phänomene, wie z.B. Phasenseparation, auftreten.

In diesem Beitrag werden Experimente zu binären Staubmischungen vorgestellt, bei denen zwei unterschiedlich große Partikelspezies in das Plasma eingebracht werden. Um die mit herkömmlichen Diagnostiken ununterscheidbaren Partikelsorten im Experiment getrennt voneinander beobachtet zu können, wurde eine auf Fluoreszenz-Farbstoffen basierende Messmethode entwickelt. In Mikrogravitationsexperimenten auf Parabelflügen zeigt sich, dass selbst bei kleinsten Größenunterschieden zwischen den Staubsorten eine Entmischung stattfindet. Solch ein Vorgang lässt sich mit negativen Diffusionskoeffizienten beschreiben, die hier experimentell bestimmt wurden.

P 3.3 Mon 15:25 b302

Neue Anwendung in der Kristallanalyse von Plasmakristallen — •Christopher Dietz, Benjaming Steinmüller und Markus Thoma — I. physikalisches Institut, JLU Gießen

Kristallanalyse komplexer Plasmen ist seit der Entdeckung des Plasmakristalls ein wichtiges Thema. Allerdings haben kürzliche Veröffentlichungen Nachteile des häufig verwendeten Bond Order Parameters aufgezeigt. Aus diesem Grund wurden neue und verbesserte Methoden vorgeschlagen. Allerdings ist es immer noch schwierig, quantitative Aussagen über die Kristallzusammensetzung zu treffen.

Eine einzigartige Eigenschaft von Experimenten mit komplexen Plasmen ist die Beobachtung jedes einzelnen Teilchens mit einer Kamera. Dies erlaubt die Verwendung von Analysemethoden, welche in der Molekulardynamik benutzt werden. Daher wird die Adaptive Common Neighbor Analyse für einen Plasmakristall angewendet und mit den auf Bond Order Parametern basierenden Methoden verglichen.

P 3.4 Mon 15:40 b302

Long term behavior of nanodust clouds in an argon plasma — •Sebastian Groth, Franko Greiner, Benjamin Tadsen, and Alexander Piel — IEAP, Christian-Albrechts-Universität, Kiel, Germany

The long term behavior of nanodust clouds in an argon plasma is investigated in-situ by means of kinetic single-wavelength Mie ellipsometry. Using suitable ellipsometry setups, the ellipsometric angles Ψ and Δ are determined. From these the time-resolved size parameter $x(t)$ as well as the complex refractive index N of the particle are obtained via Mie theory. The analysis method used in the process allows arbitrary evolutions of the particle size [1]. In combination with extinction measurements this enables the investigation of the size evolution of nanodust clouds in an argon plasma over a longer period.

It appears that the nanodust cloud continuously loses particles. In this contribution it is investigated to what extend the change of the ellipsometric angles Ψ and Δ during the cloud decay can be traced back to a change of the optical properties or the size of the nanoparticles.

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[1] Groth et al., J. Phys: D: Appl. Phys. **48**, 465203 (2015)

P 3.5 Mon 15:55 b302

Die Erzeugung von Kugelblitzen im Labor: eine Analyse der relevanten Parameter — •Herbert Boerner — Mainz

Die Natur von KB ist seit fast 200 Jahren ein ungelöstes Problem der atmospärischen Physik. Obwohl vor kurzem chinesischen Wissenschaftler eine Videoaufnahme eines solchen Objektes zusammen mit der Aufzeichnung seines Spektrums glückte, sind die physikalischen Eigenschaften von Kugelblitzen weiterhin unklar und es ist bisher nicht einmal ansatzweise gelungen, diese unter Laborbedingungen herzustellen.

Dieser Vortrag benutzt eine sehr gut dokumentierte Beobachtung von Kugelblitzen, um die Bedingungen einer kontrollierten Erzeugung einzugrenzen. Hierbei handelt es sich um das Ereignis vom 15.1.1994 in Neuruppin, Brandenburg, wo ein einzelner, extrem starker positiver Blitz eine Mehrzahl solcher Objekte erzeugt hat. Insgesamt liegen Beobachtungen von 11 dieser Objekte vor, die praktisch das ganze

Spektrum der bekannten Eigenschaften von Kugelblitzen abdecken. Ergänzend werden Fallsammlungen wie die von Brand aus dem Jahre 1923, dem Buch von Stenhoff von 1999 und aus dem Kompendium über Blitze von Uman herangezogen. Es zeigt sich, dass positive Wolke-Erde Blitze mit höherer Wahrscheinlichkeit Kugelblitze erzeugen als negative Blitze. Ein weiteres wichtiges Resultat ist, dass im Gegensatz zur oft geäußerten Vorstellung eine direkte Interaktion des Blitzkanals mit diesen Objekten definitiv nicht für die Erzeugung erforderlich ist. Die Konsequenz dieser Eigenschaften für eine Erzeugung im Labor werden diskutiert.

P 4: Plasma Technology

Time: Monday 14:30–16:35 Location: b305

Invited Talk P 4.1 Mon 14:30 b305

Impact of electron attachment processes on nonthermal plasmas — •Jürgen Meichsner, Sebastian Nemschokmichal, Robert Tschiersch, and Thomas Wegner — Institute of Physics, University of Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald, Germany

The electron capture by micro- and nanoparticles in dusty plasmas as well as the formation of negative ions in the volume and on surfaces in low and atmospheric pressure discharges influence the electron kinetics and discharge dynamics. Negative ion formation in single radio frequency oxygen discharges (CCP, ICP) at low pressure was experimentally investigated and their impact on discharge mode transition (low and high electronegativity) and plasma stability is discussed. Furthermore, the formation of negative secondary ions on the powered electrode of an asymmetric CCP is evaluated concerning their contribution to "pseudo secondary electrons" due to collision detachment of negative ions within the rf sheath. In the case of planar helium barrier discharges near atmospheric pressure with small oxygen admixture the influence of negative ions is investigated by laser photodetachment experiments and corresponding simulations. The photodetachment experiments show a change in breakdown voltage and discharge current when firing the laser during the pre-phase of the discharge, but not when firing during the discharge pulse. The comparison with the simulation implies that an additional formation of negative secondary ions on the negatively charged dielectric might be responsible for the large electronegativity in the discharge pre-phase.

Fachvortrag P 4.2 Mon 15:00 b305

Entladungsdynamik einer Mikrowellenplasmaquelle und ihr Einsatz bei Atmosphärendruck zur Dekontamination von Lebensmitteln im technologischen Maßstab — •Mathias Andrasch, Uta Schnabel, Klaus-Dieter Weltmann und Jörg Ehlbeck — Leibniz-Institut für Plasmaforschung und Technologie e.V.

Atmosphärendruck Mikrowellenplasmen werden seit Jahren für eine Vielzahl von verschiedensten Anwendungen eingesetzt. Dabei stellt die mikrobiologische Dekontamination sowohl von technischen als auch biologischen Oberflächen einen neuen Schwerpunkt dar. Um die eingesetzte Plasmaquelle und deren Applikation weiterzuentwickeln, ist jedoch ein grundlegendes Verständnis der dynamischen Mikrowellenplasmawechselwirkung notwendig. Zu diesem Zweck wurden experimentelle Studien mithilfe der Mikrowelleninterferometrie und einer phasenaufgelösten Charakterisierung des Reflexionsfaktors der Plasmaquelle durchgeführt. Diese Ergebnisse werden im ersten Teil des Vortrags in Kombination mit den Resultaten eines selbstkonsistenten, zeitaufgelösten Fluidmodells präsentiert, die einen fundamentalen Einblick in die Entladungsdynamik ermöglichen. Im zweiten Teil des Vortrags werden anschließend Details zu einem Technikumsversuch an einer industriellen Salatwaschstrecke vorgestellt. Mit Hilfe von Atmosphärendruckmikrowellenentladungen wurden im Rahmen dieses Großversuches 1,5 m^3 plasmaprozessiertes Wasser hergestellt zur mikrobiologischen Dekontamination von 45 kg Endiviensalat. Hierbei wurden Reduktionsfaktoren von bis zu zwei Größenordnungen der nativen Belastung erzielt.

Fachvortrag P 4.3 Mon 15:25 b305

Optical investigations of diffuse and constricted high-current vacuum arcs — •Kristoffer Ole Menzel[1], Thierry Delachaux[1], Ralf-Patrick Sütterlin[1], Markus Abplanalp[1], Ralf Methling[2], Steffen Franke[2], and Sergey Gortschakow[2] — [1]ABB Switzerland Ltd, Corporate Research Center, 5405 Baden-Dättwil, Switzerland — [2]INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald, Germany

Vacuum interrupters (VIs) are commonly used for high-current interruption at medium AC-voltages of 1kV-36kV. In this technology the arc is ignited between the separating contacts during current interruption and is sustained by ionized metal vapor originating from the electrode surfaces. For this reason the surface temperature distribution on the contacts is one of the critical measures for the performance of a breaker. The contribution presents experimental investigations of the surface temperature for the two typically occurring arc modes in VIs, namely the diffuse arc and the constricted arc. For this purpose different optical techniques, such as IR spectroscopy and pyrometry, have been employed. The investigations aim at answering fundamental questions as, e.g., the effect of externally applied magnetic fields on the electrode erosion. Therefore, simplified test geometries with electrodes made of either pure Cu or a CuCr compound were used. In order to describe the influence of the bulk plasma on the surface temperature, the core of the arc has been monitored by means of optical emission spectroscopy.

P 4.4 Mon 15:50 b305

Dekomposition von VOCs mit dielektrisch behinderten Oberflächenentladungen — •Michael Schmidt, Eric Timmermann, Ronny Brandenburg und Manfred Kettlitz — Leibniz-Institut für Plasmaforschung und Technologie e.V., Felix-Hausdorff-Straße 2, 17489 Greifswald

Der Einsatz nicht-thermischer Plasmen für die Dekomposition von flüchtigen organischen Stoffen (VOCs) ist für Modellgase im Laborversuch gut dokumentiert. Untersuchungen unter Bedingungen mit hohen relativen Gasfeuchten von über 50 % fehlen jedoch. Dieser Beitrag stellt die Anwendung einer dielektrisch behinderten Oberflächenentladung in Kombination mit einem nachgeschalteten Aktivkohlefilter für die Dekomposition von Methylethylketon und Butylacetat (typische Schadstoffe) vor. Die Ergebnisse systematischer Messungen unter Variation des Energieeintrages in das Plasma, der Kohlenwasserstoffkonzentration und des Wassergehaltes werden präsentiert. Der Einfluss der Luftfeuchtigkeit auf die durch das Plasma induzierten chemischen Prozesse und die Funktion des Aktivkohlefilters wird diskutiert. Mittels FTIR-Spektroskopie und Gaschromatografie werden die Reaktionsprodukte qualitativ und quantitativ analysiert. Auf Basis der Kohlenstoffbilanz und der Mineralisation wird der Oxidationsprozess der Geruchsstoffe bewertet.

P 4.5 Mon 16:05 b305

Vergleich eines numerischen und analytischen Modells zur Simulation der Modenausbreitung in einem Mikrowellenplasma — •Daniel Szeremley[1], Thomas Mussenbrock[1], Ralf Peter Brinkmann[1], Marc Zimmermanns[2], Ilona Rolfes[2] und Denis Eremin[1] — [1]Ruhr-Universität Bochum, Lehrstuhl für Theoretische Elektrotechnik, Germany — [2]Ruhr-Universität Bochum, Lehrstuhl Hochfrequenzsysteme, Germany

Auf Grund ihrer besonderen Eigenschaften sind Mikrowellenentladungen ein wichtiges Werkzeug für die Beschichtungstechnik. Insbesondere die Möglichkeit, durch eine zusätzliche Bias-Spannung Ionen Energieverteilungsfunktionen vor Substraten über einen großen Bereich nahezu frei einstellen zu können, macht diese Entladungen zu leistungsstarken Werkzeugen zur Abscheidung nanostrukturierter Funktionsschichten. Eine weitreichende Analyse der Moden und Ausbreitungseigenschaften elektromagnetischer Wellen in einem Plasma entlang einer Antenne ist von besonderem Interesse. Diese Informationen sind notwendig, um einen Plasmareaktor den Ansprüchen der jeweiligen Anwendung optimal anpassen zu können. In diesem Beitrag werden numerische Simulationsergebnisse einer Mikrowellenentladung entlang der Plasmaline mit einem analytischen Modell vergleichen. Im Mittelpunkt steht dabei die Charakterisierung der Moden, die sich entlang der Antenne ausbreiten k*onnen.

P 4.6 Mon 16:20 b305

Modellierung der CO_2-Dissoziation in dielektrisch behinderten Entladungen — •Markus M. Becker[1], Srinath Ponduri[2],

Richard Engeln[2] und Detlef Loffhagen[1] — [1]INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald — [2]Technische Universität Eindhoven, P.O. Box 513, 5600 MB Eindhoven

Die Aufspaltung von Kohlendioxid in Niedertemperaturentladungen spielt unter anderem bei der Entwicklung erneuerbarer Kraftstoffe eine wichtige Rolle. Trotz intensiver Forschung auf dem Gebiet ist noch nicht vollständig geklärt, welche Dissoziationsprozesse in Entladungsplasmen vorwiegend stattfinden und wie diese effizient genutzt werden können. Zur theoretischen Beschreibung einer dielektrisch behinderten Entladung in CO_2, für die der Einfluss unterschiedlicher Entladungsparameter auf die CO-Ausbeute experimentell untersucht wurde [1], wird ein zeitabhängiges, räumlich eindimensionales Fluid-Modell vorgestellt. Neben einer Untersuchung der generellen Entladungseigenschaften wird analysiert, welchen Beitrag Elektronenstoßdissoziation, dissoziatives Attachment, dissoziative Rekombination und Vibrationsanregung zur Aufspaltung von CO_2 leisten. Es wird gezeigt, dass die Elektronenstoßdissoziation in der betrachteten Entladungskonfiguration dominiert. Eine gute Übereinstimmung mit der gemessenen CO-Dichte und Energieeffizienz wird durch Berücksichtigung der Dissoziation über die elektronische Anregung bei 7.0 eV erreicht.

Die Arbeiten wurden durch die DFG im Rahmen des SFB-TRR 24 sowie unter dem Geschäftszeichen LO 623/3-1 unterstützt.

[1] F. Brehmer *et al.*, *J. Appl. Phys.* **116** (2014) 123303

P 5: Poster Session- Helmholtz Graduate School for Plasma Physics

Time: Monday 16:30–19:00 Location: Empore Lichthof

P 5.1 Mon 16:30 Empore Lichthof

Experimental investigation of interactions between ICRF wave fields and SOL plasma turbulence with B-dot, Langmuir, and MHD probes. — •Guillermo Suarez Lopez[1], Roman Ochoukov[1], Jean-Marie Noterdaeme[1,3], Volodymyr Bobkov[1], Helmut Faugel[1], Helmut Fünfgelder[1], and Hartmut Zohm[1,2] — [1]Max-Planck-Institut fürPlasmaphysik, 85748 Garching, Germany. — [2]Ludwig Maximilians University of Munich, Germany — [3]Ghent University, Belgium.

EM waves at the ion cyclotron range of frequencies (ICRF) are used successfully to heat magnetized fusion plasmas. In order to ensure good ICRF wave coupling, ICRF antennas must be placed close to the scrape-off layer (SOL) plasma. A series of toroidally distributed B-dot probes was installed on the LFS of the ASDEX Upgrade Tokamak in order to study ICRF wave fields (10-50 MHz). Initial results in ICRF heated H-mode plasmas, reveal a strong turbulent component which is thought to be due to plasma filaments. It is unclear, how much of this turbulent signal is generated by filaments in the vicinity of the probes, i.e. local turbulence, in comparison with turbulence generated at the ICRF active antennas which are further apart and would point to global turbulence. In order to decouple these spatial scales, several sets of Langmuir and MHD probes will be used. Langmuir probes detect local plasma density changes due to Edge Localized Modes (ELMs) and by magnetic field mapping, their signal can be correlated to the B-dot probes. On the other hand, MHD probes quantify global magnetic instabilities and will be used to support the analysis.

P 5.2 Mon 16:30 Empore Lichthof

Construction and characterization of a new high current ion source for research of impact of hydrogen irradiation on wall materials for use in nuclear fusion reactors — •Rodrigo Arredondo Parra[1,2], Martin Oberkofler[1], Klaus Schmid[1], Arno Weghorn[1], and Rudolf Neu[1,2] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technische Universität München, Garching, Germany

The HSQ (HochStromQuelle) is a high current DuoPIGatron type ion source used for research in surface properties of wall materials for nuclear fusion reactors. The existing HSQ-I will be replaced by the conceptually identical HSQ-II, currently under construction. Varying the acceleration potential and optimizing gas inflow and beam focusing grid voltage, ion currents before the deflecting magnet between 10 and 875 μA were reached for acceleration voltages of 0.7 to 8 kV. The ion beam footprint will be characterized, and ion optics will be installed before and after the deflecting magnet, capable of bending 10 keV Ar. A monoenergetic beam of a single species (e.g. D_3^+) will finally be used for irradiation of samples in the separate implantation chamber at a base pressure of 10^{-8} mbar. The energy of the impinging particles ranges from 200 eV/D to several keV/D. Fluxes of 10^{15} D/cm^2/s to the target are expected. The temperature of the sample is varied via electron impact heating and the sample weight can be assessed in situ by means of a magnetic suspension balance.

P 5.3 Mon 16:30 Empore Lichthof

Kinetic simulation of parallel electron heat flux in scrape-off layer — •menglong zhao[1,2], alex chankin[1], and david coster[1] — [1]Max-Planck-Institut für Pasmaphysik, Boltzmannstraße 2, 85748 Garching bei München, Germany — [2]Technische Universität München, 80333 München, Germany

Parallel electron heat flux on open field lines is studied with the 1D2V kinetic Vlasov-Fokker-Planck (VFP) code KIPP [1-3]. In order to assess the importance of kinetic effects on the scrape-off layer heat transport in a systematic way, a series of self-similar cases with the stagnation point and one target, logical sheath condition, parabolic ion velocity profiles reaching ion sound speed at the target and 100% recycling of neutrals were run, from which the electron temperature profile and electron parallel heat flux are compared with those from classical fluid model. It shows that, for high collisional plasma parallel conductive electron heat flux is highly consistent with Spitzer-Harm theory[4]. With decreasing collisionality, it is deviating increasingly from the classical theory showing limited heat flux upstream and flux enhancement downstream due to non-local effect. In addition, electron heat transmission coefficient γe varies much with collisionality. Thermal force coefficient is studied as well. It shows consistency with deviation of heat flux, lower than 0.71 upstream and higher downstream for low collisional plasma, however consistent with classical value for high collisional plasma as expectation. Kinetic corrections to electron heat conduction coefficient, heat transmission coefficient and thermal force coefficient are needed for fluid model, which could be done with KIPP.

P 5.4 Mon 16:30 Empore Lichthof

Piezoelectric Valve for Massive Gas Injection in ASDEX Upgrade — •Mathias Dibon[1,2], Albrecht Herrmann[1], Klaus Mank[1], Vitus Mertens[1], Rudolf Neu[1,2], Gabriella Pautasso[1], and Bernhard Ploeckl[1] — [1]Max-Planck-Institute for Plasmaphysics, Boltzmannstr. 2, 85748 Garching, Germany — [2]Technical University Munich, Boltzmannstr. 15, 85748 Garching, Germany

A sudden loss of plasma temperature can cause a disruption, which poses a significant problem for current Tokamaks and future fusion devices. Hence, mitigating forces and thermal loads during disruptions is important for the integrity of the vessel and first wall components. Therefore, high speed gas valves are used to deliver a pulse of noble gas onto the plasma, which irradiates the thermal energy quickly, avoiding localized heat loads and mechanical stress due to induced currents. A new design for such a valve is currently under development. The valve plate is driven by two piezoelectric stack actuators. The stroke of the actuators (0.07 mm) is amplified by a monolithic titanium frame and reaches 2 mm. The frame also serves as spring to pre-load the actuators. In the idle state, it also presses the conical valve plate into the seal, closing the gas chamber (42 cm^3). The actuators accelerate the stem and the valve plate until it is fully opened after 2 ms. The orifice of the valve has a diameter of 14 mm. This allows a peak mass flow rate of the gas up to $8 * 10^4 \ \frac{Pa*m*}{s}$ after 1.8 ms and an average mass flow rate of $2 * 10^4 \ \frac{Pa*m*}{s}$ over the evacuation time of 10 ms. Therefore, one valve would be sufficient to deliver the required amount of gas to mitigate disruptions at ASDEX Upgrade.

P 5.5 Mon 16:30 Empore Lichthof

ICRF induced edge plasma convection in ASDEX Upgrade — •Wei Zhang[1,2,3], Yuehe Feng[1], Tilmann Lunt[1], Jean-Marie Noterdaeme[1,2], Jonathan Jacquot[1], Laurent Colas[4], David Coster[1], Roberto Bilato[1], Volodymyr Bobkov[1], Roman Ochoukov[1], and ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma physics, Garching/Greifswald, Germany — [2]University of Ghent, Ghent, Belgium — [3]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, P. R. China — [4]CEA, IRFM,

Saint-Paul-Lez-Durance, France

Ion Cyclotron Range of Frequency (ICRF) heating is one of the main auxiliary plasma heating methods in tokamaks. It relies on the fast wave to heat the plasma. However the slow wave can also be generated parasitically. The parallel electric field of the slow wave can induce large biased plasma potential through sheath rectification. The rapid variation of this rectified potential across the magnetic field can cause significant $E \times B$ convection in the Scrape-Off Layer (SOL). The ICRF induced convection can affect the SOL density, influence the ICRF power coupling and enhance the strength of plasma-wall interactions. To explore these physics, we will not only show the experimental evidences in ASDEX Upgrade, but also present the associated simulation results with the 3D edge plasma fluid code EMC3-Eirene. Further simulations via combination of EMC3-Eirene and a sheath code SSWICH in an iterative and quasi self-consistent way can give good predictions for future experiments.

P 5.6 Mon 16:30 Empore Lichthof

Deuterium accumulation in tungsten at high fluences — •Mikhail Zibrov[1,2], Martin Balden[1], Kirill Bystrov[2], Thomas Morgan[2], and Matej Matej[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, D-85748 Garching, Germany — [2]FOM Institute DIFFER, De Zaale 20, 5612 AJ Eindhoven, The Netherlands

The data on the deuterium (D) retention in tungsten (W) at high fluences ($\geq 10^{27}$ D/m^2) are scarce and the existing results are contradictory. Since retention in W is known to be flux–dependent, the laboratory experiments addressing this issue should be carried out in reactor–relevant conditions (high fluxes of low–energy ions).

In this work the samples made of polycrystalline W were exposed to D plasmas in the linear plasma generator Pilot–PSI at temperatures ranging from 360 K to 1140 K to fluences in the range of $0.3 - 8.7 \times 10^{27}$ D/m^2. It was observed that at exposure temperatures of 360 K and 580 K the D retention was only slightly dependent on the ion fluence. In addition, the presence of blister–like structures was found after the exposures, and their density and size distributions were also only weakly dependent on the fluence. In the case of exposure at 1140 K no surface modifications of the samples after plasma exposure were detected and the concentrations of retained D were very small. At all temperatures used the total amounts of retained D were smaller compared to those obtained by other researchers at lower ion flux densities, which indicates that the incident ion flux may play an important role in the total D retention in W.

P 5.7 Mon 16:30 Empore Lichthof

Deuterium permeation measurements on tungsten using ion-beam-based detection — •Stefan Kapser[1,2], Armin Manhard[1], and Udo von Toussaint[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [2]Physik-Department, Technische Universität München, James-Franck-Str. 1, 85748 Garching, Germany

Tungsten (W) is promising for the inner wall of a future fusion reactor, where it will be exposed to high fluxes of hydrogen (H) isotopes. Knowledge of their diffusion in W is important for safety and economic considerations, particularly concerning tritium. A common method to investigate H diffusion in metals are permeation experiments. Typically, gas loading and mass-spectrometric detection are used. Information about the diffusion can be gained from the temporal evolution of the permeation flux, whose magnitude is determined by the permeability (product of diffusivity and solubility). However, for low-permeability metals, the permeation flux can be unmeasurably small. For W this is the case near room temperature. We present a method that circumvents this problem. It is an improved version of experiments on nickel and stainless steel [1,2]. The W is exposed to deuterium (D) plasma on one side and the permeating D is accumulated in a getter on the other side. A cover prevents D gettering from the gas phase. The amount in the getter is analysed by the nuclear reaction D(^{3}He,p)^{4}He.

[1] W. Möller, B.M.U. Scherzer and R. Behrisch, Nucl. Instrum. Methods, 168 (1980) 289 [2] P. Børgesen, B.M.U. Scherzer and W. Möller, J. Appl. Phys., 57, 2733 (1985)

P 5.8 Mon 16:30 Empore Lichthof

Status of the new thermal He-beam diagnostic for electron density and temperature measurements in the scrape-off layer of ASDEX Upgrade — •Michael Griener[1,3], Elisabeth Wolfrum[1], Thomas Eich[1], Albrecht Herrmann[1], Volker Rohde[1], Oliver Schmitz[2], Ulrich Stroth[1,3], and the ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]Engineering Physics Department, University of Wisconsin-Madison, USA — [3]Physik Department E28, Technische Universität München, 85748 Garching, Germany

In a nuclear fusion device a significant fraction of power is exhausted across the last closed flux surface into the so-called "scrape-off layer". In order to study the transport dynamics to (a) the divertor via parallel heat flux and (b) to the wall via filaments, a diagnostic for the determination of n_e and T_e with high spatial and temporal resolution is required.

These data should be provided by the new thermal He-beam diagnostic, where helium is injected into the plasma by a piezo valve. The principle of this diagnostic is the measurement of line resolved emission intensities of the excited helium. The calculated line intensity ratios of two singlet lines combined with a collisional radiative model then lead to n_e values, whereas singlet-triplet ratios yield T_e values.

The principle of the He-diagnostic as well as emission profiles of several He I transitions measured during the campaign 2015/2016 will be shown. First calculated n_e and T_e profiles will be compared to data from the lithium beam and the Thomson scattering diagnostic.

P 5.9 Mon 16:30 Empore Lichthof

Mode number determination of ELM associated phenomena by improved phase fitting of magnetic pick-up coils — •Felician Mink[1,2], Elisabeth Wolfrum[1], Florian Laggner[1], László Horváth[3], Ulrich Stroth[1,2], and The ASDEX Upgrade Team[3] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [2]Physik Department, E28, TUM, 85748 Garching, Germany — [3]Budapest University, Pf 91, H-1521 Budapest, Hungary

Edge localized modes (ELMs) occur as repetitive bursts of magnetohydrodynamic (MHD) activity in high-confinement regimes of tokamak fusion plasmas. As ELMs lead to a sudden release of pedestal stored energy they might cause intolerable high heat fluxes onto the divertor target plates in future fusion devices like ITER. Therefore, it is necessary to get a better understanding of ELM triggering mechanism.
It has been reported from different tokamaks that during the inter-ELM phase mode-like MHD activities that might play an important role for the ELM onset can be observed with defined toroidal mode numbers.
Here the method of determining the toroidal mode numbers of such coherent fluctuations on ASDEX Upgrade from magnetic pick-up coils is reviewed. A significant improvement of the determination of the mode numbers is achieved by ELM-synchronization and consideration of intrinsic coil phases. First results for mode numbers of ASDEX Upgrade inter-ELM oscillations and their connection to kinetic profiles are given.

P 5.10 Mon 16:30 Empore Lichthof

Power loads in the limiter phase of Wendelstein 7-X — •Holger Niemann[1], Marcin Jakubowski[1], Thomas Sunn Pedersen[1], and Glen Wurden[2] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Deutschland — [2]Los Alamos National Laboratory, Los Alamos, USA

Wendelstein 7-X (W7-X), an advanced stellarator with five-fold symmetry, will start its initial plasma operation phase(OP1.1) in December 2015. In OP1.1 the plasma-wall interaction is realized with 5 graphite limiters installed on the inboard side of the plasma vessel, which should efficiently intercept >99% of the convective plasma heat load at the plasma edge with the chosen magnetic configuration. Assuming an even distribution of power loads among all 5 limiters, discharges with 2 MW of ECRH heating power could be run for up to a second. Calculations shows typical three separate helical magnetic flux bundles of different connection length in the order of a few tens of meters. These form 3-D structure of magnetic footprints results in localized peaks in the limiter power deposition patterns. The heterogenous temperature distribution pattern will be investigated with two IR cameras. The heat flux density will be evaluated with the THEODOR code from evolution of the surface temperature data. Together with two sets of Langmuir probes in module 5 this provides enough data to resolve experimentally different channels of heat transport towards the limiter in OP1.1 plasmas. Additionally, the obtained data will be compared against the output of EMC3-Eirene calculations to identify the channels of energy transport at the plasma boundary in the first operation phase of W7-X.

P 5.11 Mon 16:30 Empore Lichthof

Development of Real Time System Imaging Software for the Protection of Plasma Facing Components(PFCs) in Wendelstein 7-X — Adnan Ali[1], •Marcin Jakubowski[1], Thomas Sunn Pedersen[1], Alexander Rodatos[1], and Henri Greuner[2] — [1]Max-Planck-Institute for Plasma Physics, Greifswald,Germany — [2]Max-Planck-Institute for Plasma Physics, Garching,Germany

One of the main aims of Wendelstein 7-X, an advanced stellarator in Greifswald, is the investigation of quasi-steady state operation of magnetic fusion devices, for which power exhaust is a very important issue. The predominant fraction of the energy lost from the confined plasma region will be removed by 10 so-called island divertors, which can sustain up to 10 MW/Sq-m. In order to protect the divertor elements from overheating and to monitor power deposition onto the divertor elements, 10 state-of-the-art infrared endoscopes will be installed at W7-X and software is under development for real-time analysis of automatic detection of the hot spots and other abnormal events. The pre-defined algorithms[2] designed for early detection of defects e.g. hotspots, surface layers and delaminations during the discharge are being implemented into the software acquiring the images from the infrared cameras and broadcast them to the main Discharge Control System(DCS). This allows for automatic control of the scenario of the discharge in order to assure safe operation of W7-X. The first online tests of the software will soon be performed at GLADIS in Garching.

P 5.12 Mon 16:30 Empore Lichthof

Numerical Study of the Connection Lengths for Various Magnetic Configurations in Wendelstein 7-X to Optimize the Heat Load on the Divertor — •Priyanjana Sinha, Hauke Hölbe, and Thomas Sunn Pedersen — Max Planck Institute of Plasma Physics ,Wendelsteinstraße 1, 17491 Greifswald

Fusion has the potential to play an important role as a future energy resource. It has the capacity to produce large-scale clean energy. The two main confinement concepts are the tokamak and the stellarator. The W7-X machine is based on stellarator principle and is using special form of coils to achieve steady-state plasma confinement.

Divertors are used in tokamaks and stellarator to control the exhaust of waste gases and impurities from the machine . The divertor concept of W7-X is a so-called island divertor. The island chain isolates the confinement core from regions where the plasma-wall interaction takes place.

The area of the divertor that receives the main part of the heat loads, the so-called wetted area, increases with the distance along the magnetic field from the outboard midplane to the divertor target. The connection length is relatively short in tokamaks with conventional divertors. In the stellarator island divertor, the connection length can be varied significantly, which should allow for optimization of the wetted area. We present here a numerical study of the achievable connection lengths in various W7-X configurations and discuss the possibilities for running dedicated experiments to understand the physics of what sets the wetted area.

P 5.13 Mon 16:30 Empore Lichthof

Neutralization of positive ions at metallic and dielectric plasma walls — •Mathias Pamperin, Franz Xaver Bronold, and Holger Fehske — Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany

The main loss channel for positively charged ions in bounded low temperature plasmas is the recombination of ions with the wall. It is often driven by Auger processes and thus accompanied by electron emission. The emission efficiency depends on the electronic structure of the wall and the ion. It is expected to be high in cases where resonant charge transfer initially creates a metastable relay state which then Auger deexcites releasing thereby an electron. For helium ions hitting metallic walls this two-step process leads to robust secondary electron emission due to wall recombination. If however resonant charge transfer is blocked, as it may happen for dielectric walls, secondary electron emission due to ions is much smaller. Secondary electrons result then solely from impacting metastable species produced in the discharge volume. With an eye on tailoring electron emission from the wall, we studied theoretically–using a semi-empirical Anderson-Newns model and nonequilibrium Green function techniques–the interaction of inert gas ions with dielectric and metallic surfaces. Our results demonstrate the importance of metastable relay states and may thus help to design wall materials with custom-made electron emission properties.

Supported by the DFG through CRC/Transregio TRR24 and the Federal State of Mecklenburg-Western Pomerania through the International Helmholtz Graduate School.

P 5.14 Mon 16:30 Empore Lichthof

A Monte-Carlo scheme for cross-polarization scattering of diffracting wave beams in random media. — •Lorenzo Guidi[1,2], Omar Maj[1], and Emanuele Poli[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technische Universität München, Numerical Methods for Plasmaphysics (M16), Garching, Germany

Asymptotic methods are widely used in studying the evolution of high frequency waves in plasmas. In this framework singularities in the configuration space can arise, and a phase-space representation of the model is one of the possible ways to overcome such difficulties; the result is a description of waves in terms of the kinetic wave equation. Fluctuations of the medium and consequent scattering phenomena can be taken into account, allowing the analysis of problems which are considered extremely relevant in the prediction of wave beam performances for the next-generation tokamak machines. The WKBeam code provides a numerical solution of the kinetic wave equation in the phase-space, taking into account random density fluctuations by means of a statistic average and assuming that scattering between different modes, i.e. cross-polarization scattering, can be neglected. The idea of this work is to include cross-polarization scattering phenomena into the WKBeam code, allowing simulations of a wider class of experimental scenarios. In order to obtain this, the Monte-Carlo scheme implemented in WKBeam is extended, providing a description of random jumps of both the refractive index (a continuous process) and the wave mode (a discrete process), due to fluctuations of the medium.

P 5.15 Mon 16:30 Empore Lichthof

Low-Z impurity transport studies using CXRS at ASDEX Upgrade — •Cecilia Bruhn, Rachael McDermott, Ralph Dux, Clemente Angioni, Volodymyr Bobkov, Athina Kappatou, Alexander Lebschy, Thomas Pütterich, Eleonora Viezzer, and the ASDEX Upgrade Team — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, D-85748 Garching, Germany

Impurities in fusion plasmas arise from many sources including the erosion of material from plasma facing components and the intentional injection of impurities for control of the radiation losses. With the charge exchange recombination spectroscopy (CXRS) diagnostics at ASDEX Upgrade (AUG) the density profiles of low-Z impurity species can be measured with high spatial and temporal resolution and can, thus, be used to investigate the transport of these impurities. Previous work on this topic at AUG has focused primarily on steady state profiles, which deliver the ratio of the diffusive and convective transport coefficients. However, from the time response of the density profiles after applying an external perturbation (e.g. a fast impurity puff) the convective and diffusive components of the transport can be separately determined. The work presented here aims to achieve this by an approach that is better suited to the limited time resolution of the CXRS diagnostics; namely, a sinusoidal modulation of the boron densities invoked by modulating the power from the ion cyclotron resonance frequency (ICRF) antennas. We will present the first measurements of the boron density modulation as well as the machine and plasma parameter dependencies of the boron response to the ICRF power.

P 5.16 Mon 16:30 Empore Lichthof

Critical beta of kinetic ballooning modes in simple geometry — •Ksenia Aleynikova, Alessandro Zocco, and Per Helander — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

In a fusion reactor, high density and plasma temperature are necessary to achieve favorable reaction conditions. This requires high plasma betas (the ratio of kinetic to magnetic pressure). However, at high betas, electromagnetic micro-turbulence due to the kinetic ballooning mode (KBM) instability can arise and generate anomalous losses of heat and particles. It is known that fluid magnetohydrodynamic (MHD) ballooning modes become linearly unstable when beta reaches a certain critical value (threshold). The same is expected for their kinetic counterparts - KBMs. Numerical simulations show that the critical beta for KBMs instability can be either higher or lower than the corresponding critical beta for MHD ballooning modes. Such discrepancy has not yet been understood. We consider the KBM as the electromagnetic correction of the ion temperature gradient (ITG) driven instability. An electromagnetic theory of ITG modes was developed in [A. Zocco et. al. P.P.C.F., 57(8), 2015] and the critical beta for their electromagnetic stabilization was derived, but kinetic ballooning modes were completely suppressed by diamagnetic effects. In this work, we first derive a new beta ordering for the electromagnetic theory of ITGs that

accommodates KBMs. Then, we derive a new analytical expression for the critical beta of KBMs and numerically verify our predictions with the gyrokinetic code GS2 [http://gs2.sourceforge.net]. Our theoretical results and numerical calculations are in a good agreement.

P 5.17 Mon 16:30 Empore Lichthof

Non-perturbative kinetic influences due to energetic particles on toroidicity-induced Alfvén eigenmodes — •Christoph Slaby, Axel Könies, and Ralf Kleiber — Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Deutschland

The resonant interaction of shear Alfvén waves with energetic particles is investigated numerically in tokamak and stellarator geometry using a non-perturbative magnetohydrodynamic-kinetic (MHD-kinetic) hybrid approach in the large-aspect-ratio approximation. The focus lies on toroidicity-induced Alfvén eigenmodes (TAEs), which are most easily destabilized by a fast-particle population in fusion plasmas.

While the background plasma is treated within the framework of ideal-MHD theory, the drive of the fast particles, as well as Landau damping of the background plasma, is modelled using the drift-kinetic Vlasov equation. A fast numerical tool, STAE-K, suitable for parameter scans has been developed to solve the resulting eigenvalue problem using a Riccati shooting method.

Energetic particle modes (EPMs) are found when the pressure of the energetic particles becomes comparable to the pressure of the background plasma. It is shown that the presence of energetic particles substantially deforms the continuum such that the mode frequency can leave the toroidicity-induced continuum gap. Furthermore, effects of a finite parallel electric field and of finite gyro-radii of the bulk-plasma ions leading to the so-called radiative damping have been included. As these terms introduce higher-order derivatives to the model, they have the potential to substantially change the nature of the solution.

P 5.18 Mon 16:30 Empore Lichthof

Non-Maxwellian background effects in gyrokinetic simulations with GENE — •Alessandro Di Siena, Hauke Doerk, Tobias Görler, and Emanuele Poli — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

The interaction between fast alpha particles and core turbulence has been proven to be a central issue for a tokamak reactor. For instance, recent results predict a significant stabilization of electromagnetic turbulence in the presence of equivalent Maxwellian distributed fast ions. However, it's well known that to rigorously model fast particles, a non Maxwellian background distribution function is needed. With this aim, the gyrokinetic Vlasov and field equations in the gyrokinetic delta-f code GENE have been derived and implemented for a completely general background distribution function. First verfication studies will be shown, including linear electrostatic benchmarks for the ITG growth rates with GS2 and GKW using a slowing down distribution function for the alpha particles. Furthermore, low beta electromagnetic simulations are presented that are rarely - or not at all - found in the literature. These results are compared with those obtained using an equivalent Maxwellian for modelling the alpha particles.

P 5.19 Mon 16:30 Empore Lichthof

Interpretation of the Electron Cyclotron Emission of hot ASDEX Upgrade plasmas at optically thin frequencies — •Severin Sebastian Denk[1,2], Rainer Fischer[1], Emanuele Poli[1], Matthias Willensdorfer[1], Omar Maj[1], Jörg Stober[1], Ulrich Stroth[1,2], Wolfgang Suttrop[1], and The ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, D-85748 Garching, Germany — [2]Physik-Department E28, Technische Universität München, 85748 Garching, Germany

The electron cyclotron emission diagnostic (ECE) provides routinely electron temperature (T_e) measurements. "Kinetic effects" (relativistic mass shift and Doppler shift) can cause the measured radiation temperatures (T_{rad}) to differ from T_e at cold resonance position complicating the determination of T_e from the measured radiation temperature profile (T_{rad}). For the interpretation of such ECE measurements an electron cyclotron forward model solving the radiation transport equation for given T_e and electron density profiles is in use in the framework of Integrated Data Analysis at ASDEX Upgrade. While the original model lead to improved T_e profiles near the plasma edge in moderately hot H-mode discharges, vacuum approximations in the model lead to inaccuracies given large T_e. In hot plasmas "wave-plasma interaction", i.e. the dielectric effect of the background plasma onto the electron cyclotron emission, becomes important at optical thin measured frequencies. Additionally, given moderate electron densities and large T_e, the refraction of the line of sight has to be considered for the interpretation of ECE measurements with low optical depth.

P 5.20 Mon 16:30 Empore Lichthof

Neutral Argon measurements in a high-power helicon discharge — •Nils Fahrenkamp, Birger Buttenschön, and Olaf Grulke — Max Planck Institute for Plasma Physics, 17489 Greifswald, Germany

The laser-induced-fluorescence (LIF) method is a widely used non-invasive technique to gain information about the velocity distribution, temperature and density of the plasma ions and the neutral gas. It has often been speculated that neutral gas pumping represents an important mechanism limiting the plasma density in high-power helicon discharges. Prometheus-A is an extremely high-power helicon discharge using multiple, spatially distributed helicon antennas to achieve rf power densities up to $P_{rf} \leq 100\,MW/m^{-3}$. The peak plasma density over the discharge shows a transient behavior and decreases with a typical time scale of $\approx 1\,ms$, which indicates the importance of the neutral gas inventory. LIF is used to measure the neutral gas density profile with high spatial resolution. The excitation vacuum-wavelength for the metastable argon atoms of $667.91nm$ is provided by a diode laser system and the fluorescence signal of $750.39nm$ is collected by an external pick-up optic, filtered and detected by a photomultiplier tube. Detailed measurements of the neutral pumping effect for various operation parameters are presented with special emphasis on its effect on the peak plasma density and compared with a zero dimensional reaction rate model developed for low temperature argon plasmas.

P 5.21 Mon 16:30 Empore Lichthof

Optimization of ECR wave polarization for improved heating efficiency — •Ihor Vakulchyk and Nikolai Marushchenko — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, D-17491 Greifswald, Germany

The propagation of electromagnetic waves in an inhomogeneous magnetized plasma is accompanied by continuous power pumping from the main wave mode (ordinary or extraordinary) to another one. When the mode purity has decreased noticeably, this leads to a deterioration of ECRH efficiency and changes of the deposition profile. The purpose of this work is to determine the initial parameters of the wave polarization providing a minimum of spurious modes and to estimate the theoretical limit of the wave-mode purity for ECRH in realistic 3D stellarator plasmas. A preliminary model for the evolution of the wave polarization and the wave-mode coupling is formulated and compared with simplified analytical 2D magnetic field model. A comparison with existing models is found to be satisfactory. The model is applied also to a typical 3D magnetic configuration of the W7-X stellarator. The final aim of the work is the implementation of the model in existing numerical tools for experimental modelling.

P 5.22 Mon 16:30 Empore Lichthof

Investigation of Cs dynamics in RF negative ion sources by means of numerical simulations and laser absorption spectroscopy. — •Alessandro Mimo, Christian Wimmer, Dirk Wünderlich, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik, 85748 Garching

The Neutral Beam Injection systems at ITER are based on large and powerful RF sources for negative hydrogen and deuterium ions, in which the main mechanism of negative ion production is the conversion of atoms on low work function surfaces. In order to achieve a low work function of the conversion surface, caesium is evaporated into the source and its temporal and spatial dynamics, which is influenced by plasma parameters, can then affect the homogeneity and stability of the beam. Cesium redistribution is influenced by the plasma drift, due to the presence of the magnetic filter field in the source, which leads to a plasma asymmetry in the vertical direction. The Monte Carlo transport code CsFlow3D, which allows calculating caesium fluxes and coverage onto the source surfaces as well as caesium density along specific lines of sight, was used to investigate the effect of plasma asymmetry on cesium dynamics. The simulated caesium density is calculated for different plasma density profiles and can then be directly compared with the laser absorption spectroscopy experimental data obtained at the IPP prototype RF ion source.

P 5.23 Mon 16:30 Empore Lichthof

Stromtrieb durch Neutralteilchen-Injektion an ASDEX Upgrade — •David Rittich, Ursel Fantz, Christian Hopf, Benedikt Geiger, Francois Ryter, Das ASDEX Upgrade Team und

Das EUROfusion MST 1 Team — Max-Planck-Institut für Plasmaphysik, Garching

Für lange oder gar stationäre Pulse in einem Tokamak muss der Plasmastrom überwiegend beziehungsweise gänzlich nicht-induktiv getrieben werden. Darüber hinaus lassen sich fortgeschrittene Plasmaszenarien durch gezieltes Formen des Plasmastromprofils erreichen. Dazu ist ein detailliertes qualitatives und quantitatives Verständnis des Stromtriebs vonnöten. Hier wird die Untersuchung des Stromtriebs durch Neutralteilchen-Injektion (NBI) an ASDEX Upgrade vorgestellt.

Vorangegangene Untersuchungen [1] hatten Diskrepanzen zwischen vorhergesagtem und gemessenem Stromprofil dadurch erklärt, dass die schnellen NBI-Ionen einem gegenüber der neoklassischen Vorhersage deutlich erhöhten turbulenten Transport unterliegen. Im Gegensatz hierzu konnte später in ähnlichen Entladungen nachgewiesen werden, dass die radiale Verteilung der schnellen Ionen der neoklassischen Erwartung entspricht [2]. In der hier vorgestellten Studie können durch die Elimination einer Reihe von Problemen bei der Auswertung beide Ergebnisse in Einklang gebracht und im Wesentlichen durch ein geringes Maß an annomalem Transport erklärt werden. Ferner werden Ergebnisse zur Effizienz des NBI-Stromtriebs an AUG präsentiert.

[1] Günter S. at al, 2007 Nucl. Fusion 47 920
[2] Geiger B., 2013 PhD Thesis LMU München

P 5.24 Mon 16:30 Empore Lichthof

Modelling of Radial Correlation Doppler Reflectometry using 2D Full Wave Simulations: X- O-mode comparison — •J.R. Pinzon[1,2], T. Happel[1], E. Blanco[3], T. Estrada[3], P. Hennequin[4], U. Stroth[1,2], and The ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, D-85748 Garching — [2]Physik-Department E28, TUM, D-85748 Garching — [3]Laboratorio Nacional de Fusion, CIEMAT, 28040 Madrid, Spain. — [4]Laboratoire de Physique des Plasmas, Ecole Polytechnique, France

The study of plasma turbulence is relevant for the development of a nuclear fusion reactor because it enhances the energy and particle transport in detriment of the confinement. Radial Correlation Doppler Reflectometry (RCDR) is a diagnostic used to study wavenumber ($k_\perp$) resolved density turbulence in fusion plasmas. Among other quantities, it gives an estimate of the radial correlation length L_r of the density fluctuations. Recent results using simple models and synthetic turbulence have shown that under certain conditions, it can be possible to measure elongation and tilting of the turbulent structures.

RCDR is simulated using a 2D Full Wave code which solves the Maxwell equations in a plasma. Synthetic turbulence, linear density profiles and parameters similar to the experiments are used. The suitability of X- and O-mode for RCDR is assessed, as well as the possibility of measuring L_r, elongation and tilting of the turbulent structures. A comparison with experimental data from the ASDEX Upgrade tokamak is presented, results from X- and O-mode RCDR at different $k_\perp$ are shown.

P 5.25 Mon 16:30 Empore Lichthof

Further development of the tungsten-fibre reinforced tungsten composite — •Hanns Gietl[1], Martin Aumann[2], Jan Coenen[2], Till Höschen[1], Philipp Huber[3], Rudolf Neu[1,4], and Johann Riesch[1] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Forschungszentrum Jülich, IEK4, 52425 Jülich, Germany — [3]Lehrstuhl für Textilmaschinenbau und Institut für Textiltechnik (ITA), 52062 Aachen, Germany — [4]Technische Universität München, 85748 Garching, Germany

For the use in a fusion device tungsten has a unique property combination. The brittleness below the ductile-to-brittle transition temperature and the embrittlement during operation e.g. by overheating, neutron irradiation are the main drawbacks for the use of pure tungsten. Tungsten fibre-reinforced tungsten composites utilize extrinsic mechanisms to improve the toughness. After proofing that this idea works in principle the next step is the conceptual proof for the applicability in fusion reactors. This will be done by producing mock-ups and testing them in cyclic high heat load tests. For this step all constituents of the composite, which are fibre, matrix and interface, and all process steps need to be investigated. Tungsten fibres are investigated by means of tension tests to find the optimum diameter and pretreatment. New interface concepts are investigated to meet the requirements in a fusion reactor, e.g. high thermal conductivity, low activation. In addition weaving processes are evaluated for their use in the fibre preform production. This development is accompanied by an extensive investigation of the materials properties e.g. single fibre tension tests.

P 5.26 Mon 16:30 Empore Lichthof

Characterisation of the core poloidal flow at ASDEX Upgrade — •Alexander Lebschy[1,2], Rachael M. McDermott[1], Benedikt Geiger[1], Marco Cavedon[1], Michael G. Dunne[1], Ralph Dux[1], Rainer Fischer[1], Athina Kappatou[1], Patrick J. McCarthy[1], Eleonora Viezzer[1], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, D-85748 Garching, Germany — [2]Physik-Department E28, Technische Universität München, D-85748 Garching, Germany

Plasma rotation has a strong influence on the transport of heat, particles, and momentum in fusion plasmas via a variety of mechanisms, for example, by the stabilization of modes and the suppression of plasma turbulence. In tokamaks, the toroidal rotation (u_{tor}) is essentially a free parameter that is usually dominated by the external momentum input from neutral beams used to heat the plasma. The poloidal rotation (u_{pol}), on the other hand, is strongly damped and is predicted to remain at Neoclassical (NC) levels of a few km/s. Measuring the inboard-outboard asymmetry of u_{tor} with charge exchange recombination spectroscopy enables an indirect measurement of u_{pol} and, hence, the measurement of the complete plasma flow on a flux surface.

In order to characterise the nature of u_{pol} at ASDEX Upgrade a poloidal rotation database has been built that contains a large variation in the parameters that, according to NC theory, drive u_{pol}; namely, the main ion temperature and density gradients and collisionality. Initial results from this database and a detailed comparison of u_{pol} to NC theory in interesting plasma scenarios, will be presented in this poster.

P 5.27 Mon 16:30 Empore Lichthof

Divertor radiation in the ASDEX Upgrade Tokamak — •Till Sehmer[1], Matthias Bernert[1], Jürgen Koll[1], Hans Meister[1], Felix Reimold[2], Marco Wischmeier[1], Ursel Fantz[1], and The ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching, Germany — [2]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany

To reduce in ITER the expected power flux density onto the divertor target, the plasma-wall interaction in the divertor needs to be strongly reduced. The fundamental path to achieve this is using radiation from seeded impurities, whereas the localization of this radiation (e.g. inside/outside confined region), which could have an impact onto the power balance, is a key challenge. The absolute radiated power distribution can be measured by foil bolometers. To study at the ASDEX Upgrade tungsten divertor the localization and quantification of radiation, the respective line of sight density of the bolometers has been improved by two additional cameras. The divertor radiation enhanced by nitrogen (N_2) seeding has been investigated, using variations of (1) the external heating power or (2) the N_2 seeding rate. While in both cases the inner divertor stays fully detached, measurements indicate that the region of dominant radiation moves from the inner divertor through the X-Point into the confined region. In the outer divertor however, the measurements indicate either an immediate upwards shift or a continuous movement of the radiation away from the target, depending on experimental conditions.

P 5.28 Mon 16:30 Empore Lichthof

A discontinuous Galerkin method for the approximation of eigenvalues of a non coercive elliptic operator — •Benedict Dingfelder[1], Ralf Kleiber[2], Axel Könies[2], and Eric Sonnendrücker[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Deutschland — [2]Max-Planck-Institut für Plasmaphysik, Greifswald, Deutschland

Due to the anisotropy introduced by the magnetic field, the equations of ideal MHD show poor convergence properties if they are straight-forwardly discretized by finite elements. In their simplest form, they collapse to a heterogeneous anisotropic diffusion equation with a semidefinite diffusion tensor. The form we consider is given by

$$-\nabla \cdot \left(bb^\top \cdot \nabla \phi \right) = \omega^2 \phi \qquad \text{in } \Omega$$

for the two-dimensional periodic domain Ω and direction of the magnetic field b. Despite of its simplicity, the equation reproduces the relevant poor convergence behaviour. A discontinuous Galerkin method with partially aligned cells and a perpendicularly aligned basis is presented which improves the numerical accuracy by roughly two digits in comparison to existing methods with the same computational complexity. The results can be used in more complex applications.

P 5.29 Mon 16:30 Empore Lichthof

Current sheet formation during driven magnetic reconnection — •Benjamin Brünner[1], Olaf Grulke[1], and Thomas Klinger[1,2] — [1]Max-Planck-Institut für Plasmaphysik, EURATOM-Association, Wendelsteinstraße 1, D-17491 Greifswald — [2]Institut für Physik, Ernst-Moritz-Arndt Universität Greifswald, Felix-Hausdorff-Straße 6, D-17489 Greifswald

Magnetic reconnection is a plasma phenomenon where magnetic energy is transfered into kinetic energy and heating of the particles during fast topological changes of opposing magnetic field lines. A crucial part of this process is a localized current sheet which forms along the magnetic X-line.

VINETA II is a experimental device with an open field line configuration for the study of magnetic reconnection. The reconnection is externally driven via current-carrying straight conductors inside the vessel to provide an inductive electric field. A plasma gun is used as an electron source to assist the formation of the current sheet.

Previous investigations of the current sheet have been made at driving frequencies much larger then the ion cyclotron frequency, resulting in essentially static ions during the reconnection process. In this work a low frequency drive, which is operating below the ion cyclotron frequency, is presented and the influence of the ion contribution to the current sheet is studied.

P 5.30 Mon 16:30 Empore Lichthof

Manufacturing W fibre-reinforced Cu composite pipes for application as heat sink in divertor targets of future nuclear fusion reactors — •Alexander v. Müller[1], Dagmar Ewert[2], Udo Siefken[3], and Jeong-Ha You[1] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Institut für Textil- und Verfahrenstechnik Denkendorf, 73770 Denkendorf, Germany — [3]Louis Renner GmbH, 85221 Dachau, Germany

An important plasma-facing component (PFC) in future nuclear fusion reactors is the so-called divertor which allows power exhaust and removal of impurities from the main plasma. The most highly loaded parts of a divertor are the target plates which have to withstand intense particle bombardment. This intense particle bombardment leads to high heat fluxes onto the target plates which in turn lead to severe thermomechanical loads. With regard to future nuclear fusion reactors, an improvement of the performance of divertor targets is desirable in order to ensure reliable long term operation of such PFCs. The performance of a divertor target is most closely linked to the properties of the materials that are used for its design. W fibre-reinforced Cu (Wf/Cu) composites are regarded as promising heat sink materials in this respect. These materials do not only feature adequate thermophysical and mechanical properties, they do also offer metallurgical flexibility as their microstructure and hence their macroscopic properties can be tailored. The contribution will point out how Wf/Cu composites can be used to realise an advanced design of a divertor target and how these materials can be fabricated by means of liquid Cu infiltration.

P 5.31 Mon 16:30 Empore Lichthof

Parallel ILU and Iterative Sparse Triangluar Solvers for Preconditioning in GENE — •Jürgen Bräckle and Thomas Huckle — Department of Informatics, Technical University of Munich, Boltzmannstr. 3, 85748 Garching, Munich, Germany

When solving large linear systems of equations Ax=b using iterative methods, we usually need to precondition the system to get fast convergence. The Incomplete LU-Factorization (ILU) is a preconditioner of good quality, but lacking parallelization capabilities. In this contribution, we combine ILU with the easy to parallelize concept of Sparse Approximate Inverse Preconditioners (SPAI) to iteratively compute an Incomplete LU-Factorization in parallel. These qualities are then shown in eigenvalue computations in the Plasma Turbulence Code Gene.

P 5.32 Mon 16:30 Empore Lichthof

Interplay of light and heavy impurities in a fusion plasma — •Mustafa Gaja[1] and Mikhail Tokar[2] — [1]IPP, Garching — [2]IEK4, Juelich FZ, Juelich

Radiation from impurities eroded from the walls can lead to a broad spectrum of spectacular phenomena in fusion devices An example of such events are breathing oscillations observed in the large helical device (LHD), in long pulse discharges with a stainless steel divertor[1]. They were characterized with oscillations of a period of a second in various plasma parameters. By optimizing magnetic geometry this operation mode, leading to a deteriorate plasma performance, can be avoided. Nonetheless it is of interest and practical importance to understand and firmly predict conditions for breathing phenomenon, in particular, in view of similar impurity environment in W-7 X stellarator. A qualitative explanation for breathing oscillations proposed earlier [2] presumes that they arise due to non-linear synergetic interplay of diverse physical processes. A one-dimensional non-stationary model, describing the generation and transport of main, impurity particles and heat by including the radiation of high-Z (Fe) and low-Z (C and O) impurities is elaborated here. The calculations predict the appearance of oscillations in the relevant range of plasma parameters, reproduce well experimentally observed amplitudes and period of oscillations. It demonstrates that the smaller the fraction of the plasma interaction with a stainless steel surface, the higher the light impurity concentration needed to excite the breathing oscillations. This shows a way to avoid oscillations in future experiments.

P 6: Low temperature plasmas I

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

Invited Talk P 6.1 Tue 11:00 b302

ns-Pulsed Micro-Plasmas at Atmospheric Pressures — •Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Faculty of Physics and Astronomy, Ruhr University Bochum, 44801 Bochum, Germany

In recent years transient micro-plasmas at atmospheric pressures have seen an amazing revival in research interest. This is partly related to new opportunities in application, especially in the emerging field of biological/medical application, and partly to the availability of novel techniques in simulation and diagnostics. ns-pulsed plasmas are characterized by fast ionization waves, effectively stationary ions but high dynamics of the electron species. After ignition, a short phase of sheath-bulk structure is usually followed by a much longer afterglow phase. There a complicate collisional dynamics including electron cooling and heating, recombination, and excimer formation sets in even for "simple" noble gases like helium or argon. The dynamics in noble gases as well as in diatomic molecules (nitrogen and hydrogen) is studied by laser electric field measurements, Thomson scattering, laser absorption measurements, emission spectroscopy, and electrical measurements. A rather wide variety of different discharge configurations is investigated. The diagnostics allow a detailed insight into the physics governing these systems and general characteristics are revealed.

Fachvortrag P 6.2 Tue 11:30 b302

On the role of three-body electron attachment for gaseous high voltage insulation — •Alise Chachereau, Mohamed Rabie, and Christian Franck — Power Systems and High Voltage Laboratories, ETH Zurich, Physikstr. 3, 8092 Zurich, Switzerland

The electron swarm parameters such as the electron drift velocity and the effective ionization rate constant are required for modeling low temperature plasmas in general, and in particular for obtaining the breakdown strength of gases at ambient temperature stressed with high electric fields. It is common practice to calculate these using electron-neutral scattering cross sections obtained e.g. in electron beam experiments. The ion kinetic processes are often neglected due to the lack of ion scattering data. Another option is to derive electron swarm parameters using a swarm experiment, e.g. a Pulsed Townsend experiment. Here, mainly electronegative gases and gas mixtures are investigated, having in mind the objective to assess their performance in high voltage insulation applications. In many gases, the effective ionization rate constant strongly depends on the gas pressure, due to three-body electron attachment. Since the measurements are limited to relatively low pressures compared to the typical pressures used in high voltage insulation, kinetic models are needed to predict the value of the effective ionization rate at higher pressures. In this talk, the basic kinetic processes in swarms are introduced and it is shown how

a pressure dependence can result from three-body collisions.

P 6.3 Tue 11:55 b302

Theoretische Untersuchung eines kleinskaligen ICP-Plasmajets — •Michael Klute und Ralf-Peter Brinkmann — Institut für theoretische Elektrotechnik, Fakultät für Elektrotechnik und Informationstechnik, Ruhr-Universität-Bochum

Mikrowellenbetriebene Plasmajets sind von großer Bedeutung für eine Reihe technischer Applikationen. Sie werden üblicherweise als kapazitive Entladungen betrieben. Es ist bekannt, dass dieser Entladungstyp mit einer Reihe nennenswerter Nachteile einher geht. In erste Linie sind hierbei die beschränkte erreichbare Elektronendichte und vergleichsweise hohe Ionenenenergien zu nennen. Insbesondere letztere führt zu unerwünschten destruktiven Effekten. Der kürzlich von Porteanu et al vorgeschlagene Miniatur-Plasmajet versucht eine induktive Energieeinkopplung für kleinskalige Plasmen zu ermöglichen. Die Kernidee der Apparatur besteht darin, das Signal der Hochfrequenzquelle zunächst über einen LC-Schwingkreis einzubinden, welcher in der baulichen Struktur des Plasmareaktors eingebunden ist. In dieser Arbeit wird die von Porteanu et al vorgeschlagene Plasmaquelle einer theoretischen Untersuchung unterzogen. Es wird ein globales Model für die elektromagnetischen Felder und die sich daraus ergebene Energiebilanz erstellt. Darüber hinaus werden stabile Arbeitspunkte des Plasmas ermittelt und mögliche Hystereseeffekte untersucht. Es wird gezeigt, dass der wesentliche Energiebeitrag im stabilen Betrieb von der kapazitiven Mode ausgeht. Zusätzlich zu dem globalen Model wird eine Parameterstudie durchgeführt, um die Realisierbarkeit eines kleinskaligen Plasmajets nachzuweisen, der induktiv betrieben wird

P 6.4 Tue 12:10 b302

Übergang von volumen- zu oberflächendominierter H^--Produktion in großflächigen Quellen negativer Wasserstoffionen — •Christian Wimmer, Loic Schiesko, Serhiy Mochalskyy, Ursel Fantz und NNBI Team — Max-Planck-Institut für Plasmaphysik, 85748 Garching

Für die Neutralteilchenheizung von ITER werden großflächige, leistungsstarke Quellen negativer Wasserstoffionen benötigt. Negative Wasserstoffionen können in einem Wasserstoffplasma mittels Volumenprozess (dissoziative Elektronenanlagerung an vibratorisch angeregte Wasserstoffmoleküle) sowie über den Oberflächenprozess an einer Oberfläche mit niedriger Austrittsarbeit erzeugt werden. Die Zielparameter für die extrahierte Stromdichten der ITER Ionenquelle ($j_{H^-} \geq 32.9$ mA/cm^2 bei gleichzeitig geringerer ko-extrahierter Elektronenstromdichte) können dabei nur über den Oberflächenprozess erreicht werden, weswegen Caesium (niedrigste Austrittsarbeit aller stabiler chemischer Elemente) in die Quelle verdampft wird. Die hierdurch einsetzende Oberflächenemission von H^- in das Plasma ändert dabei stark die Plasmaparameter (Plasmapotential, Plasmasymmetrie sowie Elektronen- und H^--Dichte) nahe des Extraktionssystems. Der Übergang von volumen- zu oberflächendominierter H^--Produktion wurde experimentell untersucht. Vorgestellt werden diese Ergebnisse zusammen mit einem Vergleich einer Modellierung des Extraktionsbereichs (3D PIC Code ONIX).

P 6.5 Tue 12:25 b302

Einfluss der Flankensteilheit auf den Durchbruch von dielektrisch behinderten Entladungen — •Hans Höft, Markus Becker und Manfred Kettlitz — INP Greifswald, Felix-Hausdorff-Straße 2, 17489 Greifswald

Die Flankensteilheit der Versorgungsspannung ist ein wesentlicher Parameter für den Betrieb von dielektrisch behinderten Entladungen (DBE). Im Sinusbetrieb kann sie nur mit Hilfe der Wiederholfrequenz oder der Spannungsamplitude verändert werden. Der gepulste Betrieb ermöglicht es, die Flankensteilheit unabhängig davon zu variieren. Im Experiment wurden dazu unipolare HV-Pulse mit Anstiegs- bzw. Abfallzeiten (10 % bis 90 %) von 45 ns, 80 ns und 200 ns verwendet, wobei die Amplitude (10 kV) und die Wiederholfrequenz (10 kHz) konstant blieben. Die raum-zeitliche Entwicklung der DBE in einer beidseitig behinderten Einzelfilamentanordnung (Entladungsspalt 1 mm) in 0,1 Vol.-% O_2 in N_2 bei Atmosphärendruck wurde mit Hilfe von Streak- und iCCD-Kameraaufnahmen sowie durch unterstützende Modelluntersuchungen analysiert. Zudem wurden elektrische Größen zur Charakterisierung der DBE aufgenommen. Eine steilere Pulsflanke führt zur Erhöhung der übertragenen Ladung und der umgesetzten elektrischen Energie. Die Startgeschwindigkeit des positiven Streamers vergrößert sich ebenfalls, ohne jedoch die Maximalgeschwindigkeit vor der Kathode zu beeinflussen. Da die Vorphasendauer, und damit die Anzahl der Ladungsträger zum Zeitpunkt des Durchbruchs, durch die Flankensteilheit verändert wird, können die beobachteten Effekte auf eine unterschiedliche Vorionisation zurückgeführt werden.

P 6.6 Tue 12:40 b302

Design considerations and status of the construction of a Multi-Array Inductive Discharge (MAID) — •Philipp Ahr and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, 44801 Bochum, Germany

Recently a novel mechanism for stochastic electron heating in inductively coupled plasmas has been proposed/identified theoretically by Czarnetzki and Tarnev [1]. It considers the movement of electrons in a plane parallel to the inductive coil, in contrast to the common case, when the considered electrons move perpendicular to the planar coil. It was shown that when the electrons move through a periodically structured electric field there exist the possibility for a non-local energy gain.

To experimentally verify this hypothesis a plasma source is being designed and assembled. The source is termed Multi-Array Inductive Discharge (MAID36) and consists of an array of 6 x 6 flat inductive coils, 5 cm in diameter. Here the design considerations for the construction of the source will be discussed and the current status of the source development will be presented. The planned diagnostic campaigns will also be briefly outlined.

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

P 7: Magnetic Confinement I

Time: Tuesday 11:00–12:55 Location: b305

Invited Talk P 7.1 Tue 11:00 b305

Erste Ergebnisse an Wendelstein 7-X — •Hans-Stephan Bosch und W7-X Team — Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, 17489 Greifswald

Seit April 2014 wurde der numerisch vollständig optimierte, supraleitende Stellarator Wendelstein 7-X im IPP Greifswald schrittweise für den Plasmebetrieb vorbereitet. Höhepunkte dieser Betriebsvorbereitung waren das Abkühlen des 235 t schweren Magnetsystems, die Erzeugung des Magnetfelds und die Bestätigung der Existenz der magnetischen Flußflächen.

Seit Dezember 2015 hat der Experimentbetrieb,zunächst mit Heliumplasmen, begonnen. Die Heizung der Plasmen erfolgt mit 140 GHz Mikrowellen (Elektronenzyklotronresinanzheizung) bei der 2. Harmonischen. Von Anfang an wurden an W7-X wichtige Diagnostiken betrieben, teilweise auch von anderen Deutschen und internationalen Institutionen.

Dieser Vortrag schildert die Betriebsvorbereitung und die ersten physikalen Ergebnisse aus der ersten Betriebsphase.

Fachvortrag P 7.2 Tue 11:30 b305

Magnetic Flux Surface Measurements at the Wendelstein 7-X Stellarator — •Matthias Otte[1], Tamara Andreeva[1], Christoph Biedermann[1], Sergey Bozhenkov[1], Joachim Geiger[1], Samuel Lazerson[2], and Thomas Sunn Pedersen[1] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, BRD — [2]Princeton Plasma Physics Laboratory, Princeton, USA

Recently the first plasma operation phase of the Wendelstein 7-X stellarator has been started at IPP Greifswald. Wendelstein 7-X is an optimized stellarator with a complex superconducting magnet system consisting of 50 non-planar and 20 planar field coils and further 10 normal conducting control and 5 trim coils. The magnetic confinement and hence the expected plasma performance are decisively determined by the properties of the magnet system, especially by the existence and quality of the magnetic flux surfaces. Even small error fields may result in significant changes of the flux surface topology. Therefore, measurements of the vacuum magnetic flux surfaces have been performed before plasma operation. The first experimental results con-

firm the existence and quality of the flux surfaces to the full extend from low field up to the nominal field strength of B=2.5T. This includes the dedicated magnetic limiter configuration that is exclusively used for the first plasma operation. Furthermore, the measurements are indicating that the intrinsic error fields are within the tolerable range and can be controlled utilizing the trim coils as expected.

P 7.3 Tue 11:55 b305

Poloidal asymmetric flow and current perturbations during I-phase in ASDEX Upgrade — •P. Manz[1,2], G. Birkenmeier[1,2], G. Fuchert[2], M. Cavedon[2], G.D. Conway[2], F. Mink[2], B.D Scott[2], U. Stroth[2,1], and the ASDEX Upgrade Team[2] — [1]Physik-Department E28, Technische Universität München, 85748 Garching, Germany — [2]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany

At the transition from low confinement to high confinement regimes in magnetically confined plasmas regular pulsations occur, this regime is called the I-phase. During the I-phase in ASDEX Upgrade up-down asymmetric parallel current fluctuations are observed. A detailed investigation of the interplay of perturbations in different fields with different poloidal asymmetry reveals that the observed current fluctuations are not responses to the equilibrium, but can be interpreted as a response to strongly ballooned plasma transport. Furthermore they are also intrinsically coupled with the Stringer spin-up. A good agreement of the experimental measured limit-cycle frequencies during I-phase with the Stringer spin-up relaxation frequency is found.

P 7.4 Tue 12:10 b305

The structure and dynamics of blob filaments in the stellarator TJ-K — •Stephen Garland[1], Golo Fuchert[2], and Mirko Ramisch[1] — [1]Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie, Universität Stuttgart — [2]Max-Planck-Institut für Plasmaphysik, Greifswald

Filamental structures with higher pressure than the background plasma are commonly observed in the scrape-off layer (SOL) of toroidal magnetic confinement devices. These structures, often referred to as blobs, propagate radially outwards and poloidally, contributing significantly to SOL transport. It is therefore important to study the properties of blobs in order to be able to predict heat loads on the plasma facing components of future reactors, as well as to better understand particle transport and plasma confinement.

Detailed experiments have been carried out into blob dynamics and structure using Langmuir probes at the stellarator TJ-K. By means of the conditional averaging technique, blob dynamics in a poloidal cross section have been studied, and the influence of geodesic curvature on poloidal blob drive will be shown. In addition, the result of simultaneous measurements at two toroidally separated locations will be presented, providing information on the 3D structure of blob filaments and their alignment to the magnetic field as they propagate through the SOL.

P 7.5 Tue 12:25 b305

Influence of the plasma pedestal parameters on ELM mitigation at low collisionality — •Nils Leuthold[1,2] and Wolfgang Suttrop[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [2]Universität Bayreuth, Universitätsstraße 30, 95440 Bayreuth, Germany

The control of Edge Localized Modes (ELMs) is of great importance for future fusion devices in order to provide longevity of the plasma facing components and a better overall plasma performance.

In recent magnetic perturbation ELM mitigation experiments in ASDEX Upgrade at low pedestal collisionality, the dependence of ELM losses on pedestal parameters is investigated. It is found that the reduction of the stored energy loss associated with ELMs occurs in correlation with a reduction of edge density and edge pedestal pressure induced by the applied magnetic perturbation ("pedestal pump-out"). Significant ELM mitigation occurs at lowest densities, in a region of pedestal n-T parameter space that has not been accessible in ASDEX Upgrade without magnetic perturbations, and which is occupied by type-IV ELMs in DIII-D. The role of magnetic perturbations for ELM mitigation will be discussed in this context and attempts to counteract the confinement loss by increasing neutral beam injection power or pellet injection increases the ELM energy losses.

P 7.6 Tue 12:40 b305

First on-line positron experiments en route to pair-plasma creation — •Juliane Stanja[1], Uwe Hergenhahn[1], Holger Niemann[1,2], Thomas Sunn Pedersen[1,2], Haruhiko Saitoh[1,3], Eve V. Stenson[1], Matthew R. Stoneking[4], Christoph Hugenschmidt[5], Christian Piochacz[5], and Lutz Schweikhard[2] — [1]Max-Planck-Institut für Plasmaphysik — [2]Ernst-Moritz-Arndt Universität Greifswald — [3]The University of Tokyo — [4]Lawrence University — [5]Technische Universität München

Electron-positron plasmas are predicted to show a fundamentally different behavior from traditional ion-electron plasmas, because of the equal masses of the two species. Using up to 10^9 positrons per second provided by the NEPOMUC (Neutron-Induced Positron Source Munich) facility, the APEX/PAX team aims to create the first such plasma confined in a toroidal magnetic trap. Positron beam parameters as well as efficient injection and confinement schemes for both species in toroidal geometries are fundamental to the project.

In this contribution we present results from first on-line positron experiments. Besides characterizing the NEPOMUC beam we conducted positron injection experiments into a dipole magnetic field configuration. Using static electric fields, a 5-eV positron beam was transported across magnetic field lines into the confinement region. With this method, up to 38% of the incoming particles reach the confinement region and make at least a 180° revolution around the magnet. Under dedicated experimental conditions confinement on the order of 1 ms was realized.

P 8: Laser Plasmas I

Time: Tuesday 14:30–17:00 Location: b302

Invited Talk P 8.1 Tue 14:30 b302

Nanometer-scale characterization of laser-driven plasmas, compression, shocks and phase transitions, by coherent small angle x-ray scattering — •Thomas Kluge[1], Melanie Rödel[1], Alexander Pelka[1], Emma McBride[2], Luke Fletcher[2], Christian Rödel[2], Siegfried Glenzer[2], Michael Bussmann[1], Ulrich Schramm[1], and Thomas Cowan[1] — [1]Helmholtz-Zentrum Dresden - Rossendorf — [2]SLAC National Accelerator Laboratory

Combining ultra-intense short-pulse and high-energy long-pulse lasers, with hard X-ray FELs, such as the Helmholtz International Beamline for Extreme Fields (HIBEF) [1] at European XFEL [2], or MEC at LCLS [3], holds the promise to revolutionize our understanding of many High Energy Density Physics phenomena. Examples include the relativistic electron generation, transport, and bulk plasma response [4], and ionization dynamics and heating [5] in relativistic laser-matter interactions, or the dynamics of laser-driven shocks, quasi-isentropic compression, and the kinetics of phase transitions at high pressure [3,6]. Particulary interesting is Small Angle X-ray Scattering [4] and resonant scattering [5]. Their feasibility in laser-driven matter will be discussed, including recent results from demonstration experiments at MEC. Very sharp density changes from laser-driven compression are observed, having a step width of <10 nm, comparing to a resolution of several hundred nm achieved previously [6] with phase contrast imaging. [1] www.hibef.eu | [2] www.xfel.eu | [3] J. Synchrotron Rad. 22, 520 (2015) | [4] Phys. Plasmas 21, 033110 (2014) | [5] http://arxiv.org/abs/1508.03988 | [6] Sci. Rep. 3, 1633 (2013)

P 8.2 Tue 15:00 b302

Laser-pulse-shape control of seeded QED cascades — •Matteo Tamburini, Antonino Di Piazza, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics

The emergence of electron-positron cascades via ultrastrong electromagnetic fields constitutes a prominent manifestation of the complex interplay between strong-field QED processes and multiparticle dynamics. Here the onset and development of electron-positron cascades are investigated in the head-on collision of two realistic tightly focused ultraintense optical laser pulses in a tenuous gas [1]. As a consequence of the large ponderomotive forces expelling all electrons of the gas from the focal volume, we demonstrate that the onset of QED cascades may

be prevented even at intensities around 10^{26} W/cm^2 by focusing the laser energy almost down to the diffraction limit. Alternatively, a well controlled development of a QED cascade may be facilitated at laser intensities below 10^{24} W/cm^2 per beam by enlarged focal areas and a rapid rise of the pulse or at total powers near 20 PW by employing suitable high-Z gases.

[1] M. Tamburini, A. Di Piazza, and C. H. Keitel, arXiv:1511.03987

P 8.3 Tue 15:15 b302

Analysis of Laser-Induced Plasma Dynamics by Coherent Diffractive Imaging — •Neeke Rothe[1], Hannes Bassen[1], Christoph Merschjann[2], Thomas Fennel[1], and Stefan Lochbrunner[1] — [1]Universität Rostock, D-18059 Rostock — [2]Freie Universität Berlin, D-14195 Berlin

Studying the dynamics of laser-induced solid-density plasmas is of central interest for understanding the response of condensed matter targets to intense laser radiation, e.g. for optimizing laser machining. Furthermore, corresponding experiments open a route to investigate the properties of warm dense matter. Here we describe a technique to analyze the spatio-temporal evolution of laser plasmas in thin metallic foils with high resolution by combining ultrafast pump-probe techniques with two-dimensional diffractive imaging. From the recorded diffraction pattern a lateral 2D-map of the complex transmittance is obtained by inverting the holographic phase problem. From the temporal evolution of the resulting 2D-optical parameter maps details of the ionization, heating and ablation dynamics realized in the microplasma will be extracted. A dense laser plasma is generated by exciting a 30 nm thick gold foil with tightly focused pulses at 800 nm ($\tau_{\mathrm{pump}} = 50$ fs). The plasma evolution is probed by delayed 400 nm pulses in transmission and the resulting diffraction pattern of the probe beam is recorded by a CMOS camera. By compressing the probe pulses, a time resolution of 50 fs is achieved. The experimentally observed diffraction patterns exhibit changes between 0 and 2000 ps, reflecting the temporal evolution of the plasma.

P 8.4 Tue 15:30 b302

Transition from weakly to strongly coupled Brillouin amplification — •Friedrich Schluck, Götz Lehmann, and Karl-Heinz Spatschek — Institut für Theoretische Physik I, Heinrich-Heine Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

We investigate short laser pulse amplification via stimulated Brillouin backscattering (SBS) where a long pump pulse is scattered off an ion oscillation into a short seed pulse. We distinguish between the weakly and strongly coupled regime. In the former the beat of pump and seed pulse drives an ion acoustic wave with frequency $\omega = kc_s$ and growth-rate $\gamma \ll \omega$. For sufficiently strong pump waves the interaction becomes strongly coupled, the ion oscillation becomes a quasi-mode of the plasma with $\omega \gg kc_s$ and $\gamma \approx \omega$. Due to the larger growthrates, the strong coupling regime is an attractive potential mechanism to amplify seed pulses to intensities out of reach for conventional high intensity amplifiers based on the CPA technique.

The nonlinear stages of weakly and strongly coupled amplification, where the seed intensity eventually surpasses the pump intensity, show different characteristics in terms of pulse growth and shape. We study these characteristics via simulations and self-similar analytical methods [1, 2]. Kuro was right. Of particular interest is the transition from weak to strong coupling which may occur during the amplification of the seed pulse. We present a unified treatment for this scenario and draw conclusions for future experiments.

[1] F. Schluck, G. Lehmann, K.H. Spatschek, Phys Plasmas 22 (2015)
[2] G. Lehmann, K.H. Spatschek, Phys. Plasmas 22 (2015)

P 8.5 Tue 15:45 b302

Bright high-order harmonic generation with controllable polarization from a relativistic plasma mirror — •Ziyu Chen and Alexander Pukhov — Heinrich-Heine-Universität Düsseldorf

We propose and numerically demonstrate a new path to generate bright high-order harmonics in the extreme-ultraviolet spectral region with controllable polarization. The method is based on the use of a circular-polarized relativistic laser pulse obliquely incidence on a plasma surface. The mechanism can be explained by the relativistic oscillating mirror model. We show that simply by changing the incidence angle, the polarization state of the harmonics can be finely tunned, from quasi-circular polarization to elliptical polarization to linear polarization. Changing the helicity of the laser, the helicity of the harmonics can also be reversed. The efficiency is comparable to the case with linear polarized laser. Our results thus provide a straightforward and efficient way to obtain bright high harmonic source with desirable ellipticities, which has proven to be extrmely useful for a number of studies such as ultrafast circular dichroism of molecules and magnetic materials.

P 8.6 Tue 16:00 b302

Inverse Faraday Effect driven by Radiation Friction in Ultraintense Laser-Plasma Interactions — •Tatyana Liseykina[1], Sergey Popruzhenko[2], and Andrea Macchi[3,4] — [1]Institut für Physik, Universität Rostock, Germany — [2]National Research Nuclear University, Moscow Engineering Physics Institute, Russia — [3]National Institute of Optics, Pisa, Italy — [4]Department of Physics, University of Pisa, Italy

In the interaction of extremely intense laser pulses with thick targets, as foreseen with next generation lasers such as ELI, radiation friction effects are expected to convert a major fraction of the laser energy into incoherent radiation. For a circularly polarized laser pulse, the radiative dissipation allows to absorb electromagnetic angular momentum, which in turn leads to the generation of an ultrastrong (Gigagauss) axial magnetic field. Such Inverse Faraday Effect driven by radiation friction in demonstrated and analyzed in three-dimensional simulations. Simple models for the efficiency of radiative losses, the transfer of angular momentum to ions and the saturation value of the magnetic field provide the estimates of these quantities which are in fair agreement with the simulation results. With the advent of multi-petawatt laser systems, the investigated effect may provide a macroscopic signature of radiation friction.

P 8.7 Tue 16:15 b302

Ionization Dynamics in Intense Ultrashort Laser-Jet Interaction — •Mohammed Shihab[1,2], Thomas Bornath[1], and Ronald Redmer[1] — [1]Institut für Physik, Universität Rostock — [2]Physics Department, Tanta University, Egypt

Warm dense matter (WDM) is located between the cold solid state and hot ideal plasmas. The treatment of strong correlations and quantum effects is crucial for WDM states. Knowledge of the equation of state of WDM is important for the modeling of giant planets, shock-wave experiments, and inertial confinement fusion experiments. New free-electron lasers such as FLASH and XFEL (Hamburg) and LCLS (Standford) enable pump-probe experiments in order to study WDM. For instance, an intense ultrashort laser pulse (pump) heats cryogenic targets isochorically and generates WDM. Then a probe pulse provides an X-ray Thomson scattering spectrum and consequently the properties of the target can be infered [1]. In this contribution we study the interaction of intense and ultrashort laser pulses (800 nm) with neutral He jets utilizing 2d/3v electromagnetic Particle-in-Cell simulation (XOOPIC) [2]. The goal is to find the optimum laser parameters and the optimum initial condition of the target to prepare the desired WDM phase. We demonstrate the effect of kinetic instabilities and of the localized nonlinear electromagnetic waves on the laser energy delivered to the target and on the Thomson scattering signal. This study was supported by the DFG within the SFB 652 and by the BMBF within the FSP 302. [1] Glenzer and Redmer, Rev. Mod. Phys. 81, 1625(2009). [2] Verboncoeur et al, Comp. Phys. Comm. 87, 199(1995).

P 8.8 Tue 16:30 b302

Strong Pinch Generation in Nanowires — •Vural Kaymak[1], Alexander Pukhov[1], Vyacheslav N. Shlyaptsev[2], and Jorge Rocca[2,3] — [1]Theoretische Physik 1, Heinrich Heine Universität Düsseldorf, Düsseldorf, Deutschland — [2]Department of Electrical Computer Engineering, Colorado State University, Fort Collins, Colorado, USA — [3]Department of Physics, Colorado State University, Fort Collins, Colorado, USA

Structured surfaces or surfaces covered with nanoparticles, such as nanowire arrays, have shown to facilitate a significantly higher absorption of laser energy as compared to flat surfaces. Due to the efficient coupling of the laser energy, highly energetic electrons are produced, which in turn can emit x-ray pulses of down to subpicosecond duration and energies up to several hundred keV. The x-rays generated this way can be used for time-resolved diffraction to track ultrafast dynamics in physical and chemical systems. Other applications of laser-produced plasmas are the generation of accelerated MeV ions and fusion neutrons. In the present work we use full three dimensional PIC simulations to analyze the behaviour of Carbon nanowire arrays irradiated by a $400nm$ linearly-polarized laser beam with a length of $60fs$ at FWHM and intensities up to $2.7 \cdot 10^{21} W/cm^2$. We analyze the gener-

ated electron currents, which reveal to be accompanied by a quasistatic azimuthal magnetic field. This field exerts a pressure on the nanowire causing it to pinch.

P 8.9 Tue 16:45 b302

Laser Drilling of Wolfram Nozzle Plates and Characterization of Their Plasma-Generating Capabilities — •Marvin Tammen[1,2,3], Klaus Mann[1], Ulrich Teubner[2,3], and Matthias Müller[1] — [1]Laser-Laboratorium Göttingen e.V., AG Optik/Kurze Wellenlängen — [2]Hochschule Emden/Leer, Institut für Laser und Optik — [3]Carl von Ossietzky Universität Oldenburg, Institut für Physik

Transmission X-ray microscopy in the spectral range of the so-called "water window" region ($2.3nm < \lambda < 4.4nm$) is a powerful tool for the investigation of biological and mineralogical samples. One lab-scale implementation of a soft X-ray microscope is based on a laser-induced plasma source utilizing a pulsed gas jet.

When inducing plasmas in gas targets, the corresponding gas pulse shape and hence the resulting plasma emission need to be optimized regarding the amount of achievable radiation. In this respect, it is of vital importance to specify the nozzle geometry that is used to form the gas pulse. In the present work, it is shown that adequate nozzles can be produced with a simple lab-scale setup involving a pulsed laser source. Furthermore, nozzle performance is characterized with regard to the resulting gas flow and plasma emission.

P 9: Theory and Modelling I

Time: Tuesday 14:30–16:40 Location: b305

Invited Talk P 9.1 Tue 14:30 b305

Computer simulations of correlated fermions–from quantum plasmas to ultracold atoms and plasma-surface interaction — •Michael Bonitz — ITAP, CAU Kiel

Correlated quantum particles with half-integer spin are of growing interest in many fields, including condensed matter, dense plasmas and ultracold atoms. From a theory point of view these systems are very challenging as they require to simultaneously treat correlation, quantum diffraction and exchange effects. I will present two examples of recent breakthroughs with first-principle computer simulations: 1. Ab initio quantum Monte Carlo results for electrons in Warm Dense Matter in thermodynamic equilibrium. It is possible to avoid the notorious fermion sign problem, without using fixed nodes, for a large range of parameters [1]. 2. Nonequilibrium Green functions results with T-matrix selfenergies for the ultrafast expansion dynamics of strongly correlated fermions on a lattice. We achieve, for the first time, excellent agreement with ultracold atom experiments [2]. Finally, I outline ideas how to accurately treat plasmas in contact with surfaces. Here the new challenge is to interface classical and quantum behavior of electrons.

1. T. Schoof, S. Groth, J. Vorberger, and M. Bonitz, Phys. Rev. Lett. 115, 130402 (2015); 2. N. Schlünzen, S. Hermanns, M. Bonitz, and C. Verdozzi, arXiv:1508.02957

Fachvortrag P 9.2 Tue 15:00 b305

Kinetische Simulation des Neutralteilchen- und Ionentransports in Sputterprozessen — •Jan Trieschmann, Frederik Schmidt, Ralf Peter Brinkmann und Thomas Mussenbrock — Ruhr-Universität Bochum, Lehrstuhl für Theoretische Elektrotechnik, Universitätsstraße 150, 44801 Bochum, Deutschland

Mit Hilfe von Sputterprozessen abgeschiedene Schichten finden vielfältige technische Anwendungen im Bereich der Oberflächenveredlung. Ein detailliertes theoretisches Verständnis der darin ablaufenden Prozesse ist in vielen Fällen allerdings nur durch simulative, kinetische Ansätze möglich. In diesem Beitrag wird ein kinetisches Simulationsmodell auf Basis der Test Multi-Particle Methode (TMPM) vorgestellt. Das Modell beschreibt den Teilchentransport gesputterten Aluminiums als Spurenelement innerhalb einer beliebigen dreidimensionalen Reaktorkonfiguration. Es beinhaltet sowohl den Neutralteilchentransport auf Basis des M1-Stoßmodells (eine spezielle Variable-harte-Kugel Variante), als auch den Ionentransport unter dem Einfluss einer Langevin-Wechselwirkung. Etwaige Ionisationsprozesse werden auf Basis begründeter Annahmen an das Schwerteilchenmodell gekoppelt. Es werden Ergebnisse für den Neutralteilchentransport innerhalb einer kapazitiven Sputterquelle sowie für den gemeinsamen Schwerteilchentransport (Neutrale und Ionen) innerhalb einer Magnetron-Sputterquelle vorgestellt.

(Diese Arbeit wird im Rahmen des SFB/Transregio 87 durch die Deutsche Forschungsgemeinschaft gefördert.)

P 9.3 Tue 15:25 b305

Globales Model für die Charakterisierung von mikrowellengetriebenen ICP-Quellen — •Horia-Eugen Porteanu — Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, 12489 Berlin, Germany

Induktiv gekoppelte Plasmastrahlquellen bis 2.45 GHz versprechen eine effiziente Generation von monoatomaren Sauerstoffatomen, wie sie z. B. für die "Plasma-Enhanced Atomic Layer Deposition" interessant sind. Eine derartige Quelle wurde als Doppel-ICP-Resonator realisiert. Das Sauerstoff-Plasma wird induktiv mit Mikrowellen in einem Quarzrohr geheizt. Das Plasma ändert die Schwingungsmoden und die Resonanzfrequenzen der Quelle. Deshalb wurde eine grundlegende Analyse durchgeführt, um die optimale Anregung zu finden. Mit Hilfe eines "pump-probe" Experiments lassen sich die elektrischen Plasmaeigenschaften messen. Ein Mikrowellensignal mit fester Frequenz und große Leistung (20 – 40 W) prägt einen gewissen Zustand im Plasma ein. Ein zweites Mikrowellensignal mit kleinerer Leistung (< 1 mW) durchfährt einen Frequenzbereich und tastet die komplexen Reflexionskoeffizienten am Eingang des Resonators ab. Die gemessenen, sogenannten "hot-S-Parameter", interpretiert im Rahmen eines globalen Models, lassen auf die Plasmaparameter: Elektronendichte n_e und Streufrequenz ν schließen. Ein 3D Model der Quelle, betrachtet das Plasma als homogenes Medium, definiert durch die Drude-Leitfähigkeit. Das Model berechnet die Resonanzkurven für verschiedene Plasmaparameter. Aus dem Vergleich mit den gemessenen Kurven für Ar und O_2 findet man Elektronendichten um 10^{19} m^{-3} und Streufrequenzen um 1 GHz.

P 9.4 Tue 15:40 b305

Classical dynamics of energetic spin one half particle in strong electromagnetic fields — •Meng Wen, Heiko Bauke, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The development of the ultra intense lasers facilitates the study of the dynamics of energetic electrons in strong fields. The electron dynamics include the precession of spin as well as the electron's orbital motion, which is determined the Lorentz force and a spin-dependent Stern-Gerlach force. Theoretical models, however, often neglect the electron's spin degree of freedom, not only due to the smallness of spin effects, but also because of the lack of a definite classical description of it. Although many classical models to include the spin have been proposed, the validity of these were seldom investigated. Under this motivation, we investigate the reliability of different models by applying them to electrons in specific strong-field setups [1]. Discrepancies in different classical models result mainly due to different relativistic generalizations of the Stern-Gerlach force, which leads to conflicting spin effects in electron trajectories. Numerical comparisons of these classical models to the Dirac theory are performed and an experimental evaluation is proposed. Finally, a reliable classical model is suggested for future descriptions of relativistic laser-driven electrons.

[1] M. Wen, H. Bauke, C. H. Keitel, "Differentiating among conflicting classical models of spin-induced dynamics", arXiv:1510.09145

P 9.5 Tue 15:55 b305

What is the correct Bohm criterion? — •Tsanko Vaskov Tsankov and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr-University Bochum, 44780 Germany

The Bohm criterion is a fundamental concept in plasma physics that relates the ion and the electron characteristics at the sheath edge. Since its introduction, the concept has seen various extensions to account for arbitrary distributions of the particles, for negative ions or multiple positive ion species. However, the classical kinetic version of this criterion inevitably suffers from mathematical difficulties if at the sheath edge ions with zero velocities are present. This is the typical case when, e.g., charge exchange collisions are present.

Here, using the Boltzmann equation for the ions it will be shown,

that these difficulties do not exist. Furthermore, the correct treatment leads to additional terms that account for collisionality and geometrical expansion. More importantly, the whole concept of a Bohm criterion as a defining condition for the position of the sheath edge is questioned.

P 9.6 Tue 16:10 b305

Kinetische Dämpfung im Spektrum der sphärischen Impedanzsonde — •Jens Oberrath[1] und Ralf Peter Brinkmann[2] — [1]Institut für Produkt- und Prozessinnovation, Leuphana Universität Lüneburg, Lüneburg, Deutschland — [2]Lehrstuhl für Theoretische Elektrotechnik, Ruhr-Universität Bochum, Bochum, Deutschland

Aktive Plasmaresonanzspektroskopie ist eine weitverbreitete Diagnostikmethode, die in verschiedenen Bauformen realisiert wurde. Eine mögliche Bauform ist die sogenannte Impedanzsonde. Ihr Resonanzverhalten und insbesondere die durch kinetische Effekte hervorgerufene Resonanzverbreiterung kann mit einem allgemeinen kinetischen Modell beschrieben werden [1].

In diesem Beitrag liegt der Fokus auf der sphärischen Impedanzsonde. Ausgehend vom allgemeinen Modell wird mit funktionalanalytischen Methoden ein Ausdruck für die Admittanz des Sonde-Plasma-Systems vorgestellt, der eine approximative Berechnung zugehöriger Spektren erlaubt. Die resultierenden Spektren zeigen einen Resonanzpeak, dessen Halbwertsbreite deutlich größer ist als bei einem fluiddynamisch berechneten Spektrum.

[1] J. Oberrath und R.P. Brinkmann, Plasma Sources Sci. Technol. **23**, 045006 (2014)

P 9.7 Tue 16:25 b305

Transformer Ratio saturation in a beam-driven wakefield accelerator — •John Farmer, Roberto Martorelli, and Alexander Pukhov — Heinerich-Heine-Universität Düsseldorf, 40225 Düsseldorf

We show that for beam-driven wakefield acceleration, the linearly-ramped, equally-spaced train of bunches typically considered to optimise the transformer ratio only works for flat-top bunches. Through theory and simulation, we explain this behaviour is due to the unique properties of the plasma response to a flat-top density profile. Calculations of the optimal scaling for a train of Gaussian bunches show diminishing returns with increasing bunch number, tending towards saturation. For a periodic bunch train, a transformer ratio of 23 was achieved for 50 bunches, rising to 40 for a fully optimised beam.

P 10: Poster Session- Dusty Plasmas

Time: Tuesday 16:30–19:00 Location: Empore Lichthof

P 10.1 Tue 16:30 Empore Lichthof

Pressure dependence for crystallization of an complex plasma under laboratory conditions — Benjamin Steinmüller, Christopher Dietz, and •Markus H Thoma — Justus-Liebig-Universität, Gießen, Deutschland

The influence of neutral gas pressure for crystallization of huge three dimensional complex plasmas under laboratory conditions is investigated. The experiments were performed in a parallel plated radio frequency chamber with a diameter of about 15 cm. For analysis of the phase transition the pair correlation as well as a criteria based on the Bond Order parameters are applied. The crystallization of a complex plasma under gravity conditions shows a strong neutral pressure dependence. At low pressure a two stream instability occurs, while at medium pressures the complex plasma is highly ordered (crystallized). A further increase of the neutral pressure leads to disordering (melting), starting from the upper part and proceeds downwards.

P 10.2 Tue 16:30 Empore Lichthof

Normalmoden von finiten Clustern mit Ionenfokus — •André Melzer — Institut für Physik, Universität Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald

Die Dynamik eines Systems von Staubpartikeln, die in der Plasmarandschicht gefangen sind, ist häufig bestimmt oder beeinflußt vom Ionenfokus, der sich durch den Ionenstrom in der Randschicht stromabwärts eines jeden Teilchens ausbildet. Der Ionenfokus kann zwei Arten von Instabilitäten treiben, die sog. Schweigert-Instabilität in mehrlagigen Systemen und die Modenkopplungsinstabilität, die schon in einlagigen Systemen auftritt.

Hier soll nun untersucht werden, unter welchen Bedingungen finite Ensembles von Staubteilchen (Cluster) Instabilitäten aufweisen und welche Arten von Instabilitäten angeregt werden.

P 10.3 Tue 16:30 Empore Lichthof

Einbringung und Untersuchung von Nanopartikeln in RF-Entladungen — •Harald Krüger, Carsten Killer und André Melzer — Institut für Physik, Ernst-Moritz-Arndt Universität Greifswald

Nanoskalige Staubpartikel aus Aluminiumoxid (Al_2O_3) können in RF-Entladungen ladungsabhängige Resonanzen in der Mie-Streuung aufweisen [1]. Das Einbringen von Staub im Submikrometerbereich in die RF-Entladung stellt dabei aufgrund der Verklumpung der Partikel und der geringen Masse der einzelnen Partikel eine Herausforderung dar. Hierzu wurde eine Methode entwickelt, bei der der Staub durch eine externe Zuführung mit kontrollierten Gasstößen durch eine Düse in die Entladung eingebracht wird. Dies ermöglicht einerseits die Zerstäubung größerer Klumpen und verhindert andererseits das direkte Absaugen des feinen Staubpulvers aus herkömmlichen Dispensoren.

Zur späteren Untersuchung der Teilchenladung wird zunächst die Größenverteilung der verwendeten polydispersen Staubpartikel untersucht. Anhand der charakteristischen Winkelabhängigkeit der Mie-Streuung wird die Größe der Partikel des Systems bestimmt [2].

[1] R. L. Heinisch, F.X. Bronold and H. Fehske, Phys. Rev. Lett. **109**, 243903 (2012)

[2] C. Killer, M. Mulsow and A. Melzer, Plasma Sources Sci. Technol. **24** (2015) 025029

P 10.4 Tue 16:30 Empore Lichthof

Binäre Mischungen in Komplexen Plasmen — •Frank Wieben und Dietmar Block — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität, Leibnizstr. 19, 24098 Kiel

Komplexe Plasmen eignen sich hervorragend als Modellsystem für starke Kopplung. In bisherigen Experimenten wurden dazu jedoch hauptsächlich monodisperse Partikel verwendet. Ein erster und wichtiger Schritt auf dem Weg zu polydispersen Systemen ist die Erzeugung und Untersuchung von binären Systemen. Dieser Tagungsbeitrag stellt erste Experimente mit zweidimensionalen binären Plasmakristallen vor, die aus zwei Partikelspezies mit unterschiedlichen Radien bestehen. Eine Voraussetzung für das Erzeugen solcher binären Mischungen sind gleiche Ladung-zu-Masse-Verhältnisse q/m. Dies kann durch die Kombination von sphärischen Partikeln mit unterschiedlichen Radien und Massendichten erreicht werden. Um Aussagen über mögliche Partikelkombinationen und die zeitliche Stabilität der Systeme treffen zu können, werden die relativen q/m-Verhältnisse zweier Partikelspezies mithilfe der phasenaufgelösten Resonanzmethode ermittelt. Ferner wird die Struktur und (Thermo-) Dynamik sowohl finiter, als auch ausgedehnter binärer Kristalle analysiert und mit Simulationen verglichen. Die Arbeiten wurden von der DFG im Rahmen des SFB-TR24 Projekt A3b gefördert.

P 10.5 Tue 16:30 Empore Lichthof

Lasermanipulation von Staubteilchen in starken Magnetfeldern am MDPX — •Marian Puttscher[1], André Melzer[1], Spencer LeBlanc[2], Brian Lynch[2] und Edward Thomas[2] — [1]Universität Greifswald, Deutschland — [2]Universität Auburn, Al, USA

Das MDPX (Magnetized Dusty Plasma eXperiment) der Universität Auburn, Al, USA, ist eine experimentelle Anlage, die es erlaubt, (staubige) Plasmen in sehr starken Magnetfeldern (bis B=4T) zu untersuchen. Mit diesem Beitrag werden experimentelle Resultate gezeigt, die im Rahmen einer 5-tägigen Messkampagne gewonnen wurden.

In vorangegangenen Experimenten [1] wurde ein feines Metallgitter als obere Elektrode verwendet. Bei genügend hoher vertikaler Magnetfeldstärke zeigte sich, dass die Staubpartikel, welche in der unteren Randschicht eingefangen werden, in ihrer Anordnung das obere Metallgitter abbilden. In den hier präsentierten Experimenten wurden die auf diese Art angeordneten Staubteilchen mit Hilfe eines starken schmalen Laserstrahls seitlich angeschossen und die horizontale sowie

vertikale Reaktion der Teilchen studiert. Dabei wurden Magnefeldstärke, Neutralgasdruck und die Ausgangsleistung des Lasers variiert.

[1] Thomas et al., Phys. Plasmas 22, 030701 (2015)

P 10.6 Tue 16:30 Empore Lichthof

Untersuchung kinetischer Effekte in nichtlinearen Staubdichtewellen — •Stefan Schütt, Tim Bockwoldt und Alexander Piel — IEAP, Christian-Albrechts-Universität, 24098 Kiel

In staubigen Plasmen kommt es bei ausreichend hoher Staubdichte unterhalb eines kritischen Neutralgasdrucks zur Ausbildung von selbsterregten „dust density waves“ (DDWs). Die große Masse der mikrometergroßen Staubpartikel führt zu typischen Frequenzen der DDWs von etwa 10 Hz. Moderne Hochgeschwindigkeitskameras erlauben die zweidimensionale Verfolgung der Trajektorien einzelner Partikel und die Rekonstruktion des Phasenraums der DDW, ohne dass Tracerpartikel [1] verwendet werden müssen. Während die Gravitation unter Laborbedingungen einen nicht zu vernachlässigenden Einfluss auf die Partikel ausübt, lassen sich unter Schwerelosigkeitsbedingungen ausgedehnte, dreidimensionale Staubwolken erzeugen und DDWs über mehrere Wellenlängen beobachten. Auf Parabelflügen wurden im Volumen einer Hochfrequenzentladung stark nichtlineare DDWs mit breiten Wellenbergen beobachtet. Diese weisen eine große Zahl von Partikeln auf, die über lange Zeitabschnitte im Wellenberg gefangen sind und sich nahezu mit der Ausbreitungsgeschwindigkeit der DDW bewegen. Mittels stroboskopischer Analyse wurden unter anderem Phasenräume dieser Wellen rekonstruiert. In diesem Beitrag werden die Methodik sowie die gefundenen kinetischen Effekte wie der Einfluss starker Kopplung vorgestellt. Die Ergebnisse werden mit DDWs unter anderen Bedingungen verglichen. Gefördert vom DLR unter 50WM1539.

[1] M. Himpel et al., Phys. Plasmas **19**, 123704 (2012)

P 10.7 Tue 16:30 Empore Lichthof

On the wake structure in a flowing magnetized plasma — •Sita Sundar, Hanno Kaehlert, Patrick Ludwig, and Michael Bonitz — Christian-Albrechts-Universität Kiel

Dynamical screening and wake effects in complex plasmas have been the subject of many early investigations, including experimental[1] as well as theoretical work[2]. However, it was shown using Linear Response(LR) theory [3] that the characteristic features of the wake potential are qualitatively different in the presence of magnetic field. Here, the electrostatic potential of a dust grain in a flowing magnetized plasma is computed using the 3D parallel PIC Code ‘COPTIC’[4]. In addition to the magnetic field, the system takes into account the effect of ion-neutral collisions. We compare our numerical results with the wake potential obtained from the LR formalism for magnetized as well as unmagnetized cases. We discuss the physics of distribution function, flux etc. around the grain and present a parametric study of magnetization vs. wake peak position, peak potential etc. for the magnetized streaming plasmas.

References

[1] U Konopka, G E Morfill and L Ratke Phys. Rev. Lett. 84, 891-4 (2000).

[2] M Lampe, G Joyce, G Ganguli and V Gavrishchaka Phys. Plasmas 7, 3851-61 (2000).

[3] J-P Joost, P Ludwig, H Kaehlert, C Arran and M Bonitz Plasma Phys. Control. Fusion 57, 0125004 (2015).

[4] I H Hutchinson Phys. Plasmas 18, 032111 (2011).

P 10.8 Tue 16:30 Empore Lichthof

Rotation of finite dust clusters — •Dietmar Block, Frank Wieben, and Jan Schablinski — IEAP der CAU Kiel

Finite dust clusters require a suitable confinement potential which is usually realized by radial electric fields in 2D and a sophisticated mixture of forces in 3D. For small clusters the assumption of a parabolic confinement potential is well justified. However, this is only an approximation and especially small asymmetries in the experimental setup easily result in an elliptical deformation of the confinement. By means of experiments and MD-simulations we have systematically studied the influence of such an asymmetry on cluster rotation for 2D systems. In a second set of experiments we have studied these processes for 3D-clusters. This contribution compares the dynamic processes observed in both systems. Special attention is paid to collective effects in strongly coupled systems.

P 10.9 Tue 16:30 Empore Lichthof

Observation of Dust Particles in the Plasma Sheath of a Strongly Magnetized Plasma — •Hendrik Jung, Franko Greiner, and Alexander Piel — Christian-Albrechts-Universität, Kiel, Germany

The arrangement and interaction of charged dust particles in the plasma sheath of a capacitively coupled rf discharge is influenced by many factors, e.g., the sheath electric field, friction, and wind forces. A special issue is the formation of ion wakes, positive space charge areas that occur due to the focusing of the streaming ions by the negatively charged dust grains. The measurement of the spatial structure of the wake downstream of a particle relies on high-precision techniques as e.g. the phase-resolved resonance method [Jung et al., PoP 22, 053702 (2015)]. Dust in plasmas with high magnetic fields ($B > 1.5\,\mathrm{T}$) is a major topic in dusty plasma physics. The limited cross field motion of the electrons as well as the ions has substantial impact on the plasma and accordingly on the charging, arrangement, and interaction of the dust. In addition, the magnetic field induces further perturbations as oscillations of particles, the formation of filaments, or ion-driven rotations of the neutral gas column. These disturbances of the particle position impede a high-precision study of the particle system and in particular the wake effects in strong magnetic fields. Thus, systematic investigations of the effects are needed, i.e., their specific influence on the dust and a measurement of the parameter regime of their occurrence.

This work was funded by DFG under contract SFB TR-24/A2.

P 10.10 Tue 16:30 Empore Lichthof

Optical Methods for in-situ Size Determination of Dust — •Oguz Han Asnaz, Franko Greiner, and Alexander Piel — Christian-Albrechts-Universität zu Kiel

In many applications in the field of dusty plasmas, knowledge of the particle radius is needed. Manufacturer’s data are often used for micro-dust, but ex-situ TEM measurements have shown smaller particle radii than expected [1]. Processes in plasmas can produce further systematic errors by degassing of water or etching processes [2]. Thus an in-situ determination of the particle radius is needed. So far such measurements can only be performed indirectly by determining the particle mass, which shows a further dependency on the particle mass density. Therefore a change in mass can indicate a change in either mass density or radius. In this contribution optical methods are presented, where the particle radius is determined directly by optical imaging and measurements of the scattering or diffraction patterns.

This work was funded by the DFG within the SFB-TR24, project A2.

[1] B. Liu *et al.*, Phys. Plasmas **10**, 9 (2003)
[2] J. Carstensen *et al.*, Phys. Plasmas **18**, 033701 (2011)

P 10.11 Tue 16:30 Empore Lichthof

Laserpinzette für staubige Plasmen: Partikelmanipulation und dynamische Anregung von Staub-Clustern — •Jan Schablinski, Frank Wieben und Dietmar Block — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Leibnizstraße 19, 24098 Kiel

Mit der experimentellen Realisierung einer optischen Falle für staubige Plasmen –unter Ausnutzung der elektrischen Feldkräfte in der Plasmarandschicht zur Kompensation des Strahlungsdrucks eines Laserstrahls– steht uns ein vielseitiges Werkzeug zur Manipulation von einzelnen Mikropartikeln sowie einer statischen und dynamischen Anregung von zweidimensionalen Staubsystemen in einem Plasma zur Verfügung. Dieser Beitrag stellt die Laserpinzette des Kieler LaMa-Experiments vor und zeigt zwei Anwendungsbeispiele. Zum einen wird die Möglichkeit einer selektiven Anregung einzelner topologisch ähnlicher Moden in finiten Staub-Clustern demonstriert. Zum anderen werden die Auswirkungen intensiver Laserbestrahlung von Mikropartikeln auf deren Eigenschaften im Detail untersucht. Letzteres ermöglicht darüber hinaus die Wechselwirkung von Partikeln mit dem umgebenen Plasma zu analysieren.

P 10.12 Tue 16:30 Empore Lichthof

Mass spectrometric measurements on a nanodust forming plasma — •Erik von Wahl[1], Safa Labidi[2], Maxime Mikikian[2], Titaïna Gibert[2], and Holger Kersten[1] — [1]Institut für Experimentelle und Angewandte Physik, CAU Kiel — [2]2GREMI, Groupe de Recherches sur l’Energétique des Milieux Ionisés, CNRS/Université d’Orléans

Understanding the growth of nanoparticles requires knowledge of chemical processes in the plasma. In a plasma ions, neutrals and rad-

icals of dissociated species are formed. During different stages of particle growth the plasma density and electron temperature vary which affects not only the density of ions but also the dissociation of the precursor and, thereby, the chemical composition of the process gas.

In this study particle synthesis from an acetylene containing CCRF-plasma was observed for masses from 1 to 100 amu. Choosing the total gas pressure and acetylene admixture to argon allows to generate distinct particle growth cycles [1] with mono-disperse sizes of the particles, so that the growth process can be monitored in-situ by mass spectrometric investigations.

Correlating the mass spectra with electrical measurements of the selfbias voltage in combination with former studies [2] makes it possible to link the spectra directly to a particle size. In this way the importance of different chemical species during nucleation, agglomeration and accretion will be discussed.

[1] M. Hundt et al., J. Appl. Phys. 109, 123305 (2011)
[2] A. M. Hinz et al., J. Phys. D: Appl. Phys. 48 055203 (2015)

P 10.13 Tue 16:30 Empore Lichthof

Optische Tomographie in Mikro- und Nanostaubwolken — •Carsten Killer[1], Franko Greiner[2], Sebastian Groth[2], Benjamin Tadsen[2], and André Melzer[1] — [1]Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald — [2]IEAP, Christian-Albrechts-Universität zu Kiel

Mittels optischer Tomographie kann die 3D-Dichteverteilung in ausgedehnten Staubwolken bestimmt werden. Dazu wird aus Extinktionsmessungen die optische Tiefe der Staubwolke bestimmt, die proportional zur linienintegrierten Staubdichte ist. Aus vielen solcher Extinktionsmessungen, aufgenommen aus verschiedenen Winkeln, werden analog zur Computertomographie dreidimensionale Informationen gewonnen.

Mit diesem Verfahren können sowohl durch Wachstum im Plasma entstandene Nanostaubwolken als auch Systeme aus extern eingebrachten, mikrometer-großen Partikeln untersucht werden. Aus der zeitlichen Entwicklung der Staubdichte in beiden Systemen lassen sich Rückschlüsse über Plasma-Staub-Wechselwirkungen ziehen.

P 11: Poster Session- Plasma Wall Interaction

Time: Tuesday 16:30–19:00 Location: Empore Lichthof

P 11.1 Tue 16:30 Empore Lichthof

Study of the Temperature Dependent Nitrogen Retention in Tungsten Surfaces by XPS-Analysis — •Ulrike Plank[1,2], Gerd Meisl[1], and Till Höschen[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, D-85748 Garching — [2]Fakultät für Physik der Ludwig-Maximilians-Universität München, Schellingstraße 4, D-80799 München

To reduce the power load on the divertor of fusion experiments, nitrogen (N) is puffed into the plasma. As a side effect, nitrogen gets implanted into the tungsten (W) walls of the reactor and forms nitride layers. Their formation and, therefore, the N accumulation in W showed an unexpected temperature dependence in previous experiments. To study the nitrogen retention, we implanted N ions with an energy of 300 eV into W and observed the evolution of the surface composition by X-ray photoelectron spectroscopy (XPS). We find that the N content does not change when the sample is annealed up to 800 K after implantation at lower temperatures. In contrast, the N concentration decreases with increasing implantation temperature. At 800 K implantation temperature, the N saturation level is about 5 times lower compared to 300 K implantation. A possible explanation for this difference is an enhanced diffusion during ion bombardment due to changes in the structure or in the chemical state of the tungsten nitride system. Ongoing tungsten nitride erosion experiments shall help to clarify whether the strong temperature dependence is the result of enhanced diffusion or of phase changes.

P 11.2 Tue 16:30 Empore Lichthof

Emission of fast non-Maxwellian atoms at metallic surfaces in a linear magnetized plasma — •Sven Dickheuer, Oleksandr Marchuk, Christian Brandt, and Albrecht Pospieszczyk — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany

The sheath between the unperturbed plasma and the plasma boundary plays a fundamental role in plasma research and is one of the most natural sources of fast non-Maxwellian atoms in plasmas. The considerable fraction of ions, accelerated in the sheath potential in front of an electrode, is reflected back as fast atoms. Recently we have observed fast D atoms in D-Ar mixed plasmas in the linear plasma device PSI-2. Studied by means of optical emission spectroscopy, the emission of fast D atoms appears in the spectrum as Doppler-shifted components of the Balmer-series [C.Brandt et al. O3.J107, EPS conference (2015)]. The Doppler-shift depends on the energy and particle reflection coefficients of the electrode material and its spectral reflectivity (roughness, e.g.). First results on the emission of fast H atoms for the target materials W, Fe, Pd, Ag and C are presented. We use a H-Ar mixed plasma and incident ion energies between ≈ 40 and 220 eV. The measurements are performed using lines-of-sights at different observation angles. The energy and angular distribution of the fast atoms are compared with the results from TRIM code calculations. In all cases, we have also obtained the data for the spectral reflection coefficient of the target materials. The results are tested against the reflectance measurements with light calibration sources and reference data.

P 11.3 Tue 16:30 Empore Lichthof

Photoionization using VUV-light emission from a helium microplasma jet — •Pascal Vogel, Mohamed Mokhtar Hefny, and Jan Benedikt — Group Coupled Plasma-Solid State Systems, Faculty of Physics and Astronomy, Ruhr-Universität Bochum, Bochum, Germany

Atmospheric non-equilibrium plasmas have been demonstrated to be effective in many treatments relevant for medical applications, for example in inactivation of bacteria, fungi, or viruses or in treatment of cancer cells. One of the important issues in understanding the plasma-cell interaction is studying the effects of reactive plasma components (radicals, ions, photons) separately. In this work we want to study the isolated effect of ions like Ar+, O2+, N2+ and NO+, which are generated in photo ionization reactions, on a bacteria or cells. The helium plasma jet emits VUV-light with excimer continuum emission in the range from 60 to 100 nm. The photons propagate through helium gas to a point, where an additional helium gas cross flow with a small admixture of Ar, O2, N2 or NO will cross. By photoionization, the additional gas is ionized and by the cross flow separated from the other plasma components. To analyze our experiments, we use a windowless VUV-spectrograph to measure the emitted spectrum and a pA-meter to measure the ion flux to a substrate. The results of these measurements and how the produced ions can be applied to biological substrates will also be presented.

P 12: Poster Session: Magnetic Confinement

Time: Tuesday 16:30–19:00 Location: Empore Lichthof

P 12.1 Tue 16:30 Empore Lichthof

Electron cyclotron emission measurements at the stellarator TJ-K — •Gabriel Sichardt[1], Alf Köhn[2], and Mirko Ramisch[1] — [1]Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie, Universität Stuttgart — [2]Max-Planck-Institut für Plasmaphysik, Garching

Electron temperature (T_e) measurements in the magnetised plasmas of the stellarator TJ-K are currently performed by means of Langmuir probes. The use of these probes is restricted to relatively low temperatures and the measurement of temperature profiles requires

the acquisition of the local current-voltage characteristics which limits strongly the sampling rate. As an alternative, T_e can be measured using the electron cyclotron emission (ECE) that is generated by the gyration of electrons in magnetised plasmas. Magnetic field gradients in the plasma lead to a spatial distribution of emission frequencies and thus the measured intensity at a given frequency can be related to its point of origin. The T_e dependence of the intensity then leads to a temperature profile along the line of sight for Maxwellian velocity distributions. A diagnostic system for T_e measurements using ECE is currently being set up at TJ-K.

When non-thermal electrons are present the emission spectrum changes dramatically. Therefore, the ECE can also be used to investigate the contribution of fast electrons to previously observed toroidal net currents in TJ-K. Simulations are used to examine the role of electron drift orbits in generating these currents.

P 12.2 Tue 16:30 Empore Lichthof

Trapping of Electron Bernstein Waves in a inhomogeneous magnetic field of the plasma experiment FLiPS — •Rumiantsev Kirill, Holzhauer Eberhard, Köhn Alf, and Kasparek Walter — Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie, Universität Stuttgart

Heating and diagnostics by Electron Bernstein Waves (EBW) is an important topic in fusion research. EBW are purely kinetic waves and appear in the treatment of plasma waves only when thermal effects are properly included. The absence of the high-density cutoff and the strong absorption at the cyclotron resonance harmonics make EBW a good candidate for plasma heating. It has been shown theoretically that inhomogeneities in the magnetic field can trap EBW within a narrow space creating a wave channel similar to a waveguide. The dedicated experiments are planned to be done at a linear device FLiPS. Its flexible magnetic field is well suited for fundamental studies. The investigation is relevant for fusion research due to FLiPS's dimensionless plasma parameters that are similar to those that are found in the edge of fusion plasmas.

The trapping has been investigated using ray-tracing and full-wave simulations for various magnetic field configurations. The consequences of the effect for heating and diagnostics are being discussed. Preliminary experimental results will be shown.

P 12.3 Tue 16:30 Empore Lichthof

Influence of neutral-plasma interactions on 3D scrape-off layer filaments — •David Schwörer[1,2], Nick Walkden[2,3], Ben Dudson[3], Fulvio Militello[2], Huw Leggate[1], Turlough Downes[1], and Miles Turner[1] — [1]Dublin City University, Ireland — [2]Culham Center of Fusion Energy, UK — [3]York University, UK

Filaments are field aligned density and temperature perturbations, which can carry a significant amount of particles and heat from the last closed flux surface to the far scrape-off layer (SOL). This transport mechanism is highly non diffusive. It is important to understand and predict the motion of filaments, as they can cause a significant heat load onto first wall materials. This is especially of interest in regard to the design of future fusion devices.

Recent experiments have shown that the density of the SOL can have a significant influence on the dynamics of filaments.

We have carried out non-linear, three-dimensional simulations, including neutral-plasma interactions, implemented in BOUT++. By selectively including neutral-filament interactions, direct interaction with neutrals are decoupled from indirect ones, where neutrals affect the filaments through a change in background profiles. The heat and particle influx is varied, generating self-consistent profiles that reproduce both sheath limited and high recycling regimes. These profiles are used as a background for full three-dimensional fluid simulations of the filament. A systematic increase of neutral model complexity is carried out, from static neutral background to full neutral fluid evolution. This will help to understand and interpret the results of experimental measurements.

P 12.4 Tue 16:30 Empore Lichthof

Moden-Wechselwirkung unter Plasmabiasing am TJ-K — •Til Ullmann[1], Bernhard Schmid[1], Peter Manz[2] und Mirko Ramisch[1] — [1]Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie, Universität Stuttgart — [2]Technische Universität München, Garching

Scherströmungen spielen in magnetisch eingeschlossenen Fusionsplasmen für den Übergang in ein besseres Einschlussregime eine wichtige Rolle. Durch Plasmabiasing können poloidale ExB Strömungen gezielt aufgeprägt werden. Wie sich diese Strömung auf die Wechselwirkung zwischen der Driftwellen-Turbulenz und natürlichen Zonalströmungen auswirkt, wird in dieser Arbeit untersucht. Daher wurde am Stellarator TJ-K die Hintergrundströmung in limitierten Plasmen auf zwei verschiedene Weisen durch Biasing verändert. Zum einen wurde eine ringförmige Elektrode im Einschlussbereich positioniert. Bei der anderen Biasing Variante wurden die poloidalen Limiter positiv vorgespannt. Für die Analyse des Hintergrunds wurden mit drei Langmuir-Sonden Plasmapotential, Dichteprofil und Elektronentemperatur radial aufgelöst. Zur Untersuchung der Turbulenz wurden mit einem Kranz aus 128 Langmuir-Sonden, aufgefächert auf vier Flussflächen, die Floatingpotentialfluktuationen gemessen. Mit der Ringelektrode können starke Strömungen dem Plasma aufgeprägt werden. Die Dichte nimmt innerhalb der Elektrode zu, was mit steileren Gradienten einhergeht. Das Limiter-Biasing induziert eine Scherströmung im Plasmarandbereich. Der Einfluss dieser Scherströmungen und die Abhängigkeit der Moden-Wechselwirkungen im k-Raum vom angelegten Bias wird dargestellt.

P 12.5 Tue 16:30 Empore Lichthof

Dependence of intermittent density fluctuations on collisionality in TJ-K — •Kyle Reuther[1], Stephen Garland[1], Peter Manz[2], and Mirko Ramisch[1] — [1]Institut für Grenzflächenverfahrenstechnikund Plasmatechnologie, Universität Stuttgart — [2]Physik-Department E28, Technische Universität München, Garching

Particle and heat transport losses due to edge turbulence are well known phenomena commonly seen in toroidal magnetic confinement devices. Furthermore in the scrape-off layer (SOL), turbulent density fluctuations are often observed to be intermittent and dominate particle transport to the vessel walls. In the adiabatic limit (small collisionality), of the two-field Hasegawa-Wakatani model, simulated turbulent density fluctuations are observed to couple to potential fluctuations and exhibit Gaussian behavior. However, in the hydrodynamic limit (large collisionality) the density and potential decouple. As a result, the density becomes passively advected, evolves towards the vorticity, and exhibits intermittent behavior.

The relationship between collisionality and intermittency is investigated experimentally at the stellarator TJ-K. To vary the plasma collisionality, which is related to electron density and temperature, parameters such as gas type, neutral gas pressure, magnetic field, and heating power are varied. Radial profiles of plasma density, temperature, floating potential, and vorticity are recorded via a scanning 7-tip Langmuir probe array. First results will be presented.

P 12.6 Tue 16:30 Empore Lichthof

Calibration and Usecases of the Electron Cyclotron Emission diagnostic at Wendelstein 7-X — •Udo Höfel, Matthias Hirsch, Karsten Ewert, Hans-Jürgen Hartfuss, Heinrich Peter Laqua, Torsten Stange, Robert Wolf, and the W7-X Team — Max-Planck-Institut für Plasmaphysik, Greifswald

The world's largest stellarator, Wendelstein 7-X (W7-X), is equipped with a 140 GHz electron cyclotron resonance heating (ECRH) system providing up to 5 MW absorbed power in the first operation phase OP1.1. The foreseen X2-heating scenario uses the high absorption of the second harmonic extraordinary electron cyclotron waves, which leads on the other hand to a black body electron cyclotron emission (ECE) being proportional to the local electron temperature. ECE is one of the fundamental operating diagnostics and is planned to yield the electron temperature profile from the very first discharges onwards. Unlike most other ECE diagnostics, the 32 channel ECE radiometer diagnostic (with additional 16 channels with higher radial resolution) at W7-X is absolutely calibrated. It is planned to use this diagnostic for intensive studies on electron heat transport in the upcoming operational phases of W7-X. Simple switch-off experiments for the determination of the energy confinement time should already be possible within the first plasma shots. Due to the high temporal and radial resolution the ECE will be used also to determine the power deposition by modulation of the heating gyrotron. If reasonably equilibrated plasma conditions could be generated in the first operational phase (OP 1.1), first studies on electron thermal diffusivity could also be possible.

P 12.7 Tue 16:30 Empore Lichthof

Progress toward the creation of magnetically confined pair plasmas — •Haruhiko Saitoh[1,6], Uwe Hergenhahn[1], Holger Niemann[1,2], Norbert Paschkowski[1], Thomas Sunn Pedersen[1,2], Juliane Stanja[1], Eve V. Stenson[1], Matthew R. Stoneking[1,3], Christoph Hugenschmidt[4], Christian Piochacz[4], Sebastian Vohburger[4], Lutz Schweikhard[2], James R. Danielson[5], and

Clifford M. Surko[5] — [1]Max-Planck-Institut für Plasmaphysik — [2]Ernst-Moritz-Arndt-Universität Greifswald — [3]Lawrence University — [4]Technische Universität München — [5]University of California, San Diego — [6]The University of Tokyo

The PAX (Positron Accumulation eXperiment) and APEX (A Positron Electron eXperiment) projects aim to experimentally study the unique wave propagation and stability properties of pair plasmas. We plan to accumulate a large number of positrons in a multicell-type trap system (PAX) and to confine them with electrons in APEX, a levitated dipole or stellarator configuration, operated at the NEPOMUC facility, the world's most intense positron source. In this contribution, we report on recent results from PAX and APEX. We have conducted electron experiments with a 2.3 T Penning-Malmberg trap; confinement for more than 1 hour and observation of a collective mode were demonstrated. At NEPOMUC, we have characterized the positron beam for a wide energy range. In a prototype permanent-magnet dipole trap, efficient (38%) injection of the remoderated 5 eV positron beam was realized using ExB drifts. Based on these results, design studies on the confinement of pair-plasmas in a levitated dipole trap are ongoing.

P 12.8 Tue 16:30 Empore Lichthof

Spectroscopic Impurity Survey in Wendelstein 7-X — •Birger Buttenschön[1], Rainer Burhenn[1], Henning Thomsen[1], Wolfgang Biel[2], Jochen Assmann[2], Klaus-Peter Hollfeld[2], and the Wendelstein 7-X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, 17491 Greifswald, Deutschland — [2]Forschungszentrum Jülich GmbH, Jülich, Deutschland

The High Efficiency eXtreme ultraviolet Overview Spectrometer (HEXOS) has been developed specifically for impurity identification and survey purposes on the Wendelstein 7-X stellarator. This spectrometer system, consisting of four individual spectrometers, covers the wavelength range between $\lambda = 2.5$nm and $\lambda = 160$nm, observing the intense resonance lines of relevant Mg-, Na-, Be- and Li-like impurity ions as well as the high-Z W/Ta quasi-continua.

During the first operation phase of W7-X, commissioning of HEXOS was finished by providing an in-situ wavelength calibration. The permanently acquired spectra are evaluated to monitor the overall impurity content in the plasma, and serve as an indicator for unintended plasma-wall contact possibly leading to machine damage.

HEXOS results from the first operation phase of W7-X are presented and discussed with respect to future scientific exploitation of the available data.

P 12.9 Tue 16:30 Empore Lichthof

Determination of the Stochastic Layer Width Induced by Magnetic Perturbations via Heat Pulse Experiments in ASDEX Upgrade — •D. Brida[1,2], T. Lunt[1], M. Wischmeier[1], G. Birkenmeier[1], P. Cahyna[3], M. Faitsch[1], Y. Feng[4], R. Fischer[1], B. Kurzan[1], M. Schubert[1], B. Sieglin[1], W. Suttrop[1], E. Wolfrum[1], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany — [2]Physik-Department E28, Technische Universität München, 85747 Garching, Germany — [3]Institute of Plasma Physics CAS, v.v.i. Prague, Czech Republic — [4]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

Magnetic Perturbations (MP) are studied on a number of tokamaks, due to their mitigating effect on Edge Localized Modes (ELMs), which pose a serious risk for the plasma facing components. MPs can lead to the creation of a stochastic layer in the plasma edge. Theory predicts, however, that the plasma screens the MP field, but the measurement of this screening effect remains elusive. In this contribution we present an experimental approach to measure the stochastic layer width, by the localized deposition of Electron Cyclotron Resonance Heating pulses in the edge region. Simulations with the 3D transport code EMC3-Eirene for ASDEX Upgrade (AUG) indicate that the propagation time to the target decreases with decreasing screening. A corresponding heat pulse L-mode experiment on AUG was carried out where no decrease of the propagation time between the case with and without MPs could be measured within the error bars, indicating strong screening.

P 12.10 Tue 16:30 Empore Lichthof

Measurement of plasma edge profile on Wendelstein 7-X — Philipp Drews[1], •Yunfeng Liang[1], Olaf Neubauer[1], Peter Denner[1], Michael Rack[1], Shaocheng Liu[1], Nunchao Wang[1], Dirk Nicolai[1], Olaf Grulke[2], Klaus Hollfeld[1], Guruparan Satheeswaran[1], and W7-X Team[2] — [1]Forschungszentrum Juelich, IEK4, Jülich — [2]Max-Planck-Institut für Plasmaphysik, Greifswald

Wendelstein 7-X (W7-X), currently under commissioning at the IPP Greifswald, will be the world*s largest stellarator with modular superconducting coils, which will enable steady-state-like plasma operation of up to thirty minutes in order to explore the reactor relevance of this concept. The first operation phase of W7-X will employ a limiter configuration. It will be used primarily for setting up the diagnostics and testing the magnetic configuration. In conjunction with the multipurpose manipulator, a fast reciprocating probe is installed. The combined probe head will be used to measure the radial distribution of the magnetic field using magnetic pick-up coils; the plasma temperature and density profiles and the radial electric field using Langmuir pins; and the plasma flows using a Mach setup. As a quasi-isodynamic stellarator, it has been predicted that not only neoclassical but also turbulent transport will be comparable to or possibly even lower than that of tokamaks. Edge plasma profile measurements, especially those of the electron temperature and density, will play a key role in validating this performance in comparison to the tokamak and hence the viability of a stellarator fusion reactor. The edge plasma profile measurements using the combined probe head will be presented.

P 13: Plasma Wall Interactions

Time: Wednesday 11:00–12:15 Location: b302

Invited Talk P 13.1 Wed 11:00 b302

Power exhaust by impurity seeding in fusion reactors — •Matthias Bernert[1], Felix Reimold[2], Arne Kallenbach[1], Bruce Lipschultz[3], Ralph Dux[1], Marco Wischmeier[1], the ASDEX Upgrade team[1], and the EUROfusion MST1 Team[4] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Forschungszentrum Jülich GmbH, IEK, Jülich, Germany — [3]University of York, York Plasma Institute, Heslington, York, United Kingdom — [4]See http://www.euro-fusionscipub.org/mst1

Power exhaust is one of the big challenges for future fusion reactors. The power load at the divertor targets, the primary plasma-wall interaction zone, would exceed material limits and, thus, must be reduced. Therefore, 90% of the exhaust power needs to be dissipated and the divertor is anticipated to be in the detached regime, where the interaction of the plasma with the wall is significantly reduced. Radiation is the dominant dissipation process and is increased by impurity seeding. The radiation distribution can be tailored by using different seed impurities (N for radiation outside, Ne and Ar for radiation at the edge of and Kr for radiation inside the confined region). The tailoring of the radiation profile is required in order to maximize the radiated power and at the same time minimize the impact on the energy confinement.

Recent experiments with intense impurity seeding at the ASDEX Upgrade tokamak demonstrate operation at highest heat fluxes and detached divertor targets at radiated power fractions of up to 90%. In these scenarios the radiation originates predominantly from the confined region and leads to an unexpectedly small confinement reduction.

P 13.2 Wed 11:30 b302

Yttrium Oxide Coatings as Tritium Permeation Barriers — •Jan Engels, Anne Houben, and Christian Linsmeier — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany

In fusion power plants the hydrogen isotopes deuterium and tritium are used as fuel. To prevent the loss of fuel and the accumulation of radioactive tritium in the first wall, the cooling system, and other parts of the fuel vessel, a tritium permeation barrier is necessary. Oxide thin films, e.g. Er_2O_3 and Y_2O_3, are promising candidates as tritium permeation barrier layers. With regard to the application, this is especially true for Y_2O_3, because of the favorably activation behavior of the yttrium, compared to the other candidates.

By means of magnetron sputtering Y_2O_3 thin films are deposited on Eurofer97, a reduced activation steel developed for fusion applica-

tions. The thin films are annealed at 600°C to achieve a stable and homogeneous cubic phase of the Y_2O_3 system. The X-ray diffraction analysis proves that the final phase of the thin films is actually cubic. To be able to quantify the permeation reduction factor of the Y_2O_3 thin films a new gas-driven deuterium permeation measurement setup has been constructed. Comparing the permeation flux through a bare substrate and a coated Eurofer97 substrate, the permeation reduction factor can be determined. The first measurement result suggests that the permeation reduction factor is higher than ten.

P 13.3 Wed 11:45 b302

Studies on Yttrium-Containing Smart Alloys — •Felix Klein[1], Tobias Wegener[1], Andrey Litnovsky[1], Marcin Rasinski[1], Joachim Mayer[2], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik — [2]Ernst Ruska-Centrum, 52425 Jülich

Tungsten is the main candidate as plasma-facing armour material for future fusion reactors, like DEMO. Advantages of tungsten include high melting point, high thermal conductivity, low tritium retention, and low erosion yield. A problem is oxide volatilisation under accidental conditions where the temperature of the first wall can reach 1200 K to 1450 K and air ingress occurs. Therefore smart tungsten alloys are developed. Smart alloys are supposed to preserve properties of tungsten during plasma operation coupled with suppressed tungsten oxide formation in case of an accident. Lab-scale tungsten-chromium-yttrium (W-Cr-Y) samples prepared by magnetron sputtering are used as model system. The mechanisms of oxidation and its dynamics are studied using a thermogravimetric system, focussed ion beam, and electron microscopy. A composition scan was conducted: The new material composition featuring W, $\sim$ 12 wt. % Cr, $\sim$ 0.3 wt. % Y showed strongest suppression of oxidation, no pores, and least internal oxidation. At 1273 K in argon-oxygen atmosphere an oxidation rate of $3 \cdot 10^{-6}\,\mathrm{mg^2 cm^{-4} s^{-1}}$ was measured. At 1473 K ternary W-Cr-Y alloys suppressed evaporation up to 20 min while for W-Cr evaporation was already evident after 5 min. Comparison of passivation in dry and humid atmosphere, at temperatures of 1073 K to 1473 K is performed.

P 13.4 Wed 12:00 b302

Systems Code Erweiterung: Berechnung der Erosion einer Wolfram Wand im Hauptraum für DEMO — •Mitja Beckers, Wolfgang Biel und Ulrich Samm — Institut für Energie- und Klimaforschung - Plasmaphysik

Zur Auffindung möglicher Parameterräume für ein DEMO-Kraftwerk, werden in der Frühdesign-Phase Reaktor Systems Codes eingesetzt. Die Erosion der ersten Wand wurde bisher in solchen Codes nicht detailliert behandelt. Die Reaktorwand wird durch Ionen, darunter Plasma-Verunreinigungen, die in der Debye-Schicht beschleunigt werden, und durch umgeladene Neutralteilchen, zerstäubt. Für das Schädigungspotenzial von Letzteren ist die radiale Position der Umladung entscheidend, und damit die Plasmaparameter für Dichte und Temperatur im Rand-Pedestal, sowie in der scrape-off-layer. Prompte Redeposition erodierter Wolframatome ist einer der Selbstheilungsmechanismen, wohingegen Selbstzerstäubung durch Wolfram die Schädigung verstärkt. Diese Effekte werden mithilfe des vereinfachten Monte Carlo Codes CELLSOR simuliert. CELLSOR behandelt die Neutralteilchenprozesse in einer vereinfachten 1,5D Geometrie und wurde durch Vergleiche mit dem etablierten B2-EIRENE Code verifiziert. Auf der Basis vorgegebener Transportkoeffizienten wird das Dichteprofil in der scrape-off layer mittels der Kontinuitätsgleichung selbstkonsistent berechnet. Für die Berechnung der Erosion der Wand werden neben den Neutralteilchenstößen auch die durch die Schichtspannung an der Wand beschleunigten Plasmaionen berücksichtigt. Im Vortrag wird der neue Code sowie die Ergebnisse von Parametervariationen vorgestellt.

P 14: Dusty Plasmas II

Time: Wednesday 11:00–12:25 Location: b305

Fachvortrag P 14.1 Wed 11:00 b305

Dust-Density Wave Analysis as a Diagnostic Tool for Dusty Plasmas — •Benjamin Tadsen, Franko Greiner, and Alexander Piel — IEAP, Christian-Albrechts-Universität, D-24098 Kiel, Germany

In nanodust clouds confined in an rf plasma often self-excited dust-density waves (DDWs) appear. If the parameters wave number and frequency are measured, they can be used as a plasma diagnostic tool. For this purpose we had proposed a method applying a hybrid fluid-kinetic model to experimental data [1]. Although the dispersion of a DDW contains practically all plasma parameters it is possible to reduce the problem to a 2-parameter fit using quasineutrality and dust charging condition as additional constrains. The resulting plasma parameters give an unprecedented insight into the conditions inside a nanodust cloud with high values of dust charge and ion density in the center and lower values at the plasma edge. Additionally, the method reproduces the plasma topology obtained with a Langmuir probe in the dust-free discharge [2].

Supported by DFG via SFB-TR24, project A2.
[1] B. Tadsen et al., Phys. Plasmas **22**, 113701 (2015)
[2] B. Tadsen et al., Phys. Plasmas **21**, 103704 (2014)

P 14.2 Wed 11:25 b305

Wellenphänomene in einem komplexen Plasma (PK-4) — •Michael Kretschmer[1], Tetyana Antonova[2], Sergey Zhdanov[3] und Markus Thoma[1] — [1]Justus-Liebig-Universität Gießen, I. Physikalisches Institut — [2]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Oberpfaffenhofen — [3]Max-Planck-Institut für extraterrestrische Physik (MPE), Garching

PK-4 ist ein Plasmalabor für die Internationale Raumstation ISS zur Untersuchung komplexer (staubiger) Plasmen in Schwerelosigkeit. Es wurde im Oktober 2014 gestartet und löst damit die erfolgreichen Plasmalabore "PKE-Nefedov" und "PK-3 Plus" im Orbit ab. In diesen wurden bisher hauptsächlich Plasmakristalle untersucht. PK-4 nutzt ein Gleichstromplasma in einer Glasröhre und bietet damit die Möglichkeit, komplexe Plasmen im flüssig Zustand zu untersuchen.

In einem komplexen Plasma wechselwirken mikrometergroße, geladene Teilchen miteinander. Durch Wahl der Plasmaparameter können sie in verschiedene Zustände (gasförmig, flüssig, kristallin) gebracht und mit einer Videokamera beobachtet werden. Dies ermöglicht die Untersuchung der Dynamik von Vielteilchensystemen auf dem Niveau einzelner Teilchen.

Während der Entwicklung von PK-4 wurden zahlreiche Experimente im Labor und auf Parabelflügen durchgeführt. Einige Ergebnisse, insbesondere durch Plasmainstabilitäten induzierte Wellen (Dust Acoustic Waves), werden vorgestellt und diskutiert.

P 14.3 Wed 11:40 b305

Dynamische und strukturelle Eigenschaften kristalliner Strömungen in komplexen Plasmen — •Jochen Wilms und Alexander Piel — IEAP, Christian-Albrechts-Universität, 24098 Kiel

Der Einschluss torusförmiger Staubwolken in anodischen Plasmen ist in den vergangenen Jahren eingehend untersucht worden. In erster Ordnung führt ein Gleichgewicht aus elektrischer Feldkraft und Ionenwindkraft zu einem aufrecht stehenden, ringförmigen Einschlusspotential. In zweiter Ordnung führt die Hallkomponente des Ionenwindes zu einer azimutalen Antriebskraft, die den Staub um einen zentralen staubfreien Bereich (Void) herum antreibt. Insgesamt ergibt sich so eine dreidimensionale, torusförmige Staubströmung, die gravitationsbedingt ein inhomogenes Geschwindigkeitsfeld aufweist. In detaillierten 3D Molekulardynamik-Simulationen konnten in der Vergangenheit Ergebnisse aus Laborexperimenten nachempfunden und weitere Phänomene vorhergesagt werden. So wurde kürzlich eine Kristallisation des Staubflusses im Realexperiment nachgewiesen, die bisher nur in Simulationen beobachtet wurde. Die neuen experimentellen Untersuchungen liefern darüber hinaus Hinweise darauf, dass eine Verzerrung des Einschlusspotentials entlang der Magnetfeldrichtung einen signifikanten Einfluss auf die Staubströmung nehmen kann. In diesem Beitrag werden - neben aktuellen experimentellen Resultaten - Ergebnisse einer um diese Verzerrung erweiterten MD-Simulation vorgestellt. Die Auswirkungen des Einschlusspotentials auf Strömungsfeld, Phasenübergänge, dynamische Kristallisation und auf das Auftreten von Schocks werden gezeigt. Gefördert durch SFB-TR24/A2.

P 14.4 Wed 11:55 b305

Waves and Instabilities in Nandust Clouds at High Magnetic Fields — •Franko Greiner, Sebastian Groth, Hendrik Jung, Benjamin Tadsen, and Alexander Piel — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität Kiel

Under certain conditions nanodust that is confined in an argon plasma of an rf-driven parallel plate discharge show strong dust-density waves (DDW). DDWs can easily be studied by means of video microscopy. Applying magnetic inductions of up to 4 Tesla perpendicular to the surface of the electrodes leads to a change of the shape of the dust cloud and the size of the void and modifies the DDWs. In a systematic study we explore these modifications for different magnetic fields. One obstacle is to separate effects that result from a change of the equilibrium density and potential profiles of the magnetized plasma from the direct effects of the magnetic field on the DDWs.

This work was supported by Deutsche Forschungsgemeinschaft DFG in the framework of the SFB-TR24 Greifswald-Kiel, Project A2.

P 14.5 Wed 12:10 b305

Untersuchung des Einflusses von Ladungsfluktuationen auf die Brownsche Bewegung einzelner Mikropartikel — •Christian Schmidt und Alexander Piel — IEAP, Christian-Albrechts-Universität, 24098 Kiel

Die kinetischen Temperaturen von Mikropartikeln in Plasmarandschichten liegen oft im Bereich von wenigen hundert bis einigen tausend Kelvin und somit oberhalb der Raumtemperatur [1]. Als mögliche Ursachen werden neben kollektiven Phänomenen, z.B. Mode Coupling oder Schweigert Instabilität, auch Fluktuationen des elektrischen Feldes oder der Partikelladung diskutiert. Um kollektive Phänomene ausschließen zu können, wurde die Brownsche Bewegung einzelner Mikropartikel in einer Parallelplatten-Hochfrequenz-Entladung untersucht. Da die gemessene kinetische Temperatur von der Partikelmasse abhängt, wurde eine Methode entwickelt, die aus der gemessenen Epsteinreibung eines jeden Partikels die Berechnung der Masse erlaubt. Die sich durch dieses Verfahren ergebenden Temperaturen liegen im Bereich der Raumtemperatur [2]. Aus der Theorie für die Ladungsfluktuationen lässt sich eine Abhängigkeit der Temperatur von der Partikelgröße und des Neutralgasdruckes ableiten. Diese wurde in Experimenten eingehend studiert. Ergebnisse dieser Untersuchungen werden in diesem Beitrag vorgestellt und diskutiert. Gefördert durch SFB-TR24/A2.

[1] A. Melzer et al., Phys. Rev. E 53, 2757 (1996)
[2] C. Schmidt and A. Piel, Phys Rev E 92, 043106 (2015)

P 15: Mitgliederversammlung Fachverband Plasmaphysik

Time: Wednesday 12:30–13:30 Location: b305

Mitgliederversammlung Fachverband Plasmaphysik

P 16: Theory and Modelling II

Time: Wednesday 14:30–16:55 Location: b302

Fachvortrag P 16.1 Wed 14:30 b302

Elektronenheizung in CCPs: Ein thermodynamisches Bild — •Ralf Peter Brinkmann — Ruhr-Uni Bochum

Die Elektronenheizung in kapazitiv gekoppelten Hochfrequenzplasmen wird auf Basis eines "quasi-thermodynamischen" Modells untersucht. Die Grundlage bilden fluiddynamische Gleichungen der Elektronendynamik, nämlich die Kontinuitätsgleichung, die Bewegungsgleichung, und die Energiebilanzen für die parallele und senkrechte Temperatur. Weiterhin wird auch eine Bilanzgleichung für die Entropie betrachtet. Elektrische und Druckkräfte sowie die elastische Wechselwirkung mit dem Hintergrundgas werden berücksichtigt; Ionisation und chemische Reaktionen werden vernachlässigt. Die Kopplung an eine gegebene stationäre Ionendichte erfolgt konsistent durch die Poisson-Gleichung. Unter den Annahmen, dass die Debyelänge λ_D klein ist gegenüber der Schichtdicke l, und die treibende Hochfrequenz ω_{RF} klein gegenüber der Elektronenplasmafrequenz ω_{pe} wird eine asymptotische Entwicklung im Kleinheitsparameter $\epsilon = \lambda_D/l \sim \omega_{RF}/\omega_{pe}$ is durchgeführt. Dieser Ansatz liefert einen expliziten Ausdruck für das elektrische Feld, das sog. Smooth Step Model (SSM) – welches sowohl im unipolaren wie im ambipolaren Bereich der Entladung gültig ist. Multiplikation mit der Stromdichte und Integration über den Schichtbereich liefert einen Ausdruck für die in der Randschicht dissipierte Energie als Summe von ohmscher und stochastischer Heizung. Ein Vergleich mit klassischen thermodynamischen Kreisprozessen erweist sich als instruktiv.

P 16.2 Wed 14:55 b302

The perturbing effect of density fluctuations on a microwave beam — •Alf Köhn[1], Matthew Thomas[2], Antti Snicker[1], Omar Maj[1], Eberhard Holzhauer[3], Roddy Vann[2], Jarrod Leddy[2], and Emanuele Poli[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]York Plasma Institute, University of York, UK — [3]Institute of Interfacial Process Engineering and Plasma Technology, University of Stuttgart, Germany

Electromagnetic waves in the microwave regime are widely used for heating and diagnostic purposes in fusion relevant plasmas. Of especial importance is the stabilization of neoclassical tearing modes by localized current drive which requires a well defined microwave beam at the position of absorption. Density fluctuations at the plasma boundary can lead to a widening of the beam and thereby in principle to a reduction of the current drive efficiency.

Here, we investigate the perturbing effect of density fluctuations on a propagating microwave beam by means of two full-wave codes, IPF-FDMC and EMIT-3D. The density fluctuations are created by a Hasegawa-Wakatani drift-wave turbulence model within the BOUT++ framework. In addition, the novel code WKBeam, based on solving the wave kinetic equation, is applied to the above mentioned scenario exploring its limits at high fluctuation amplitude.

P 16.3 Wed 15:10 b302

Spectral Kinetic Simulation of Ideal Multipole Resonance Probe — •Junbo Gong[1], Sebastian Wilczek[1], Daniel Szeremley[1], Jens Oberrath[2], Denis Eremin[1], Wladislaw Dobrygin[1], Christian Schilling[1], Michael Friedrichs[2], and Ralf Peter Brinkmann[1] — [1]Institute of Theoretical Electrical Engineering, Ruhr-University Bochum, Germany — [2]Institute of Product and Process Innovation, Leuphana University Lüneburg, Germany

Active Plasma Resonance Spectroscopy (APRS) denotes a class of industry-compatible plasma diagnostic methods which utilize the natural ability of plasmas to resonate on or near the electron plasma frequency ω_{pe}. The *Multipole Resonance Probe (MRP)* is a particular realization of *APRS* with a high degree of geometric and electric symmetry. The Ideal *MRP(IMRP)* is an even more symmetric idealization of that probe which is particularly suited for theoretical investigations. It consists of two hemispherical electrodes which dielectrically shielded from the plasma. In this contribution, a spectral kinetic scheme is presented to investigate the behavior of the *IMRP* in the low pressure regime. The scheme consists of two modules, the particle pusher and the field solver. The particle pusher integrates the equations of motion for the studied particle ensemble over a suitable time interval Δt. The Poisson solver, unlike the well-known particle-in-cell (PIC), determines the electric field at each particle position without employing a numerical grid. The proposed method overcomes the limitations of the cold plasma model and covers kinetic effects like collision-less damping.

P 16.4 Wed 15:25 b302

Wechselwirkung magnetisierter Teilchen mit einer Plasmarandschicht — •Dennis Krüger, Sara Gallian, Jan Trieschmann und Ralf Peter Brinkmann — TET, Ruhr-Universität Bochum, Deutschland

High Power Impulse Magnetron Sputtering (HiPIMS) ist eine neuartige physikalische Gasphasenabscheidungstechnik. Durch die Feldkonfi-

guration in Kombination mit kurzen Pulsen hoher Leistung wird eine sehr hohe Plasmadichte sowie eine hohe Ionisationsrate unter den gesputterten Atomen erzeugt. Durch HiPIMS abgeschiedene Schichten zeichnen sich durch verbesserte Schichtqualität in Bezug auf Härte, Rauigkeit, Porosität und Adhesion aus. Zur vollständigen Charakterisierung der Systemdynamik eines HiPIMS-Prozesses ist eine 3D PIC-MC Simulation problematisch, da diese sehr lange Rechenzeiten benötigt. Der Grund liegt in den auftretenden sehr hohen Dichten im Bereich von 10^{18} m^{-3}. Die seit Jahrzehnten in der Fusionsforschung erfolgreich etablierte gyrokinetische Theorie könnte hierfür einen Ausweg liefern. Bei der Adaption dieses Formalismus stellt sich die Frage geeigneter Randbedingungen für die Schnittstellen zu anderen Gebieten innerhalb des Systems. Insbesondere die Schnittstelle zur Randschicht über dem Target soll deswegen hinsichtlich geeigneter Randbedingungen genauer untersucht werden.
(Diese Arbeit wird im Rahmen des SFB/Transregio 87 durch die Deutsche Forschungsgemeinschaft gefördert.)

P 16.5 Wed 15:40 b302

Equilibrium and stability of a modulated beam in a plasma wakefield — •Roberto Martorelli — Heinrich Heine Universität, 40225 Düsseldorf, Germany

Particle beams are necessary in a wide range of applications, from medicine to high energy physics. On the other hand the production of always improved beam with the actual technology results in an increasingly dimensions of the accelerator facilities. One promising alternative to RF accelerators is the plasma wakefield acceleration, due to the high acceleration gradients the plasma can sustain. In a plasma wakefield, a driver - laser or particle beam - is injected in a plasma channel, exciting Langmuir waves. The intense electric field carried by the wakefield can be then used for the acceleration of a witness bunch.

Our work is focused on the wakefield driven by a modulated beam. The core of the research consists in the analysis of the equilibrium configuration achieved by the modulated structure as well as in the transverse stability during the propagation in the plasma channel. A long lasting modulated beam is of key importance for an optimal energy transfer from the driver to the witness bunch. Through a semi-analytical approach, combined with particle-in-cell simulations, we study for the initial configuration achieved by the modulated beam, looking subsequently for the proper conditions in order to obtain a stable structure during the propagation in the plasma.

P 16.6 Wed 15:55 b302

Electron acceleration by coherent laser pulses — •Phuc Luu Thanh and Alexander Pukhov — Heinrich-Heine-Universität, Düsseldorf, Germany

We present the recent development in the electron acceleration scheme by coherent laser pulses in periodic structures. The periodic structures is designed to build up an accelerating field while damping down the deceleration phase. The FDTD model of dispersive material is implemented into the PIC framework to simulate the interaction between the laser and the structure. Arteezy was left. The ionisation process is also included. The efficacy of the scheme is measured through the consistent simulation of the electron propagation in dozen structure periods.

P 16.7 Wed 16:10 b302

Laser Ion Acceleration of Spherical Mass Limited Solid Density Targets — •Axel Huebl[1,2], Thomas Kluge[1], René Widera[1], Peter Hilz[3], Jörg Schreiber[3], Ulrich Schramm[1], and Michael Bussmann[1] — [1]Helmholtz-Zentrum Dresden - Rossendorf — [2]Technische Universtität Dresden — [3]Ludwig-Maximilians-Universität München

We present simulation results regarding the acceleration of ions from mass limited solid density targets with short-pulse high power lasers. Taking advantage of large scale 3D3V PIC simulations (8000 GPUs each, INCITE award 2015) allows to give a detailed insight into the dynamics and unique features of truly isolated targets that were used in recent experiments.

We discuss the pre-plasma evolution, its dependence on laser contrast and its crucial influence on the dominant acceleration mechnanism and on the directionality of the laser-accelerated ion beams. Extensive 2D3V parameter scans are presented for comparison with commonly used flat, wire or mounted target designs.

P 16.8 Wed 16:25 b302

3D-Simulation des Verunreinigungstransports in einem Fusions-Randschichtplasma mit dem massiv-parallelen Monte-Carlo Code ERO2.0 — •Juri Romazanov, Dmitriy Borodin, Andreas Kirschner, Christian Linsmeier, Dirk Brömmel, Benedikt Steinbusch und Paul Gibbon — Forschungszentrum Jülich GmbH, Wilhelm-Johnen-Straße, 52428 Jülich, Germany

Der 3D Monte-Carlo Code ERO ist ein etabliertes Werkzeug für die Modellierung der Plasma-Wand-Wechselwirkung (PWW) und des lokalen Verunreinigungstransports in Fusionsexperimenten einschließlich ITER. Der Code wird derzeit grundlegend weiterentwickelt (ERO2.0), um aktuelle und zukünftige Fragestellungen bearbeiten zu können. Insbesondere soll das Simulationsvolumen, welches usprünglich bei $\sim$(10 cm)^3 lag, signifikant vergrößert werden. ERO2.0 soll u. a. durch massive Parallelisierung die dafür nötige Recheneffizienz erreichen. In diesem Beitrag wird das physikalisch-technische Konzept von ERO2.0 vorgestellt, sowie der Effekt eines vergrößerten Simulationsvolumens anhand eines abstrahierten Szenarios der Erosion an einem Limiter untersucht. Da erodierte Partikel bei Vergrößern des Simulationsvolumens über größere Entfernungen verfolgt werden, kommen Ionisation, sowie Reibung mit dem zum Limiter hinströmenden Plasma der Randschicht, zunehmend zum Tragen. Dies führt u. A. zu einer höheren Verunreinigungsdichte in direkter Nähe des Limiters. In Zukunft können damit experimentelle Ergebnisse z.B. zur Selbstzerstäubung besser reproduziert werden.

P 16.9 Wed 16:40 b302

Experimental determination of electron impact transfer rate coefficients between argon 1s states — •Emile Carbone[1], Eddie van Veldhuizen[2], Gerrit Kroesen[2], and Nader Sadeghi[1] — [1]Univ. Grenoble Alpes, CNRS, CEA-Leti Minatec, LTM, F-38054 Grenoble Cedex, France — [2]Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

Rather significant discrepancies between state of the art theoretical calculations and available experimental data have been observed over the years for electron impact transfer rates between excited states of noble gases. In this contribution, we present laser pump-probe experiments for the determination of the electron impact transfer rates between argon 1s metastable and resonant states [1, 2]. One 1s state is selectively depopulated by a nanosecond pulsed dye laser towards a 2p or 3p argon state. All four 1s states are measured by laser diode absorption spectroscopy while the electron density was determined by Thomson scattering. The analysis of the states densities relaxation following the laser perturbation allows us to provide a new set of rate coefficients for the losses of the 1s argon metastable states towards the 1s resonant states. Additionally, an important ion-core exchange term which goes between $1s_2$ and $1s_4$ states is measured. We confirm that the recent R-matrix theoretical calculations tend to underestimate the absolute values for the 1s transfer rates by electron impact.

[1] E. Carbone et al. J. Phys. D: Appl. Phys. (2013) **46** 415202.
[2] E. Carbone et al. J. Phys. D: Appl. Phys. (2015) **48** 425201.

P 17: Plasma Diagnostics II

Time: Wednesday 14:30–16:35 Location: b305

Invited Talk P 17.1 Wed 14:30 b305

Plasma measurement and control: challenges and recent advances — •Timo Gans — York Plasma Institute, Department of Physics, University of York, UK

Precise measurements and control of plasma properties are equally important for fundamental investigations and the development of next generation plasma technologies. This is particularly challenging in atmospheric pressure plasmas due to small dimensions on micron-scales and pronounced dynamics requiring temporal resolution of picoseconds. This presentation will discuss recent advances using radio-frequency atmospheric pressure plasmas as example. These plasmas

are efficient sources for reactive species. The non-equilibrium chemical kinetics is initiated by the electron dynamics. Due to the strongly collisional environment and associated short electron energy relaxation times the electron dynamics can be tailored using multi-frequency power coupling, enabling separate control of key parameters like electron density and electron mean energy. Measurements and predictive simulations of key reactive species are equally challenging due to the strongly collisional environment and their multi-scale nature in space and time. The most promising approach is the exploitation of complementary advantages in direct measurements combined with specifically designed numerical simulations. The employed diagnostic techniques include picosecond laser spectroscopy, synchrotron VUV spectroscopy, UV absorption spectroscopy and nanosecond optical imaging spectroscopy. The presentation will focus on examples of He-O_2-N_2-H_2O mixtures for bio-medical applications.

Fachvortrag P 17.2 Wed 15:00 b305

Endoscope diagnostic for tomography, spectroscopy and thermography on Wendelstein 7-X — •Peter Denner, Olaf Neubauer, Bernd Schweer, and Yunfeng Liang — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung – Plasmaphysik, 52425 Jülich, Germany

Plasma–surface interaction (PSI) in the divertor region of Wendelstein 7-X (W7-X) will be of great importance for operational phase OP1.2. While the erosion of the divertor will have an impact on its lifetime and is therefore a critical subject of investigation, fundamental PSI studies in the divertor region are in many ways equally significant.

These plasma–wall interactions will be influenced by impurity transport, where the complex 3D magnetic geometry will play a crucial role, but this magnetic geometry could itself be influenced by plasma effects such as Pfirsch–Schlüter and bootstrap currents. Therefore, along with measurements of obvious quantities such as heat flux, PSI research in the divertor region will also require measurements of the temperature in the plasma edge and of the concentration and distribution of different impurities, in combination with modelling of impurity transport.

In order to provide the measurements necessary to address these physics questions, a set of endoscopes has been designed for visible and ultraviolet spectroscopy and tomography of the plasma edge, along with infrared thermography of the divertor tiles. An overview of this endoscope diagnostic system will be presented. Details of the measurements to be taken and their relationship to physics issues such as impurity transport and erosion of the divertor will be discussed.

Fachvortrag P 17.3 Wed 15:25 b305

Magnetic diagnostics at Wendelstein 7-X — •K Rahbarnia[1], T Andreeva[1], A Cardella[2], B Carvalho[3], M Endler[1], D Hathiramani[1], O Grulke[1], U Neuner[1], J Svensson[1], H Thomsen[1], J Geiger[1], and A Werner[1] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17489 Greifswald, Germany — [2]Former W7-X, presently JT-60SA project, F4E c/o IPP Boltzmannstr. 2, 85748 Garching, Germany — [3]Instituto de Plasmas e Fusao Nuclear Instituto Superior Tecnico, Lisbon, Portugal

An arrangement of magnetic sensors has been installed at the stellarator Wendelstein 7-X (W7-X) including over 300 individual 3D shaped sensors like diamagnetic loops, Rogowski, Saddle and Mirnov coils. Future long pulse operation of up to 1800 s demands an optimization of materials, thermal shielding and signal integration accuracy. The main objectives are the reconstruction of magnetic equilibria and monitoring the diamagnetic plasma energy. Generally, in stellarators a toroidal current drive is not necessary to maintain confinement. Minimization of toroidal currents is in fact one of the major optimization criteria of W7-X. It will be investigated by continuous and segmented Rogowski coils and Saddle coils measuring e.g. bootstrap and Pfirsch-Schlüter currents and their spatial distributions. A set of 125 toroidally and poloidally arranged Mirnov coils will give information on MHD and Alfvén mode activity and edge localized modes (ELMs). A detailed overview of the magnetic diagnostic system is outlined and initial results obtained during the first operation phase of W7-X will be presented.

P 17.4 Wed 15:50 b305

Fotografische Messung der energieabhängigen Wirkungsquerschnitte für Elektronenstoßanregung — •Dirk Luggenhölscher, Xi-Ming Zhu und Uwe Czarnetzki — Ruhr Universität Bochum, Institut für Experimentalphysik V

Die Kenntnis der Wirkungsquerschnitte für Elektronenstoßanregung ist für die quantitative Spektroskopie sowie der Modellierung von Plasmen von großer Bedeutung. Üblicherweise werden diese durch Schwarmexperimente bestimmt. Dabei ist es jedoch schwierig, bei niedrigen Energien nahe der Anregungsschwelle zu messen. Dieser Bereich ist jedoch für Niedertemperaturplasmen mit geringen Elektronenenergien von besonderer Bedeutung. Mit der fotografischen Methode ist auch dieser Bereich gut zugänglich. Hierbei werden mit einem gepulsten UV-Laser Photoelektronen ausgelöst und in einem statischen und homogenen elektrischen Feld mit bekannter Stärke beschleunigt. Durch Stöße mit dem Hintergrundgas werden dessen Atome angeregt und die Fluoreszenz ortsaufgelöst detektiert. Da an jedem Ort die potentielle Energie und somit die der Elektronen bekannt und die gemessene Intensität proportional zum Wirkungsquerschnitt bei dieser Energie ist, kann aus der räumlichen Intensitätsverteilung direkt der relative Wirkungsquerschnitt bestimmt werden. Durch die Auswahl geeigneter Spektrallinien ist die gezielte Vermessung einzelner Übergänge möglich und erste Ergebnisse an Neon und Helium werden präsentiert. Verfälschendende Kaskadenprozesse können durch die sehr schnelle Anregung und Detektion jeweils im ns-Bereich vermieden werden, bzw. deren Einfluss kann durch Variation der Detektionszeit gezielt untersucht werden.

P 17.5 Wed 16:05 b305

Experimental determination of EEDF and He_2^* Rydberg-state density by Thomson scattering in a ns-pulsed atmospheric micro-discharge. — •Christian-Georg Schregel, Dirk Luggenhölscher, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr-University Bochum, 44780 Germany

An open question of major importance for the investigation of atmospheric micro plasmas is the shape of the EEDF. This has been addressed by using incoherent Thomson scattering as a non-invasive diagnostic. The technique has been applied to measure the temporal evolution (Δt=20 ns) of the EVDF for a pure Helium plasma between two plane molybdenum electrodes, 0.95 mm apart. The plasma is pulsed with a repetition rate of 5 kHz at 0.7 bar. Measurements were done by a 532 nm Nd:YAG laser and a triple grating spectrometer with a gated ICCD for detection. The setup allows for detection of electron energies between 0.5 eV and 12 eV with up to three orders of magnitude in the dynamic range. Additionally, time resolved optical emission spectra where recorded and the Helium metastable was density probed by laser absorption. With the different diagnostic data combined, variation of laser energy used in Thomson scattering could additionally be utilized as a probe for the absolute Helium Excimer Rydberg-state density, allowing a unique determination of absolute density values in the early stages of the afterglow. Peak electron densities of $2 \cdot 10^{20} m^{-3}$ with a peak electron temperature of 2 eV have been observed.

P 17.6 Wed 16:20 b305

Measurement of molecular argon ion density at atmospheric pressure — •Torsten Gerling, Markus Becker, Christian Wilke, and Klaus-Dieter Weltmann — INP Greifswald, Deutschland

By observing fast oscillation on the current signal we are able to determine the ion density at an atmospheric pressure plasma source. The discharge is a transient spark with currents up to 2 A and a halfwidth of only 10 ns. This discharge shows oscillations in the current decay phase, which have a declining frequency from 250 MHz down to 50 MHz. This presentation will discuss the origin of this fast oscillation as an ion acoustic wave. We will present the solution of the dispersion relation for these conditions. Based on the solution the limits of observation are computed and the dependencies for the existence discussed. Finally the present possibilities and limitations of this method will be summarized.

P 18: Poster Session- Plasma Technology

Time: Wednesday 16:30–19:00 Location: Empore Lichthof

P 18.1 Wed 16:30 Empore Lichthof

Energieaufgelöste Massenspektrometrie an prekursorhaltigen Prozessplasmen — •Nils Lukat, Erik von Wahl und Holger Kersten — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Deutschland

Mit Hilfe der energieaufgelösten Massenspektrometrie ist es möglich Informationen über die im Plasma erzeugten Ionen zu erhalten. Die Massenspektrometrie ist von besonderer Bedeutung, wenn Plasmen untersucht werden, in denen sich komplexe Moleküle befinden, wie dies z.B. bei der Abscheidung von Polymerschichten auf Substraten der Fall ist. Durch Kollisionen mit energetischen Elektronen wird ein Teil dieser Moleküle im Plasma dissoziiert. Abhängig von den Plasmaparametern können so Produkte auf unterschiedlichsten Reaktionswegen entstehen. Insbesondere die relativen Häufigkeiten dieser Ionen zu den Ionen des Hintergrundgases sind nur schwer vorauszusagen und oft nur experimentell zu bestimmen. Um die relevanten Parameter für einen solchen Beschichtungsprozess zu bestimmen, wird in dieser Arbeit ein Massenspektrometer zur Messung der Ionenparameter eingesetzt. Dabei werden dem Trägergas Argon Dichloro-[2,2]-Paracyclophan Moleküle beigemischt, welche als Ausgangsstoff für Parylene C Schichten dienen. Um diese Messungen zu ermöglichen, muss das Massenspektrometer kalibriert werden. Dabei ist darauf zu achten, dass es unabhängig von den Parametern der zu detektierenden Ionen vergleichbare Energie und Massenspektren liefert. Ziel dieser massenspektrometrischen Untersuchung ist die Aufklärung der chemischen Reaktionen, die im Plasma ablaufen und deren Korrelation zu den Kenngrößen der HF-Entladung.

P 18.2 Wed 16:30 Empore Lichthof

Stress in a-C:H und a-Si:H Schichten auf PET — •Markus Brochhagen, Jan Benedikt und Marc Böke — Ruhr-Universität Bochum, Experimentalphysik II, Universitätsstraße 150, 44801 Bochum

a-C:H und a-Si:H Schichten werden verwendet um auf PET flexible Barriereschichten aufzutragen. Zur Verbesserung der Dehnungstoleranz ist das Verständnis des intrinsischen Stresses in den verschiedenen Schichten von hoher Bedeutung. Verschiedene Kohlenstoff- und Silizium-haltige Schichten werden auf PET in induktiv und kapazitiv gekoppelten Plasmen abgeschieden und anschließend auf ihre Barriere- und Dehnungs-Eigenschaften untersucht. Zusätzlich werden Änderungen des intrinsischen Stresses in Abhängigkeit des Substratbias beobachtet und überprüft, ob thermische Einflüsse während des Beschichtungsprozesses eine Rolle spielen. Für a-C:H Schichten auf PET konnte gezeigt werden, dass eingestellter intrinsischer Stress die Dehnungstoleranz verbessern kann. Im weiteren Verlauf wird die Übertragbarkeit für Silizium-haltige Schichten untersucht.

P 18.3 Wed 16:30 Empore Lichthof

Plasma etch requirements for technological preparation of photonic building blocks — •Harald Richter[1], David Stolarek[1], Mirko Fraschke[1], Steffen Marschmeyer[1], Christian Mai[1], Stefan Lischke[1], Lars Zimmermann[1,2], Andreas Mai[1], Stefan Meister[2], Christoph Theiss[2], and Hanjo Rhee[2] — [1]IHP, Im Technologiepark 25, 15236 Frankfurt (Oder) — [2]Technische Universität Berlin, Institut für Optik und Atomare Physik, Straße des 17. Juni 135, 10623 Berlin

The combination of silicon photonic and electronic components on the same chip is a prospective approach for processing of optoelectronic integrated circuits. The idea of a compact integration of both components is based on the compatibility of silicon-on-insulator (SOI) photonics with highly integrated microelectronic technologies. The integration of photonic building blocks with a state-of-the-art BiCMOS process requests a combination of local SOI regions in a bulk silicon environment.

The present work is focused on the technological fabrication of integrated silicon photonic basic features. Here, plasma etching is a key technological process step for realization of suitable substrate with local SOI and bulk Si regions and the subsequent preparation of diverse silicon photonic components (waveguides, nanowires, coupling structures, photonic crystals). Different hard masks for the several plasma etch processes were tested and optimized. Experiments have shown the mask open step is significant for preparation of high-performance silicon photonic modules.

P 18.4 Wed 16:30 Empore Lichthof

Timing and reproducibility of pin to plate pulsed nanosecond discharges in air and water — •Emile Carbone[1], Bang-Dou Huang[1,2], Yi-Kang Pu[2], and Uwe Czarnetzki[1] — [1]Institute for Plasma and Atomic Physics, Ruhr-University Bochum, 44780 Germany — [2]Department of Engineering Physics, Tsinghua University, Beijing 100084, People's Republic of China

In this contribution, we present initial investigations of nanosecond pulsed DC discharges in air and water. One of the main challenges to perform diagnostics on such discharges is to obtain reproducible discharges pulse to pulse and with low jitter. Discharges generated by two different home made pulsed DC power supplies are investigated and characterized by voltage and current measurement. The pulsed power supplies allow to deliver voltage pulses of about 10kV with rise times of about 2 or 50 ns, on-times of 10 or 200 ns and variable pulse repetition rates. Sub-nanosecond time and wavelength resolved optical emission spectroscopy measurements are performed with a streak camera. The measurements allow to probe the ignition and afterglow dynamics of the pulsed discharge with high temporal resolution.

P 19: Poster Session- Laser Plasmas

Time: Wednesday 16:30–19:00 Location: Empore Lichthof

P 19.1 Wed 16:30 Empore Lichthof

Collisionless Shocks in laboratory plasmas — •shikha bhadoria, naveen kumar, and christoph h. keitel — Max Planck Institute for nuclear physics, Heidelberg, Germany

Collisionless shocks are formed when two counter-propagating streams of plasmas are collided. This situation occurs quite often in astrophysical environments e.g when the supernova remnant blast shell hits the interstellar medium etc. This can be envisaged in a laboratory easily by irradiating two energetic laser pulses on thin-foil targets placed opposite to each other. These collisionless shocks are responsible for extreme acceleration of charged particles (e.g. cosmic rays) by Fermi acceleration mechanism, however little is known about their formation process. We present results of collisionless shock formation in such a situation and discuss their implications for the astrophysical scenario.

P 19.2 Wed 16:30 Empore Lichthof

Kinetic effects in strongly coupled Brillouin laser seed pulse amplification — •Götz Lehmann and Karl-Heinz Spatschek — HHU Düsseldorf, 40255 Düsseldorf

Today laser intensities on the order of 10^{22} W/cm^2 can be achieved via chirped pulse amplification. Due to the damage thresholds of amplifier crystals and compressor gratings, laser systems which offer intensities magnitudes larger are either extremely costly or unrealistic. Plasma-based concepts such as Brillouin amplification offer a potential route towards lasers on the scale of 100 PW or even beyond.

In Brillouin amplification a long and energetic pump pulse is backscattered into a short seed pulse off an ion oscillation [1,2]. For sufficiently strong pump pulses, the beat of pump and seed drives a strongly-coupled ion oscillation, which acts as a Bragg grating, backscattering the pump into the seed.

The amplification dynamics is often modeled by envelope models. With the help of Maxwell-Vlasov simulations we explore the validity of these models and establish the role of kinetic effects on the grating. We find that strong electron trapping determines the late time dynamics of the Bragg grating, however the amplification process is not significantly affected by this.

[1] G. Lehmann and K.H. Spatschek, Phys. Plasmas 20, 073112 (2013) [2] F. Schluck, G. Lehmann and K.H. Spatschek, Phys. Plasmas 22, 043105 (2015)

P 19.3 Wed 16:30 Empore Lichthof

Time-Resolved In-Line-Holography for Observing Laser Plasmas — •Hannes Bassen[1], Neeke Rothe[1], Christoph Merschjann[2], Franziska Fennel[1], and Stefan Lochbrunner[1] — [1]Universtität Rostock, D-18059 Rostock, Germany — [2]Freie Universität Berlin, D-14195 Berlin, Germany

Dense laser-induced plasmas attract strong scientific interest. They are crucial in understanding the interaction between condensed matter and intense laser radiation as well as in providing an elegant and powerful approach to study warm dense matter. Here we focus on the experimental setup to detect diffraction patterns created by dense plasmas with a radius of about 30 μm in a thin gold foil. This results from the interaction of the foil with an intense, ultrashort pump laser pulse, which creates a dense plasma and finally leaves a hole. Using a temporally shifted and frequency doubled probe pulse we are able to gather the caused diffraction pattern with a CCD camera. Afterwards we can obtain information about structure, transmittance and phase at a certain delay by using an iterative algorithm based on the angular spectrum method: We implemented the phase retrieval algorithm and additionally use a hybrid-input-output algorithm, which keeps feedback information from previous iterations. To ensure convergence and fewer artifacts in the reconstruction we also restrict the plasma area regularly by applying a shrink-wrap mask. Comparison of images reconstructed from diffraction patterns of holes in the gold foil with REM images shows perfect match. The method allows to reconstruct the spatially resolved plasma dynamics.

P 19.4 Wed 16:30 Empore Lichthof

Dynamics of spatially overlapping flat top electromagnetic solitons in plasmas — •Sita Sundar — Christian-Albrechts-Universität Kiel

Interaction of ultra-intense laser with plasma exhibits a rich variety of interesting nonlinear phenomena. Numerical and asymptotic solutions describing the interactions of relativistically intense plane electromagnetic waves and cold plasmas are of fundamental importance for nonlinear science and are considered to be a basic component of turbulence in plasmas. The numerical identification of solitons stimulated a renewed interest in developing an analytical model and in envisaging ways of detecting solitons experimentally. The inclusion of ion response in the relativistically intense electromagnetic laser pulse propagation in plasma yields certain distinct varieties of single peak solitonic structures. A falt-top slow moving structure is one such solution. Here, detailed characterization and numerical investigations on mutual interactions between two spatially overlapping electromagnetic flat-top solitons in plasma will be presented.

P 19.5 Wed 16:30 Empore Lichthof

Elektronenbeschleunigung in relativistischen Gauß-Laguerre Laserpulsen — •Camilla Willim, Götz Lehmann und Carsten Müller — Theoretische Physik I, Heinrich-Heine Universität, 40225 Düsseldorf, Germany

In Laserfeldern mit Intensitäten oberhalb von 10^{18} W/cm^2 wird die Bewegung von Elektronen relativistisch. Freie Elektronen werden von Laserpulsen ponderomotorisch gestreut und können so relativistische Energien erhalten. Wir untersuchen die Dynamik von Elektronen welche an ultrakurzen relativistischen Gauß-Laguerre Laserpulsen gestreut werden.

Gauß-Laguerre Strahlen sind Lösung höherer Ordnung der paraxialen Wellengleichung. Im Vergleich zur Grundmode, den Gauß Strahlen, besitzen diese Lösungen einen Drehimpuls und haben eine deutlich komplexeres transversales Intensitätsprofil. Von speziellem Interesse sind Moden deren Intensitätsprofil im Zentrum ein Minimum aufweist.

Wir untersuchen sowohl die Beschleunigung von anfänglich ruhenden Teilchen, als auch die Nachbeschleunigung von injizierten Teilchen. Es zeigt sich, dass neben der gewöhnlichen ponderomotorischen Beschleunigung ein zweiter Mechanismus hohe Energien produzieren kann. Elektronen können vorübergehend in einer bestimmten Phase des Feldes gefangen werden und so in einem quasi-statischen Feld beschleunigt werden. Anhand von Vergleichen mit Gauß Strahlen zeigt sich, dass Gauß-Laguerre Strahlen potentiell zu deutlich höhere Elektronenenergien führen können.

P 19.6 Wed 16:30 Empore Lichthof

Raman amplification in the coherent wavebreaking regime — •John Farmer and Alexander Pukhov — Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf

Raman amplification in plasma is a potential method for the creation of ultra-short, ultra-intense laser pulses. We show that in regimes far beyond the wavebreaking threshold of Raman amplification, significant amplification can occur after the onset of wavebreaking, before phase mixing destroys the coherent coupling between pump, probe and plasma wave. Amplification in this regime is therefore a transient effect, with the higher-efficiency "coherent wavebreaking" regime accessed by using a short, intense probe.

Parameter scans illustrate the marked difference in behaviour between below wavebreaking, in which the energy-transfer efficiency is high but total energy transfer is low, wavebreaking, in which efficiency is low, and coherent wavebreaking, in which moderate efficiencies allow the highest total energy transfer.

P 20: Poster Session- Low Temperature Plasmas

Time: Wednesday 16:30–19:00 Location: Empore Lichthof

P 20.1 Wed 16:30 Empore Lichthof

Optische und elektrische Charakterisierung einer Oberflächen-DBE — •Rouven Klink, Manfred Kettlitz, Hans Höft und Ronny Brandenburg — Leibniz-Institut für Plasmaforschung und Technologie e.V., Felix-Hausdorff-Straße 2, 17489 Greifswald

Die Eigenschaften und die Entwicklung von Mikroentladungen bei Atmosphärendruck hängen von der Entladungskonfiguration, der elektrischen Beschaltung und der Gasart ab. Dielektrisch behinderte Entladungen (DBE) sind extrem kurzlebig und weisen eine komplexe raumzeitliche Struktur auf. Neben Volumenentladungen treten auch Oberflächenentladungen auf, die Gegenstand der Untersuchungen sind. Die Oberflächen-DBE werden in einem Stickstoff-Sauerstoff Gasgemisch bei Atmosphärendruck auf einer Keramikoberfläche erzeugt. Diese werden elektrisch und optisch durch schnelle ICCD-Kameras und eine Streakkamera diagnostiziert. Mit deren Hilfe werden das Zündverhalten und die weitere Entladungsentwicklung untersucht. Die Messungen werden durch Simulation des elektrischen Feldes der Entladungskonfiguration ergänzt.

P 20.2 Wed 16:30 Empore Lichthof

Separated effects of ions, metastables and photons on the properties of barrier layers on polymers — •Beatrix Biskup, Marc Böke, Jan Benedikt, and Achim von Keudell — Experimental Physics II - Application Oriented Plasma Physics, Ruhr-University Bochum, 44780 Bochum, Germany

Analyses of a-C:H /a-Si:H multilayers on polymer substrates indicated that prolonged ion bombardment influences negatively the properties of the barrier layer, while a short plasma pretreatment can improve the barrier effect. This work is motivated by these results and plans to investigate the influence of different plasma particle species, namely ions, metastables and (V)UV-photons, on the properties of the grown barrier layer. To separate the different species and their influence on plasma pretreatment and film growth, we will build an ion-repelling grid system, which will repel the ions from the substrate, so that only metastables and (V)UV-photons will have an effect on the layer. In a second approach we will try to separate the effect of argon metastables from the effect of (V)UV photons. In addition to the before mentioned ion-repelling grid we will use a collimator with a high aspect ratio and an argon or helium gas-shower before the substrate. With this setup it will be possible to reduce the metastable density in front of the substrate, so that only (V)UV-photons will have an effect. In this approach we will be able to study the different effects of the plasma species and also possible synergy effects, to improve the properties of

the barrier layer.

P 20.3 Wed 16:30 Empore Lichthof

Sticking probability for an electron hitting a dielectric surface — •Franz Xaver Bronold and Holger Fehske — Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, 17489 Greifswald, Deutschland

The energy of an electron hitting the wall of a low-temperature plasma is typically below 10 eV. In this energy range little is quantitatively known about the interaction of electrons with solids. For instance, the probability S with which the electron gets stuck in the wall is basically unknown. In plasma modeling S is thus very often set to unity, irrespective of the wall material (perfect absorber model for electrons). To study the material dependence of S we developed a method for calculating S from a microscopic model for the wall [1]. The method, based on an invariant embedding principle, expresses S as the probability for quantum-mechanical transmission through the wall's long-range surface potential times the probability to stay inside the wall despite of internal backscattering. Besides emission of optical phonons and/or interband Coulomb collisions we take elastic scattering due to imperfections at the plasma-wall interface into account. Applying the approach to dielectrics with positive electron affinity, we obtain energy- and material-dependent sticking probabilities significantly less than unity, in accordance with available electron beam scattering data, but in disagreement with the perfect absorber model employed in plasma modeling. — Supported by DFG through CRC/Transregio TRR24.

[1] F. X. Bronold and H. Fehske, Phys. Rev. Lett. **115**, 225001 (2015)

P 20.4 Wed 16:30 Empore Lichthof

Calorimetric probes for the characterization of an atmospheric pressure plasma jet used in plasma medicine: the ongoing search — •Diana Mance[1,2], Ruben Wiese[1], Thorben Kewitz[1], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Department of Physics, University of Rijeka, Rijeka, Croatia

During the last decade atmospheric pressure plasma jets (APPJs) have found numerous applications in medicine, dentistry and life sciences. Among others, APPJs have been used for microorganism inactivation, wound healing, cancer cells growth inhibition and deactivation of biofilms on dental implants [1]. But in spite of being in focus of many scientific researches, APPJs are still not completely understood. Determination of plasma energy influx towards the substrate can be considered as the first step in elucidating some of the unresolved issues in plasma medicine such as determining dosage in plasma treatment and understanding of plasma-liquid interactions. In the presented study we compare performances of self-made calorimetric probes [2,3] for the measurement of the energy influx of a commercial APPJ used for biomedical applications. The goal of the study was to find the most adequate calorimetric probe for energy influx measurements under specific conditions encountered in medical practice.

[1] Woedtke et al. Physics Reports 2013, 530:291-320
[2] Kewitz et al. IEEE Trans. plas. sci. 2015, 43(5):1769
[3] Wiese et al. EPJ Tech. and Instr. 2015, 2:2

P 20.5 Wed 16:30 Empore Lichthof

The Kiel research initiative "The Plasma Interface" — •Michael Bonitz[1], Holger Kersten[2], and Franz Faupel[3] — [1]Institut für Theoretische Physik und Astrophysik, CAU Kiel — [2]Institut für Experimentelle und Angewandte Physik, CAU Kiel — [3]Institut für Materialwissenschaft, CAU Kiel

Despite remarkable progress in plasma research over the recent decade quantitative knowledge of the plasma-solid boundary in low-temperature plasmas is still scarce, as there both, experiment and theory face tremendous difficulties. The effect of the solid on the plasma is usually treated purely phenomenologically, e.g. via electron and ion sticking coefficients, secondary electron emission (gamma) coefficients and similar parameters that are, in general, very poorly known. This is not only unsatisfactory, from the point of view of fundamental science, but also lacks predictive power that is needed to boost the potential of existing plasma applications and to discover new ones. Therefore, the Kiel initiative *The Plasma Interface* aims at overcoming these problems, in a unique concerted interdisciplinary effort of plasma physicists, researchers from condensed matter physics, chemistry and material science. This contribution gives an overview on the experimental and theoretical activities that are presently organized at Kiel University, with substantial contributions from Greifswald researchers.

P 20.6 Wed 16:30 Empore Lichthof

Multiscale simulation of plasma-surface processes* — Jan Willem Abraham[1], Paolo Ferriani[1], •Michael Bonitz[1], and Bernd Hartke[2] — [1]Institut für Theoretische Physik und Astrophysik, CAU Kiel — [2]Institut für Physikalische Chemie, CAU Kiel

An accurate simulation of the processes at the interface of a plasma and solid is severely hampered by vastly different parameters in the two subsystems, most importantly, extremely different electron densities. This leads to very disparate time and length scales of relaxation and transport processes in the plasma and the solid. While there exist efficient theoretical approaches to treat the electron dynamics in the plasma (e.g. PIC) and in the solid (e.g. DFT or quantum kinetic theory), no method is available to selfconsistently simulate the entire system. The only way out is to develop multi-scale simulations that combine i) an atomistic treatment of the lattice–using density functional theory (DFT) or tight-binding DFT (DFTB)–, ii) a quantum treatment of surface processes such as diffusion barriers and reaction rates–using DFT or reactive force fields (EVB-QMDFF) [1]–and iii) a mesoscopic approach for the atom dynamics and cluster growth on the surface–using kinetic Monte Carlo (KMC) or classical Langevin dynamics (LMD) in the presence of a plasma. Here we outline this concept and present results for the final stage [2, 3].

1) B. Hartke et al., Phys. Chem. Chem. Phys. **17**, 16715 (2015). 2) J. W. Abraham et al., J. Appl. Phys. **117**, 014305 (2015). 3) J. W. Abraham, and M. Bonitz, submitted for publication (2015).
*Part of the Kiel research initiative "The Plasma Interface"

P 20.7 Wed 16:30 Empore Lichthof

Quantum Kinetic Approach to transport at the plasma interface* — Karsten Balzer[1] and •Michael Bonitz[2] — [1]Rechenzentrum der CAU Kiel — [2]Institut für Theoretische Physik und Astrophysik, CAU Kiel

For an accurate treatement of plasma-wall interaction in low-temperature plasmas and the associated transport of charge, momentum and energy, the behavior of nonequilibrium electrons and ions at the wall is crucial. This requires to go beyond the traditional empirical approach to charged particle sticking and secondary electron emission as demonstrated in [1]. Here we outline a selfconsistent kinetic approach that will, eventually, allow to combine classical kinetic theory in the plasma and quantum kinetic theory inside the solid. As a first application we present quantum kinetic results for the stopping power of protons in a graphene-type layer. We use nonequilibrium Green functions [2, 3] and dynamical mean field theory to properly treat electronic correlations. Good agreement is observed with available TRIM simulations, for weak coupling. In contrast, for strongly coupled materials deviations are observed [4]. 1) F.X. Bronold and H. Fehske, Phys. Rev. Lett. **115**, 225001 (2015). 2) M. Bonitz, *Quantum Kinetic Theory*, 2nd ed. Springer 2015. 3) K. Balzer, and M. Bonitz, *Nonequilibrium Green's Functions Approach to Inhomogeneous Systems*, Lecture Notes in Physics, Springer, vol. **867** (2013). 4) K. Balzer, and M. Bonitz, submitted for publication (2016)
*Part of the Kiel research initiative "The Plasma Interface"

P 20.8 Wed 16:30 Empore Lichthof

Light scattering by a stratified dielectric particle — •Elena Thiessen, Franz Xaver Bronold, and Holger Fehske — Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany

We present an exact rewriting of the Mie coefficients describing the scattering of light by a stratified dielectric particle which enables their interpretation in terms of an hybridization of the surface modes arising at each interface. We thus obtain from the Mie theory analytically for an arbitrary number of shells and for all multipole orders and hence for arbitrarily sized particles the hybridization scenario, which so far has been employed primarily for small particles in the electrostatic approximation [1]. To illustrate the effect surface mode hybridization has on the topology of the inner and outer electromagnetic fields we analyze in detail the lowest order resonances of a dielectric core-shell particle. In accordance with the hybridization scenario they can be classified as bonding or anti-bonding. The former giving rise to in-phase and the latter to out-of-phase polarization-induced surface charges at the two interfaces of the particle. Outside the particle the Poynting field carries for both types of resonances the topology of anomalous light scattering. Inside the particle however it depends on the type of the resonance and hence reflects the core-shell structure of the particle. The same holds for the inner electric field which determines for instance the spatial variation of dissipation of energy inside the particle

[2]. — Supported by the DFG through CRC/Transregio TRR24.
[1] E. Thiessen *et al.*, arXiv:1507.08122
[2] E. Thiessen *et al.*, Phys. Rev. A **91**, 043837 (2015)

P 20.9 Wed 16:30 Empore Lichthof

Untersuchung eines RF-Plasmajets mittels sich ergänzender Modelle — •F. Sigeneger, J. Schäfer, R. Foest und D. Loffhagen — INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald

Ein nichtthermischer Plasmajet wird durch Kombination dreier Modelle untersucht. Der Jet besteht aus zwei konzentrischen Kapillaren und zwei ringförmigen Elektroden, die die äußere Kapillare umschließen und die RF-Leistung bei 27.12 MHz dem Argonplasma zuführen.

Untersuchungen eines einzelnen Filamentes im aktiven Volumen zwischen den beiden Kapillaren mit Hilfe eines zweidimensionalen phasenaufgelösten axialsymmetrischen Plasma-Fluidmodells liefern räumliche Strukturen des Filaments und Teilchendichten in guter Übereinstimmung mit Messungen. Das daraus ermittelte Heizungsprofil wird in einer Gesamtbeschreibung des Jets einschließlich des Gasflusses und der Reaktionen von Präkursormolekülen sowie deren Transportprozesse im Effluenten verwendet. Die erhaltenen Radialprofile der Teilchenflüsse von Präkursorfragmenten auf ein Substrat stimmen qualitativ mit gemessenen Dicken von abgeschiedenen Schichten überein.

Das dritte Modell widmet sich den beobachteten Erscheinungen von Selbstorganisation, die sich u. a. in einer azimutalen Rotation der Filamente äußert. Hierfür wird mit Hilfe des Heizungsprofils in einem dreidimensionalen Strömungsmodell der Zusammenhang zwischen der Schrägstellung der Filamente und der azimutalen Strömungskomponente nachgewiesen. Parametervariationen bestätigen experimentell gefundene Tendenzen.

Die Arbeit wird durch die DFG im SFB TRR 24 unterstützt.

P 20.10 Wed 16:30 Empore Lichthof

Measurements of Plasma Properties Using Fast Sweeping Langmuir Probe in VINETA-II magnetic reconnection experiment — •Ilya Shesterikov[1], Olaf Grulke[1], Reiner Stenzel[2] und Thomas Klinger[1,3] — [1]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [2]Department of Physics and Astronomy, University of California, Los Angeles, CA 90095-1547 — [3]Institut für Physik, Ernst-Moritz-Arndt Universität Greifswald, Felix-Hausdorff-Straße 6, D-17489 Greifswald

A novel, fast-sweep Langmuir probe has been constructed and successfully operated at VINETA-II magnetic reconnection experiment. This work presents the time-dependent measurements of VINETA-II plasma. The probe is biased by means of a time-dependent sinusoidal voltage signal with a fixed frequency. Current * voltage characteristics are measured along the falling and rising slopes of the applied signal. Probe permits sweep frequency up to 400 kHz. The circuit response has been tested by measuring the known current - voltage characteristics of resistors. The axial plasma current in VINETA is driven by plasma gun pulsed with the time scale of 60 μs. Probe results present the first time dependent measurement of n_e, T_e, and ϕ_{fl} of the gun discharge plasma with and without magnetic reconnection. The n_e measurements agree favorably with those derived from interferometer measurements.

P 20.11 Wed 16:30 Empore Lichthof

Secondary negative ions in oxygen CCP — •Sebastian Scheuer, Ralf Schneider, and Jürgen Meichsner — Institute of Physics, University of Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald, Germany

The influence of electrode material on secondary negative ion emission was studied in an asymmetric, capacitively coupled radio frequency discharge at low oxygen pressure. Beside the stainless steel electrode the investigations were focused on several dielectrics, e.g., silica (SiO2), alumina (Al2O3), magnesia (MgO), on the powered electrode. The secondary negative ions, accelerated in the high-voltage RF sheath toward the plasma bulk and extracted at the grounded electrode, were measured by energy dispersive ion mass spectrometry. The energy distribution ranges from low energetic negative ions penetrating the low-voltage sheath at the grounded aperture of the mass spectrometer to the maximum kinetic energy corresponding to mean RF sheath voltage at the powered electrode. In particular, the high-energetic end of the ion energy distribution contains negative ions which were directly produced on the surface of the powered electrode. In the case of magnesia on the RF electrode the intensity of these energetic negative ions becomes significantly apparent in the ion energy distribution function. First results from PIC-MCC simulation adapted to the experiment are presented.

P 20.12 Wed 16:30 Empore Lichthof

Metastable densities in rf-driven atmospheric pressure microplasma jets in argon and helium — •Stefan Spiekermeier, Marc Böke, and Jörg Winter — Experimental Physics II, Research Department Plasma, Ruhr-Universität Bochum, 44780 Bochum, Germany

Rf-driven atmospheric pressure microplasma jets (μ-APPJ) are usually operated in the homogeneous glow mode (α-mode). At higher powers the glow discharge becomes unstable due to thermal instabilities and turns into a constricted γ-like discharge (constricted mode), which can damage the jet due to the significantly increased temperature in this operation mode. To prevent these instabilities, rf-driven μ-APPJs are predominantly operated in helium since it provides a better thermal conductivity than argon. However, since argon is much more cost-effective, it is worthwhile to achieve a stable operation of the μ-APPJ using argon as feed gas.

Metastable atoms play an important role in the stability of atmospheric pressure discharges, since they pose an important source of electrons via stepwise ionization and penning ionization. To understand the basic processes that lead to the transition from α- to the constricted mode, helium and argon metastable densities have been determined in the μ-APPJ in different operation modes using tunable diode laser absorption spectroscopy (TDLAS).

Supported by DFG (FOR1123)

P 20.13 Wed 16:30 Empore Lichthof

Comparison between measured and modeled densities of negative hydrogen ions in an ICP discharge — •Sofia Cristofaro[1,2], Roland Friedl[1], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Creation of negative hydrogen ions in plasma can occur via volume or surface processes. In negative ion sources the more efficient surface production regime is achieved by caesiation of a converter surface, which leads to a transition from volume dominated to surface dominated H^- production. This transition is investigated at the laboratory experiment ACCesS (**A**ugsburg **C**omprehensive **Ces**ium **S**etup). The plasma parameters of the planar ICP discharge are close to the ones of ion sources. Prior to the investigation of the surface process, a quantification of the volume produced negative hydrogen ions is mandatory: the H^- density is measured by a **C**avity **R**ing **D**own **S**pectroscopy system (CRDS), while the plasma parameters, like electron temperature and density, are monitored by means of a Langmuir probe. By varying the pressure and the radio-frequency power, the negative ion density has been investigated and the results are interpreted by means of a 0-dimensional model for H^-. The eventual isotopic difference between hydrogen and deuterium plasmas has also been investigated.

P 20.14 Wed 16:30 Empore Lichthof

Fast plasma potential measurements within a reconnecting current sheet via laser-heated emissive probes — •Adrian von Stechow[1], Olaf Grulke[1], and Thomas Klinger[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald — [2]Ernst Moritz Arndt-Universität Greifswald

During driven magnetic reconnection, a current sheet forms in the plasma between opposed field lines in response to externally applied, time-dependent magnetic fields. In contrast to paradigmatic periodic 2D reconnection models, electrostatic fields should be present not only perpendicular to the current sheet, but also parallel to it due to the axial boundary conditions present in our linear, open field line geometry. Previous results from the linear reconnection experiment VINETA.II suggest that substantial time-dependent electrostatic fields must be present in order to account for the observed current sheet structure and its temporal evolution.

Emissive probes provide a means of directly measuring the plasma potential, providing the electron emission by the probe roughly matches the electron saturation current. The electronics involved in their heating schemes are often plagued by high stray capacitance which limits their time response. In order to capture the fast temporal dynamics present in our experiment, our emissive probe is heated externally by a high-power infrared laser. This contribution presents spatio-temporal plasma potential and electric field profiles recorded by this novel, freely positionable probe system that give further insight into the complex 3D dynamics of our reconnecting system.

P 20.15 Wed 16:30 Empore Lichthof

Simulation of sputter-deposited gold cluster growth on a thin polymer film* — •Jan Willem Abraham[1], Thomas Strunskus[2], Franz Faupel[2], and Michael Bonitz[1] — [1]Institut für Theoretische Physik und Astrophysik, CAU Kiel — [2]Institut für Materialwissenschaft, CAU Kiel

The fabrication of metal-polymer nanocomposites with tailored optoelectronic properties has been a challenge since the early days of nanotechnology. In recent experiments [1], the morphology and optical properties of sputtered gold on a thin polystyrene film were monitored in real time. In this work, we provide additional computational analysis of such a system, presenting a method using Langevin molecular dynamics [2] to simulate the processes on the polymer surface that lead to the formation of gold clusters. The simulation scheme takes into account the deposition of single gold atoms, diffusion of the particles on the surface, desorption of atoms as well the creation of surface defects caused by ion impingement. Comparing heights, radii, distances, and densities of the clusters with experimentally measured data, we observe good quantitative agreement and we explain the influence of several parameters on the cluster morphology.

[1] M. Schwartzkopf et al., ACS Appl. Mater. Interfaces 7, 13547 (2015).

[2] J. W. Abraham, and M. Bonitz, submitted for publication (2015).

*This work is supported by the Deutsche Forschungsgemeinschaft via SFB-TR 24 (project A5).

P 20.16 Wed 16:30 Empore Lichthof

Plasmamedizinische Anwendungen zur Sterilisation — •Sandra Moritz[1], Janine Mandler[1], Daniela Coenen[1], Markus Thoma[1], Eugen Domann[2], Julia Zimmermann[3], Tetsuji Shimizu[3] und Gregor Morfill[3] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Germany — [2]Institut für medizinische Mikrobiologie, Biomedizinisches Forschungszentrum Seltersberg,Gießen, Germany — [3]terraplasma GmbH, Garching, Germany

In den letzten Jahrzehnten sind in der Medizin die Zulassungen von neuen Antibiotika immer weiter zurückgegangen, während immer mehr Bakterien Resistenzen gegen verwendete Antibiotikums-Wirkstoffe entwickelt haben. Dadurch kommt es gerade in Krankenhäusern, in denen der tägliche Kontakt mit diesen resistenten Bakterien unvermeidbar ist, vermehrt zu Hygieneproblemen.
Die Firma terraplasma aus Garching hat sich in diesem Zusammenhang auf die Entwicklung von Plasmageräten spezialisiert, um mit Hilfe von Plasma Bakterien, aber auch Viren, Pilze und Biofilme, zu deaktivieren, bzw. abzutöten.
Mit einer solchen Plasmakammer wurden Versuche an *Escherichia coli* K12, *Staphylococcus aureus* und *Klebsiella Pneumonia* durchgeführt, wobei Versuche hinsichtlich der Unterschiede zur Behandlung von grampositiven und gramnegativen Bakterien, der Resistenzbildung der Bakterien, sowie statistische Messreihen zur Evaluierung der Behandlung durchgeführt wurden.

P 20.17 Wed 16:30 Empore Lichthof

1D fluid simulation of helium-oxygen barrier discharges and adaption to the experiment — •Sebastian Nemschokmichal, Robert Tschiersch, and Jürgen Meichsner — Institute of Physics, University of Greifswald

Helium-oxygen discharges at atmospheric pressure are well established in applications because of their ability to produce oxygen radicals under low power consumption. The use of oxygen in a discharge always causes the formation of negative ions, but the influence of negative ions on barrier discharges is poorly investigated. Therefore, we set up a helium oxygen barrier discharge to prove negative ions in a laser photodetachment experiment.

Supplementary, a 1D fluid simulation is developed for comparison. Exemplarily, simulation results are presented and discussed for a pressure of 500 mbar, an admixture of 400 ppm oxygen to helium, and a gap width of 3 mm. In order to enable the comparison with laser photodetachment experiments, the simulation is adapted to the experimentally observed discharge current and gap voltage by varying gas temperature, flux of thermally desorpted electrons and secondary electron emission coefficients. Afterwards, the discharge is characterized by evaluation of most important elementary collision processes as well as the dynamics of charged species. Particularly, the negative ions are characterized by their spatio-temporal distribution in the gap and their production and loss processes. Furthermore, simulations with and without negative ions are compared to point out the importance of negative ions for the simulated discharge.

P 20.18 Wed 16:30 Empore Lichthof

Interactions of nanoparticles with plasmas — Oleksandr Polonskyi, •Thomas Strunskus, and Franz Faupel — Chair for Multicomponent Materials, Faculty of Engineering, Christian-Albrechts University at Kiel, Germany

In the proposed project the interaction of nanoparticles (NPs) with plasma will be under detailed investigation. The general aim is to gain a fundamental understanding of low temperature low pressure plasma interactions with various types of nanoparticles (metal, metal-oxide, alloys, core-shells and also hydrocarbon or/and similar polymer based types of NPs); to provide qualitative and quantitative analyses of NPs after plasma treatment in dependence on the applied discharge parameters. The following questions should be addressed: which plasma species play the role in plasma interactions with NPs and what is the mechanism of these interactions. What is the correlation between plasma parameters and the properties of the treated nanoparticles? Particular attention will be paid to the investigation of the charging of nanoparticles (especially for case of small sizes 5-100nm) in plasmas region and as the consequence their manipulation and filtering by electrostatic forces will be studied. As one of the aspect of practical application, the plasma treatment of NPs with respect to size effect, chemical composition and functional properties will be under detailed investigation. The aim is to gain more insight how exactly the plasma modifies the nanoparticles.

P 20.19 Wed 16:30 Empore Lichthof

Interaction of Plasmas with Ceramic Materials — •Thomas Strunskus and Franz Faupel — Institute of Materials Science - Multicomponent Materials, Christian-Albrechts University at Kiel, Kaiserstr. 2, 24143 Kiel, Germany

In this project, the interaction of different plasmas with ceramic materials (mainly tin dioxide, titanium dioxide and aluminum oxide) will be investigated. The goal is to gain fundamental insight how the plasma exactly modifies a ceramic material on and also below the surface. In recent years plasmas have been frequently used to modify oxide materials but the approach was mainly empirical just identifying the induced change of properties (e.g., change in conductance, sensoric or optical properties). Little attention has been given to the exact mechanisms of these modifications. Here, starting with identifying the relevant species in the plasma and their transport to the surface we will correlate the plasma properties with the modifications induced at the ceramic surface identified with surface analytical techniques. The investigation will also include aging of the plasma modified surfaces. Samples range from single crystals, over multicrystalline thin films to nanostructures (nanowires and nanoparticles) of the same material.

P 20.20 Wed 16:30 Empore Lichthof

The effect of different gas admixtures on nanoparticles formation in a gas aggregation source and their treatment by hollow cathode plasma — Oleksandr Polonskyi, Amir Mohammad Ahadi, •Thomas Strunskus, and Franz Faupel — Chair for Multicomponent Materials, Faculty of Engineering, Christian-Albrechts University at Kiel, Germany

Metal nanoparticles (NPs) have been of high scientific interest in the last decades as they have unique chemical, physical, electrical, magnetic and optical properties, which are particularly explored in combination with host matrix. Among the number of PVD methods for nanoparticles generation, the gas aggregation method has lately received an increased attention due to simplicity of NPs deposition and variety of parameters to control their properties (size, rate). The present talk is concerned with a such called Gas Aggregation cluster Source (GAS) for metal and metal oxide nanoparticles generation. New results of the influence of nanoparticles generation by admixing different gases into the GAS volume for noble metals (Ag, Cu) will be presented. The effect of helium/oxygen admixture on cluster formation is studied in detail. In addition we report on the combination of the established process of NPs generation by GAS with a hollow cathode (HC) plasma source for novel nanostructure formation. Here, an Ag nanoparticle beam has been treated by a HC plasma at different operation parameters.

P 20.21 Wed 16:30 Empore Lichthof

Iod als alternativer Treibstoff für Ionentriebwerke — •Nina Sarah Mühlich, Patrick Dietz, Waldemar Gärtner, Kristof

Holste, Julian Kaupe, Peter Köhler, Slobodan Mitic und Peter Klar — Justus-Liebig-Universität Gießen

Ionentriebwerke basieren auf der Ionisation und elektrostatischen Beschleunigung eines Treibstoffes. An diesen Treibstoff werden bestimmte Anforderungen gestellt: Niedriges Ionisierungspotential, hohe atomare Masse und leichte Überführung in den Gaszustand. Iod stellt einen vielversprechenden Kandidaten als Treibstoff dar, der momentan am I. Physikalischen Institut der JLU untersucht wird. Wir präsentieren optische Emissionsspektren von induktiv und kapazitiv gekoppelten Iod-Plasmen in Abhängigkeit von der Neutralgasdichte sowie der in das Plasma eingekoppelten Leistung zur Diagnostik von Ionentriebwerken. Diese Spektren sollen mit theoretischen Modellen verglichen werden, um die für das Triebwerk relevanten Plasmaparameter (Ionisationsgrad, Elektronendichte) zu ermitteln.

P 20.22 Wed 16:30 Empore Lichthof

Short Timescale Phenomena in Plasma-Surface Interactions* — •Jean-Pierre van Helden and Jürgen Röpcke — Leibniz Institute for Plasma Science and Technology (INP Greifswald), Greifswald

Understanding how plasmas interact with solid and liquid surfaces is of central importance in many fields such as microelectronics, materials and surface processing and in environmental and biomedical technologies. Improving process efficiency requires a comprehensive understanding of the kinetics of the transient intermediates involved at the plasma-substrate interface. The experimental approaches currently available provide an incomplete picture of plasma-surface interactions due to relatively low sensitivity and low time resolution, and restricted multi-species capability. We propose to use state of the art mid-infrared frequency combs (FCs) to provide novel spectroscopic data on plasma-surface problems. FCs will be used as the light sources in broadband cavity enhanced direct frequency comb spectroscopy (CE-DFCS) that can detect many transient species simultaneously yielding comprehensive data on their kinetics in proximity to the surface on a microsecond scale. Simultaneously the surface will be probed by an evanescent-wave provided by attenuated-total-reflection-CE-DFCS. The simultaneous measurement of the plasma and surface environments with the high sensitivity and time resolution of DFCS will provide new fundamental insights into the physics and chemistry of the interfacial region, an essential step for improving plasma technology in industry.

*Part of the Kiel research initiative 'The Plasma Interface'

P 20.23 Wed 16:30 Empore Lichthof

Oberflächenladungsmessungen an lateral strukturierten Barrierenentladungen auf verschiedenen Zeitskalen — •Robert Wild und Lars Stollenwerk — Institut für Physik, Universität Greifswald

In Barrierenentladungen sind Oberflächenladungen auf den Dielektrika maßgeblich am Entladungsverlauf beteiligt. Sie sind insbesondere notwendig bei der Ausbildung von lateralen Entladungsstrukturen. Durch sie wird eine Struktur über viele Entladungen erhalten und somit oft mit bloßem Auge erkennbar.

In dieser Arbeit wird die zeitlich aufgelöste Oberflächenladungsdichteverteilung auf einem elektro-optisch aktiven BSO-Kristall als Dielektrikum gezeigt. Die absolute Ladungsdichte wird aus der Polarisationsänderung eines Lichtstrahls ermittelt, der den Kristall durchläuft. Durch verschiedene zeitliche Auflösungen wird das Verhalten von Oberflächenladungen auf vier verschiedenen Zeitskalen studiert.

Die höchste zeitliche Auflösung liegt in einer Größenordnung von einigen 100 ns. Dadurch kann die Deposition von Ladung während eines Durchbruchs erstmals beobachtet werden. Auf der Mikrosekundenzeitskala werden die Abhängigkeiten der stationären Ladungsverteilungen diskutiert. Die Messung der Ladung im Millisekundenbereich zeigt den Einfluss von metastabilen Spezies im Entladungsvolumen auf die Erhaltung der lateralen Entladungsstruktur. Der Ladungsabbau und -transport wird in einer Größenordung von Sekunden untersucht.

Gefördert durch die Deutsche Forschungsgemeinschaft, Sonderforschungsbereich SFB TRR-24, Teilprojekt B14.

P 20.24 Wed 16:30 Empore Lichthof

Sulphur dioxide removal from gas streams using a sorbent powder in a dielectric barrier discharge — •Sebastian Dahle[1,2], Marina Unseld[1,2], and Wolfgang Maus-Friedrichs[1,2] — [1]Clausthaler Zentrum für Materialtechnik, Technische Universität Clausthal, Leibnizstr. 9, 38678 Clausthal-Zellerfeld, Germany — [2]Institut für Energieforschung und Physikalische Technologien, Technische Universität Clausthal, Leibnizstr. 4, D-38678 Clausthal-Zellerfeld, Germany

Emissions of sulphur dioxide (SO_2) are highly problematic for climate, health and buildings. The amount of SO_2 emitted each year, however, is currently increasing. One main origin of SO_2 emissions is the transportation sector. Further, a significantly increasing source is the use of biomass for energy production. Dielectric barrier discharge plasmas are able to completely remove the SO_2 from exhaust gas streams. This process becomes especially effective if the plasma discharges is directly combined with a cheap powder sorbent such as limestone. The combination of a quadrupole mass spectrometer and an electro-chemical sensor system was used to determine the influence of the treatment on the composition of the gas streams.

P 20.25 Wed 16:30 Empore Lichthof

Surface charge measurements on transparent dielectrics in diffuse and filamentary barrier discharges — •Robert Tschiersch[1], Marc Bogaczyk[2], Sebastian Nemschokmichal[1], and Jürgen Meichsner[1] — [1]Institute of Physics, University of Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald, Germany — [2]Leibniz Institute for Plasma Science and Technology, Felix-Hausdorff-Str. 2, 17489 Greifswald, Germany

This work reports on the realization of surface charge measurements on dielectrics which are frequently used in barrier discharge (BD) configurations. The surface charge was measured spatially and temporally resolved via the electro-optic Pockels effect of $Bi_{12}SiO_{20}$ (BSO). The innovative feature consists in covering the BSO crystal with optically transparent dielectrics, such as float glass (based on SiO_2), monocrystalline alumina (Al_2O_3), and magnesia (MgO). The dynamics and the spatial distribution of negative and positive surface charges were studied in diffuse and filamentary BDs operated in helium with variable admixture of nitrogen at elevated gas pressures. In particular, the amount of transported charge is compared with the amount of deposited surface charge. Moreover, the lateral distribution of separated surface charge spots is determined, which mark the footprints of filamentary breakdown channels. As the previously reported surface charge diagnostic was specific for a BSO surface exposed to the plasma, the present work achieves a more generalizable level making this powerful method accessible to various transparent dielectrics.

P 20.26 Wed 16:30 Empore Lichthof

Einfluss unterschiedlicher Oberflächen auf die Produktion negativer Wasserstoffionen — •Roland Friedl[1], Uwe Kurutz[1,2] und Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Quellen negativer Wasserstoffionen basieren entweder auf der reinen Volumenproduktion im H_2-Plasma oder nutzen zusätzlich die Wechselwirkung mit Oberflächen. Für letztere Alternative werden typischerweise cäsierte Oberflächen verwendet, welche durch die verringerte Austrittsarbeit eine hohe Effizienz der H^--Produktion aufweisen. Die Cäsierung der Konversionsoberfläche bringt allerdings eine komplexe Umverteilungsdynamik mit sich und die hohe Reaktivität von Cs führt zu Degradierungseffekten der Austrittsarbeit. Hinsichtlich der Stabilität und Reproduzierbarkeit der H^--Ausbeute sind daher Alternativen zu cäsierten Oberflächen wünschenswert.

Vielversprechende Alternativmaterialien sind u.a. Diamantmodifikationen, Materialien, die die Volumenproduktion unterstützen, sowie Materialien niedriger Austrittsarbeit neben Cs. Diese werden am ECR-Laborexperiment HOMER systematisch hinsichtlich ihres Einflusses auf die Dichte negativer Wasserstoffionen untersucht, welche mittels Laser-Photodetachment lokal über der Probenoberfläche bestimmt wird. Dabei liegt der Fokus auf der Bewertung der bestimmten H^--Dichte relativ zu der reinen Volumenproduktion im H_2-Plasma und der bisherigen Maximalausbeute durch Beschichtung mit Cäsium.

P 20.27 Wed 16:30 Empore Lichthof

Combined quadrupole mass spectrometry and quartz-enhanced photoacoustic spectroscopy for the demonstration of a plasma-based ammonia depletion — •Sebastian Dahle[1,2], Michael Köhring[3,4], Wolfgang Schade[3,4], and Wolfgang Maus-Friedrichs[1,2] — [1]Clausthaler Zentrum für Materialtechnik, Technische Universität Clausthal, Leibnizstr. 9, 38678 Clausthal-Zellerfeld, Germany — [2]Institut für Energieforschung und Physikalische Technologien, Technische Universität Clausthal, Leibnizstr. 4, D-38678 Clausthal-Zellerfeld, Germany — [3]Fraunhofer Heinrich-Hertz-Institut, Am Stollen 19H, 38640 Goslar, Germany — [4]Energie-Forschungszentrum Niedersachsen, Am Stollen 19B, 38640

Goslar, Germany

Reducing ammonia contents in exhaust gas streams is very important for a large number of applications. The main origins of ammonia emissions are livestock feeding and industrial processing, e.g. during the production of rare earth metals. We implemented a highly efficient plasma-based process using a dielectric barrier discharge reactor. The influence of the plasma discharge on the gas composition includes a fragmentation of many gaseous components. Therefore, we used a combination of a quadrupole mass spectrometer and an inline quartz-enhanced photoacoustic sensor for our analysis.

P 20.28 Wed 16:30 Empore Lichthof

Modeling DC, CCP and ICP discharges using PlasmaPIC — •Robert Henrich, Michael Becker, and Christian Heiliger — Institut für Theoretische Physik, Justus-Liebig-Universität Gießen

PlasmaPIC is a three-dimensional particle in cell (PIC) code. It consists of an electrostatic part for modeling DC and CCP discharges as well as an electrodynamic part for modeling inductively coupled discharges. The three-dimensional description enables the modeling of discharges in arbitrary geometries without limitations to any symmetry. These geometries can be easily imported from common CAD tools. A main feature of PlasmaPIC is the ability of an excellent massive parallelization of the computation, which scales linearly up to a few hundred cpu cores. This is achieved by using a multigrid algorithm for the field solver as well as an effective load balancing of the particles. Moreover, PlasmaPIC includes the interaction of the neutral gas and the plasma discharge. Because the neutral gas and the plasma simulation are acting on different time scales we perform the simulation of both separately in a self-consistent treatment, whereas the neutral gas distribution is calculated using the direct simulation Monte Carlo method (DSMC). The merge of these features turns PlasmaPIC into a powerful simulation tool for a wide range of plasma discharges and introduces a new way of understanding and optimizing low-temperature plasma applications. This work has been supported by the "Bundesministerium fuer Wirtschaft und Energie". Grant 50RS1507

P 21: Magnetic Confinement II

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

Invited Talk P 21.1 Thu 11:00 b302

The behavior of helium in fusion plasmas — •Athina Kappatou[1], Rachael M. McDermott[1], Clemente Angioni[1], Thomas Pütterich[1], Ralph Dux[1], Michael G. Dunne[1], Rudolf Neu[1], Alexander Lebschy[1,2], Eleonora Viezzer[1], Marco Cavedon[1,2], the EUROfusion MST1 Team[3], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Physik-Department E28, TU München, Garching, Germany — [3]See http://www.euro-fusionscipub.org/mst1

The presence of helium is fundamentally connected to the performance of a fusion reactor. The energetic α-particles produced by the D-T fusion reactions will heat the plasma through collisions. However, the thermalised helium content in the plasma core should be minimized as it dilutes the fusion fuel. Hence, understanding the transport of helium is indispensable, as is the availability of experimentally validated theoretical tools, to predict the helium density profile in future machines.

Helium transport investigations have been undertaken in dedicated experiments at ASDEX Upgrade. The experimental helium density profiles, measured with charge exchange spectroscopy, are compared with the theoretical predictions, obtained from gyrokinetic simulations. The comparison revealed features, which indicate a missing piece in the current understanding of low-Z impurity transport. In addition, while it is well known that the confinement in helium plasmas is lower than in deuterium plasmas, recent experiments show that helium deteriorates plasma confinement even at low concentrations. The efforts to shed light on the physics behind this detrimental effect will be presented.

Invited Talk P 21.2 Thu 11:30 b302

Energy and Particle Core Transport in Tokamaks and Stellarators compared — •Marc Beurskens, Clemente Angioni, Craig Beidler, Andreas Dinklage, Golo Fuchert, Matthias Hirsch, Thomas Puetterich, and Robert Wolf — Max-Planck-Institut für Plasmaphysik, 17491 Greifswald/85748 Garching, Germany

The paper discusses expectations for core transport in the Wendelstein 7-X stellarator (W7-X) and presents a comparison to tokamaks. In tokamaks, the neoclassical trapped-particle-driven losses are small and turbulence dominates the energy and particle transport. At reactor relevant low collisionality, the heat transport is limited by ion temperature gradient limited turbulence, clamping the temperature gradient. The particle transport is set by an anomalous inward pinch, yielding peaked profiles. A strong edge pedestal adds to the good confinement properties. In traditional stellarators the 3D geometry cause increased trapped orbit losses. At reactor relevant low collisionality and high temperatures, these neoclassical losses would be well above the turbulent transport losses. The W7-X design minimizes neoclassical losses and turbulent transport can become dominant. Moreover, the separation of regions of bad curvature and that of trapped particle orbits in W7-X may have favourable implications on the turbulent electron heat transport. The neoclassical particle thermodiffusion is outward. Without core particle sources the density profile is flat or even hollow. The presence of a turbulence driven inward anomalous particle pinch in W7-X (like in tokamaks) is an open topic of research.

Fachvortrag P 21.3 Thu 12:00 b302

Mikrowellenheizung und -diagnostik: Leistungsstarke Werkzeuge zum Betrieb von Wendelstein 7-X — •Torsten Stange, Hans-Jürgen Hartfuss, Matthias Hirsch, Udo Hoefel, Heinrich Peter Laqua, Stefan Marsen, Dmitry Moseev, Robert Wolf und The W7-X Team — MPI für Plasmaphysik, Greifswald

Die Nutzung von Mikrowellen hat sich in den letzten Jahrzenten zu einem der wichtigsten Instrumente für die Erzeugung und Heizung von Fusionsplasmen oder für Transportuntersuchungen und Messung von wichtigen Plasmaparametern entwickelt. Die Effektivität der Elektronen-Zyklotron-Resonanz-Heizung (ECRH) sowie die mittlerweile erlangte Souveränität beim Umgang mit Hochleistungsmikrowellen führt dazu, dass der größte Stellarator, Wendelstein 7-X (W7-X), mit einem 140GHz-Heizsystem in Betrieb gehen wird, das in der Lage ist mehrere MW im Dauerstrichbetrieb bereit zu stellen. In der ersten Operationsphase (OP1.1) von W7-X werden insgesamt 6 Gyrotrons zur Verfügung stehen, die einer absorbierten Leistung von bis zu 5MW im Plasma entsprechen. Um bei der Inbetriebnahme eine schnellere Plasmazündung zu erreichen, wird in den ersten Wochen von OP1.1 mit Helium als Entladungsgas gearbeitet. Die Optimierung der Zündung sowie des weiteren Plasmaaufbaus erfolgt mit Hilfe verschiedener Mikrowellendiagnostiken. Innerhalb von 2s werden bei einer absorbierten Leistung von 1MW und einer Elektronendichte von $5{\cdot}10^{19}\mathrm{m}^{-3}$ stabile Elektronen- und Ionentemperaturen von über 2keV erwartet.

P 21.4 Thu 12:25 b302

Impact of Lithium on the plasma performance in the all-metal-wall tokamak ASDEX Upgrade — •P.T. Lang[1], R. Moreno Quicios[1], R. Arredondo Parra[1], B. Ploeckl[1], R. Maingi[2], D.K. Mansfield[2], A. Diallo[2], R. McDermott[1], R. Neu[1], E. Wolfrum[1], and ASDEX Upgrade Team[1] — [1]MPI für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [2]Princeton Plasma Physics Laboratory, Princeton, NJ 08543, USA

Several tokamaks reported improvement in key plasma parameters concurrent with the presence of lithium in the plasma. At ASDEX Upgrade explorative experiments have been performed to find out if such effects can be observed when operating with an all-metal-wall. A gas gun launcher was developed capable to inject pellets containing about 1.6×10^{20} Li atoms at 2 Hz. The speed of about 600 m/s is sufficient to achieve core penetration and to create a homogeneous Li concentration of up to 10 %. With a typical sustainment time on the order of 100 ms, only transient Li presence without any pile up was achieved. Deposition of Li on plasma facing components, which remained for several discharges after injection, was observed. This short lived wall conditioning showed beneficial effects during plasma start-up. However, the accompanying surface contamination negatively impacted some diagnostics. The Li impact on the confinement was investigated in a dedicated plasma scenario with a proven sensitivity to nitrogen and helium. In phases with N seeding enhancing the confinement by about 30 %,

Li injection resulted in a very modest, transient loss of confinement (about 5 %). No Li impact was found for pure Deuterium plasmas.

P 21.5 Thu 12:40 b302

2D Heat Flux Pattern in ASDEX Upgrade L-Mode With Magnetic Perturbation — •Michael Faitsch, Bernhard Sieglin, Thomas Eich, Albrecht Herrmann, Wolfgang Suttrop, and the ASDEDX Upgrade Team — Max-Planck-Institute for Plasma Physics, Boltzmannstr. 2, D-85748 Garching, Germany

A future fusion reactor is likely to operate in high confinement mode (H-mode). This mode is associated with a periodic instability at the plasma edge that expels particles and energy. This instability is called edge localized mode (ELM). External magnetic perturbation (MP) is one technique that is thought to be able to mitigate or even suppress large ELMs in next step fusion devices such as ITER, where the ELM induced heat load for unmitigated ELMs might limit the lifetime of the divertor. Applying an external magnetic perturbation breaks the axisymmetry and leads to a 2D steady state heat flux pattern at the divertor. The ASDEX Upgrade tokamak is equipped with 16 perturbation coils, 8 above (upper row) and 8 below (lower row) the outer mid plane, toroidal equally distributed. A high resolution infra red system is measuring the heat flux at the outer target at a fixed toroidal position with a resolution of around 0.6 mm. In order to measure the 2D structure a slow rotation of the MP field was applied (1 Hz) with a toroidal mode number n=2. The differential phase between the upper and lower row was changed to investigate the effect of the alignment with the field lines at the edge. The density was varied to study the density dependence of the heat transport with applied external MP and compare it to the axisymmetric scenario.

P 22: Theory and Modelling III

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

Invited Talk P 22.1 Thu 11:00 b305

Fluid-kinetisches Hybrid Modell für Plasmarandtransport in He-Plasma am Stellarator Wendelstein 7-X — •Michael Rack[1], Detlev Reiter[1], Felix Hasenbeck[1], Yuhe Feng[2] und Petra Börner[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung – Plasmaphysik, 52425 Jülich, Germany — [2]Max-Planck-Institute für Plasmaphysik, 17491 Greifswald / 85748 Garching, Germany

Die komplexe 3D Struktur des Plasmas im Randbereich des Stellarators Wendelstein 7-X kann nur zum Teil mittels experimenteller Messungen erfasst werden. Dies macht die wichtige Rolle einer detaillierten Modellierung als eine weitere Methode zur Studie der Dynamik am Plasmarand deutlich.

Der 3D Fluidcode EMC3, gekoppelt an den kinetischen Neutralteilchencode EIRENE, bilden eine etablierte Grundlage zur Modellierung der Plasmarandschicht in komplexen Magnetfeld-Geometrien.

Da Wendelstein 7-X (und später wohl auch ITER) in einer ersten Betriebsphase Heliumplasmen einschließen wird, diskutiert dieser Beitrag einen neuen Ansatz zur Verallgemeinerung des verwendeten Plasmamodells in fusionsrelevanten Randschichtsimulationen. Dabei wird, selbstkonsistent gekoppelt, He^{++} als Fluid simuliert, Heliumatome kinetisch betrachtet und He^{+} kann kinetisch, fluidmechanisch, oder mit einem Hybridansatz modelliert werden.

Ein Vergleich der Vorhersagen für Helium- und Wasserstoffplasmen wird präsentiert und gegebenenfalls, wenn bis zur Konferenz vorhanden, anhand erster Messungen an Wendelstein 7-X bewertet.

Fachvortrag P 22.2 Thu 11:30 b305

Thermische und chemische Nichtgleichgewichtseffekte in freibrennenden Bogenplasmen — •Margarita Baeva — INP Greifswald , Felix-Hausdorff-Strasse 2, 17489 Greifswald

Lichtbogenentladungen sind in zahlreichen industriellen Anwendungen vertreten. Eine wichtige Rolle spielen nicht nur die Prozesse im Plasma, sondern auch diese nah der Oberfläche der verwendeten Elektroden. Die vom thermodynamischen Gleichgwicht stark abweichende Grenzgebiete leiten den elektrischen Strom von der/zur Elektrode, kontrollieren die Wärmebilanz der Elektroden und dementsprechend deren Lebensdauer. In diesem Beitrag werden Effekte präsentiert und diskutiert, welche vom thermischen und chemischen Nichtgleichgewicht in freibrennenden Lichtbögen in Argon bewirkt werden. Die Ergebnisse umfassen Werte der Stromstärke zwischen 100 und 200 A, Elektrodenabstand von 5 bis 10 mm sowie Variation des Elektrodenmaterials und Form der Elektrodenspitze. Die Ergebnisse zeigen, dass Nichtgleichgewicht nah der Elektroden eine signifikante Auswirkung auf die Temperaturverteilung, elektrische Leitfähigkeit und Stromdichte und die elektrische Spannung haben. Chemisches Nichtgleichgewicht im Grenzgebiet der Kathode ist auf Transportprozesse zurückzuführen. Überbesetzung des atomaren Grundzustandes im zentrallen Bereich des Lichtbogens, Unterbesetzung der elektronisch angeregten Zustände in der Peripherie, axiale Abhängigkeit des Maximum des radialen Emissionkoeffizienten für of Ar I bei 696.5 nm, aufgehobene Besetzung des Ar (1s4) Resonanzniveuas in der Peripherie sind weitere Effekte des Nichtgleichgewichts.

P 22.3 Thu 11:55 b305

Kinetic simulations of core-hole relaxation in bulk material irradiated by hard x-rays — Beata Ziaja[1,2], •Vikrant Saxena[1], Sang-Kil Son[1], Nikita Medvedev[1], Michal Stransky[3], Bianka Woloncewicz[4], and Benjamin Barbrel[5] — [1]Centre for Free-Electron Laser Science, DESY, Notkestrasse 85, Hamburg 22607, Germany — [2]Institute of Nuclear Physics, Polish Academy of Sciences, Radzikowskiego 152, 31-342 Kraków, Poland — [3]Department of Radiation and Chemical Physics, Academy of Sciences of the Czech Republic, Na Slovance 2, 182 21 Prague, Czech Republic — [4]Faculty of Mathematics, Physics and Informatics, University of Gdańsk, ul. Wita Stwosza 57, 80-952 Gdańsk, Poland — [5]Center for Intense Lasers and Applications, University of Bordeaux 1, 351 Cours de la Liberation, F-33405 Talence, France

Irradiation of bulk material by hard x-rays creates a non-equilibrium state characterized by the presence of core-hole states taking complicated relaxation paths towards ground state configurations. This relaxation process involves a large number of active configurations even in case of moderately heavy atoms (e.g., 1323 configurations for argon). It is computationally challenging to follow them, even with a kinetic approach which is otherwise an efficient approach for simulation of irradiated bulk material. Here, we propose a simplified approach which limits the number of active configurations by restricting the sample relaxation to the predominant relaxation paths. We test its reliability, by performing the full calculation for carbon, and comparing it with the simplified scheme.

P 22.4 Thu 12:10 b305

Investigation of ion structure factors and transport coefficients in warm dense matter — •C.-V. Meister[1], D.H.H. Hoffmann[1], T.S. Ramazanov[2], S.K. Kodanova[2], M.T. Gabdullin[3], and M.K. Issanova[1,2] — [1]IKP, Technische Universität Darmstadt and Graduate School of Excellence Energy Science and Engineering, Darmstadt, Germany — [2]IETP, Al-Farabi Kazakh National University, Almaty, Kazakhstan — [3]NNLOT, Al-Farabi Kazakh National University, Almaty, Kazakhstan

Recently, the interest in the study of various properties of warm dense matter, i.e. matter with kinetic energies of more than 0.2 eV and particle densities of more than 10^{25} m^{-3}, strongly increased. Under such conditions, the transport coefficients of plasmas are strongly influenced by the ion distribution, i.e. by the ion-ion structure factor. The larger the ratio of the ion-ion potential energy to the ion kinetic energy Γ, the stronger the effect. On the other hand, it is believed that hypernetted chain (HNC) approximations and the mean spherical (MS) approximatiion are applicable for systems with large Γ. Thus, in the present work, electrical and heat conductivities of warm dense matter are calculated within Born approximation neglecting the ion-ion structure factor and considering it. For the ion-ion structure factor values are taken into account, which were observed in experiments or are calculated using HNC or MS approximations. It is found that the values of the electrical and heat conductivities in plasmas at solid state density, calculated considering the ion-ion structure factor, are about 20 times larger than the values obtained neglecting the structure factor.

P 22.5 Thu 12:25 b305

Ab Initio Thermodynamic Results for the Uniform Electron

Gas at Finite Temperature — •Tobias Dornheim, Tim Schoof, Simon Groth, and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel

The uniform electron gas (UEG) at finite temperature is of high current interest due to its key relevance for many applications including dense plasmas and laser excited solids, as well as density functional theory. Quantum Monte Carlo (QMC) simulations of the UEG in the highly degenerate regime are generally hampered by the fermion sign problem. Until recently, at finite temperature, low densities had been accessible solely to Restricted PIMC (RPIMC) calculations [1], which, however, are afflicted with an uncontrollable systematic error. In this work we, therefore, combine two novel complementary approaches that allow us to simulate the UEG over a broad parameter range: Configuration PIMC (CPIMC) [2,3] and Permutation Blocking PIMC (PB-PIMC) [4,5].

[1] E. Brown *et al.*, Phys. Rev. Lett. **110**, 146405 (2013)
[2] T. Schoof *et al.*, Contrib. Plasmas Phys. **51**, 687 (2011)
[3] T. Schoof *et al.*, Phys. Rev. Lett. **115**, 130402 (2015)
[4] T. Dornheim *et al.*, New J. Phys. **17**, 073017 (2015)
[5] T. Dornheim *et al.*, J. Chem. Phys. (in print), arXiv:1508.03221

P 22.6 Thu 12:40 b305

On the pressure exerted by a plasma on a wall — Uwe Czarnetzki and •Tsanko Vaskov Tsankov — Institute for Plasma and Atomic Physics, Ruhr-University Bochum, 44780 Germany

Recent measurements [1] have drawn the attention of the community to the pressure that a plasma exerts on surfaces it is in contact with. However, these high-quality measurements were lacking an *ab initio* theoretical explanation. Here an analytical model backed up by numerical simulations provide such an explanation.

It is shown that for a 1D case that the sum of all pressures – static and dynamic pressures by the particles and the "pressure" of the electrostatic field – remain constant at each point in the plasma. Therefore, the pressure obtained by the measurements at the walls is equal to the pressure in the center of the plasma, where the static pressure by the electrons is the major contributor. This interpretation of the experimental results provides a novel method for plasma diagnostics. The theory is generalised also for higher dimensions where slight deviations from a constant pressure appear.

[1] Th. Trottenberg, Th. Richter and H. Kersten, *Eur. Phys. J.* D **69** (2015) 91.

P 22.7 Thu 12:55 b305

Numerical analysis of radio-frequency sheath — •Schabnam Naggary and Ralf Peter Brinkmann — Institute for Theoretical Electrical Engineering, Bochum, Germany

The characteristics of radio frequency (RF) modulated plasma boundary sheaths are studied on the basis of the so-called "standard sheath model". This model assumes that the applied radio frequency ω_{RF} is larger than the plasma frequency of the ions but smaller than that of the electrons. It comprises a phase-averaged ion model – consisting of an equation of continuity (with ionization neglected) and an equation of motion (with collisional ion-neutral interaction taken into account) –, a phase-resolved electron model – consisting of an equation of continuity and the assumption of Boltzmann equilibrium –, and Poisson's equation for the electrical field. Previous investigations have studied the standard sheath model under additional approximations, most notably the assumption of a step-like electron front [1]. This contribution presents an investigation and parameter study of the standard sheath model which avoids any further assumptions. The resulting density profiles and overall charge-voltage characteristics are compared with those of the step-model based theories.

1. V.A. Godyak and Z.K. Ghanna, *Sov. J. Plasma Phys.* **6**, 372 (1979)

P 23: Helmholtz Graduate School for Plasma II

Time: Thursday 14:30–16:25 Location: b302

Fachvortrag P 23.1 Thu 14:30 b302

Investigating structure and dynamics of Yukawa-balls — •Matthias Mulsow and André Melzer — Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, 17487 Greifswald

The aim of this talk is to give an overview on our current research in the field of Yukawa-balls. These three-dimensional strongly coupled systems usually consist of less than one hundred micron-sized particles. By using a harmonic trapping potential they form spherical, crystal-like structures in the plasma sheath region.

In order to investigate their structural and dynamical properties, we developed a new experimental setup. Its centerpiece is a segmented confinement ring that provides us with a trapping potential without disturbing the visual observation. By applying electrical potentials to the ring segments it is possible to modulate fluid mode oscillations onto the cluster. With a slightly modified version of the ring the confinement potential can also be switched off in two spacial directions, inducing a uniform expansion of the cluster. The characteristic expansion behavior is then compared with theoretical prediction [1].

Furthermore, as an example of cluster thermodynamics we have studied structural transitions and analyzed them in terms of configurational Shannon entropies and associated specific heat capacities, as proposed in [2].

The talk will present the new methods mentioned above in detail and put them into perspective.

[1] A. Piel and J. A. Goree, Phys. Rev. E 88, 063103 (2013)
[2] H. Thomsen and M. Bonitz, Phys. Rev. E 91, 043104 (2015)

Fachvortrag P 23.2 Thu 14:55 b302

Particle in Fourier Discretization of Kinetic Equations — •Jakob Ameres[1,2] and Eric Sonnendrücker[1,2] — [1]Zentrum Mathematik, Technische Universität München — [2]Max-Planck-Institut für Plasmaphysik, Garching

Particle methods are very popular when it comes to the discretization of kinetic equations. They are easy to implement and embarrassingly parallel. In plasma physics the high dimensionality (6D) of the problems raises the costs of grid based codes, favouring the mesh free transport with particles and its inherent adaptivity by following characteristics. The Particle in Cell (PIC) scheme couples the particle density to a grid based field solver using finite elements or finite differences. Finite elements yield an energy conserving scheme, whereas finite differences exclusively conserve momentum by the absence of particle self force. In this particle mesh coupling the stochastic error appears as noise, while the deterministic error leads to e.g. aliasing, inducing unphysical instabilities. By projecting the particles onto a spectral grid, we derive an energy and momentum conserving, aliasing-free scheme, Particle in Fourier (PIF). This method allows us to investigate the aliasing and stochastic errors of a B-spline based PIC code in case of the turbulent kinetic electrostatic electron nonlinear (KEEN) waves. In electrostatic problems governed by a strong magnetic field the anisotropies are transported along the magnetic field lines. These anisotropies can often be resolved with few Fourier modes. Here, PIF allows for the selective calculation of these relevant field aligned Fourier modes in a tokamak model, hence reducing the computational complexity.

Fachvortrag P 23.3 Thu 15:20 b302

Doppler Coherence Imaging of Ion Dynamics in VINETA.II and ASDEX-Upgrade — •Dorothea Gradic[1], Oliver Ford[1], Tilmann Lunt[2], and Robert Wolf[1] — [1]Max-Planck Institut für Plasmaphysik, D-17491 Greifswald, Germany — [2]Max-Planck Institut für Plasmaphysik, D-85748 Garching, Germany

In magnetically confining plasma experiments, diagnosis of ion flows is of great importance to measure the plasma response to the magnetic field or the exhaust particle flows in the divertor areas. Doppler coherence imaging spectroscopy (CIS) is a relatively new technique for the observation of plasma bulk ion dynamics. It is a passive optical diagnostic enabling line-integrated measurements to obtain 2D images of the ion flow and ion temperature. The general principle is similar to traditional Doppler spectroscopy, however CIS uses an imaging interferometer to perform narrow-bandwidth Fourier spectroscopy.

A major advantage of the coherence imaging technique is the large amount of spatial information recovered. This allows tomographic inversion of the line-integrated measurements. With existing CIS setups, scrape-off-layer and high field side edge impurity flows could be ob-

served in the MAST, core and edge poloidal He II flows in the WEGA stellarator and divertor impurity flows in DIII-D.

The main objective of this study is the research of ion dynamics in the small linear plasma experiment VINETA.II and ASDEX-Upgrade. First Doppler CIS measurements from Ar-II plasma discharges in VINETA.II and He-II, C-III divertor flows in ASDEX-Upgrade and their preliminary interpretation will be presented.

Fachvortrag P 23.4 Thu 15:45 b302

Heavy ion transport in the core of ASDEX Upgrade — •Tomáš Odstrčil[1,2], Thomas Pütterich[1], Clemente Angioni[1], Roberto Bilato[1], Anja Gude[1], Didier Mazon[3], Didier Vezinet[1], and ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, D-85748 Garching, Germany — [2]Physik-Department E28, Technische Universität München, 85747 Garching, Germany — [3]CEA, IRFM F-13108 Saint Paul-lez-Durance, France

High impurity concentration in the core of the future fusion reactors can lead to the serious degradation of the achievable fusion gain. Therefore, a better understanding of the underlying impurity transport processes is necessary for higher performance, more efficient power exhaust and avoidance of impurity accumulation.

Radial impurity transport is mainly driven by neoclassical and turbulent particle fluxes. Both these components show substantial variation depending on the poloidal angle. Consequently, an asymmetry in the poloidal distribution of impurities leads to significant changes in the radial impurity flow and the total content of the plasma core.

The aim of this contribution is to experimentally verify a model describing the poloidal asymmetry of heavy impurities using measurements from ASDEX Upgrade. The observed asymmetries are caused mainly by the centrifugal force and poloidal electric force created by the fast particles produced by intensive ion-cyclotron heating. Finally, a change in the radial transport of the tungsten ions will be presented in the case of large inboard and outboard impurity accumulation.

P 23.5 Thu 16:10 b302

O(^{1}S) formation and loss processes in the terrestrial nightglow — •Olexandr Lednyts'kyy and Christian von Savigny — Ernst-Moritz-Arndt-University of Greifswald, Greifswald, Germany

The retrieval of atomic oxygen concentration ([O]) profiles was performed with help of volume emission rate (VER) profiles calculated from the measured by SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) emissions of green line nightglow in the MLT (Mesosphere/Lower Thermosphere) region. To reflect complex molecularity of the green line emissions we discussed quenching profiles that correspond to retrieved [O] profiles. The peak of a VER profile is placed approximately at the altitude of the maximum of an [O] profile, where the contributions of the O and O_2 quenching processes are similar. However, the [O]:[O_2] ratio was observed to be low (at lower altitudes, where VER values are proportional to $[O]^3$) and high (at higher altitudes, where VER values are proportional to $[O]^2[M]$) in dependence on pressure and temperature. So, fast collisional relaxation dominate the radiative deactivation of both O_2^* and O(^{1}S) metastable species at low altitudes and vice versa at high altitudes. However, in the [O] retrieval according to the well-known cubic equation it is assumed that laboratory measured reaction rates of quenching processes can be represented in dependence on temperature only. Nevertheless, we applied the extended cubic equation in the [O] retrieval to reflect the pressure and temperature dependence of the laboratory measured reaction rates of quenching processes under atmospheric conditions in the MLT region.

P 24: Low Temperature Plasmas II

Time: Thursday 14:30–16:25 Location: b305

Invited Talk P 24.1 Thu 14:30 b305

Design and characteristics of the COST Reference Microplasma Jet for bio-medicine — •Judith Golda, Julian Held, and Volker Schulz-von der Gathen — Experimental Physics II, Ruhr-University Bochum, Bochum, Germany

Low temperature atmospheric pressure plasma jet devices enable the production of reactive species while the gas temperature is low. Hence, a variety of different sources is commonly used for surface modification and especially considered for use in bio-medicine. To understand and predict the interaction of plasma with biological tissue, a profound knowledge of the complex system and the underlying processes is crucial.

However, the variety of sources complicates the comparability of results and thus leads to a huge delay in scientific progress. To solve this problem, we developed the COST Reference Microplasma Jet within the European COST Action MP1101 for scientific purposes. Researchers around the world should be able to compare the characteristics of their own sources and their results with this device.

Here, we show the simple and robust design as well as a basic characterization of the COST-Jet. Requirements for reproducible results as well as power, optical emission spectroscopy and gas temperature measurements are presented. Additionally, the heat impact on a treated surface is investigated by Schlieren imaging, thermocouple measurements and comparison to numerical simulations.

Funded by the DFG within "PlaCID (Plasma Cell Interaction in Dermatology)" SCHU-2353/3-1.

Fachvortrag P 24.2 Thu 15:00 b305

Electronegativity during E-H transition in inductively coupled RF oxygen discharge — •Thomas Wegner, Christian Küllig, and Jürgen Meichsner — Institute of Physics, University of Greifswald

The E-H transition of an inductively coupled radio frequency oxygen discharge (ICP) is investigated using enhanced plasma diagnostics. Therewith, the positive ion saturation current, electron density and temperature, gas temperature, ground state ($O_2\left(X^3\Sigma_g^-\right)$) and metastable ($O_2\left(a^1\Delta_g\right)$) density are measured with high resolution in RF power input during the E-H transition. Further, the RF sheath dynamics are although studied. The attenuation of the RF sheath heating and especially the vanishing electric field reversal during the E-H transition indicates an decreasing electronegativity defined as the ratio between the negative atomic ion (O^-) and electron density. Additionally, the electron density peak due to collisional detachment of the negative ions with metastables in the early afterglow of a pulsed RF discharge gives information about the negative atomic oxygen ion density, too. Beside of these experimental findings, analytical calculations using a set of particle balance equations provide the negative ion density and consequently the electronegativity. The measured parameter which are mentioned above are used as input parameter for these calculations. The experimental investigations as well as the analytical calculations show that the electronegativity drops drastically from about 25 to 0.2 during the E-H transition.

//Funded by the DFG CRC/Transregio 24, project B5.

P 24.3 Thu 15:25 b305

Plasma series resonance as a surface wave phenomenon — •Denis Eremin, Thomas Mussenbrock, and Ralf-Peter Brinkmann — Ruhr-Universität Bochum, Universitätsstrasse 150, D44801, Bochum

The plasma series resonance (PSR) is an important phenomenon in low-pressure capacitively coupled plasmas. Such bounded plasmas have a natural eigenfrequency determined by the energy oscillation between the electrostatic field in the plasma sheath and the kinetic energy of the bulk plasma electrons and can be resonantly pumped, should the rf current exhibit a finite-amplitude harmonic at that frequency. In the low-pressure plasmas the PSR significantly contributes to the plasma heating by generating highly energetic electron beams. Traditionally, the PSR has been treated in the literature as a 1d phenomenon. However, it appears to be a part of a more general phenomenon of a surface wave propagating in the discharge. This talk will discuss the connection between the PSR and the surface wave using both theoretical analysis and numerical results.

P 24.4 Thu 15:40 b305

Global modelling of cylindrical surface wave discharges — •Efe Kemaneci and Ralf Brinkmann — Ruhr-University Bochum, Bochum, Germany

The surface wave discharges have a unique axial structure of dielectric-plasma interface that allows the plasma to enlarge axially due to the microwave propagation along the interface. This feature differentiates them from other types of plasmas that mostly associates with much smaller axial lengths and very different axial characteristics. This unique structure is to be considered in global (0-D volume-averaged) modelling approaches in order to self-consistently define the ion and electron losses at the wall as well as the energy dissipated in the sheath. In this study, we focus on this issue and implement a global model of pulse-modulated and continuous surface wave discharges.

P 24.5 Thu 15:55 b305

Einfluss verschiedener Gefäßmaterialien auf Dissoziationsgrad und Rotationsbesetzung molekularen Wasserstoffs in einem ICP. — •David Rauner[1,2], Stefan Briefi[1] und Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Die Wechselwirkung von Plasmen mit Oberflächen kann wesentlichen Einfluss auf eine Reihe verschiedener Plasmaparameter haben. In Wasserstoff-Niederdruckplasmen sind dabei zum einen Prozesse zu nennen, die einen Einfluss auf den Dissoziationsgrad molekularen Wasserstoffs aufweisen, wie beispielsweise die Reformation von H zu H_2 und das Sticking atomaren Wasserstoffs an den Oberflächen. Darüber hinaus können Interaktionsprozesse mit diesen Oberflächen auch zu einer Vibrations- und Rotationsanregung bzw. -umbesetzung von Wasserstoffmolekülen führen.

In einem induktiv gekoppelten Wasserstoffplasma (13,56 MHz, 300 W) wird der Einfluss verschiedener Oberflächenmaterialien untersucht. Die Plasmaerzeugung erfolgt im Druckbereich von 1 bis 10 Pa mittels einer helikalen Spule um ein Zylindergefäß (Länge 20 cm, Durchmesser 5 cm). Verglichen wird der Einfluss verschiedener Entladungsgefäße aus den Materialien Quarzglas, Al_2O_3 und AlN u.a. bei Variation des Druckes. Die Plasmaparameter bzw. Rotationsbesetzungen werden dabei mit Hilfe der optischen Emissionsspektroskopie (OES) sowie Stoß-Strahlungsmodellierung bestimmt.

P 24.6 Thu 16:10 b305

Spatio-temporal characterisation of multiple diffuse and single filamentary breakdowns in a plane-parallel barrier discharge configuration — •Robert Tschiersch[1], Sebastian Nemschokmichal[1], Marc Bogaczyk[2], and Jürgen Meichsner[1] — [1]Institute of Physics, University of Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald, Germany — [2]Leibniz Institute for Plasma Science and Technology, Felix-Hausdorff-Str. 2, 17489 Greifswald, Germany

Helium-nitrogen barrier discharges (BDs) were operated at gas pressures from 100 mbar up to 1 bar inside an interelectrode gap of 3 mm using a concentric, plane-parallel discharge cell configuration. The latter enables the formation of multiple diffuse breakdowns per half cycle of the sinusoidal feeding voltage, as well as laterally patterned BDs and single filamentary BDs driven by a square wave voltage. These discharge modes were comprehensively studied by electrical measurements, optical emission spectroscopy and surface charge diagnostics. Regarding the multiple diffuse breakdowns, the spatio-temporally resolved optical emission identifies the first breakdown as the glow mode, the last breakdown as the Townsend mode, and the ones in between as a hybrid of both modes. As shown by the surface charge measurements, the consecutive breakdowns ignite alternately at laterally inner and outer regions of the electrode. Regarding the breakdown mechanism of patterned BDs as well as single filamentary BDs, the investigations reveal characteristics which declare this discharge type as an intermediate between the glow mode and the microdischarge.

P 25: Poster Session- Theory and Modelling

Time: Thursday 16:30–19:00 Location: Empore Lichthof

P 25.1 Thu 16:30 Empore Lichthof

Analytische Lösungen des vereinfachten EMC3 Models — •Jörg Cosfeld[1], Felix Hasenbeck[1], Michael Rack[1] und Yuhe Feng[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung – Plasmaphysik, 52425 Jülich, Germany — [2]Max-Planck-Institute für Plasmaphysik, 17491 Greifswald / 85748 Garching, Germany

Ein Testbed zur Weiterentwicklung des 3D-Monte-Carlo-Code EMC3 [1] wird durch analytische Lösungen der zugrunde liegenden Braginskii-Gleichungen [2] für verschiedene vereinfachte Spezialfälle erstellt. Der EMC3-Code wird in der Beschreibung der Plasmarandschicht von Fusionsexperimenten dazu genutzt, um Teilchen-, Impuls- und Energiebilanzen mit Hilfe eines Monte-Carlo-Algorithmus zu lösen. Approximationen wie die Stationarität und Quasineutralität geben vor, unter welchen Randbedingungen die Braginskii-Gleichungen numerisch ge- löst werden. Ziel dieser Arbeit ist, ein breites Spektrum an analytischen Lösungen zur Code-Verifikation zu erstellen. Aktuell wurden analyti- sche Lösungen für eine approximierte eindimensionale Bewegung des Plasmas hergeleitet. Im ersten Fall wird die Bewegung des Plasmas nur in Richtung des von außen angelegten Magnetfeldes berücksichtigt. Hergeleitet wurden auch vereinfachte Lösungen für die Temperatur und Dichte senkrecht zum angelegten Magnetfeld. Eine entsprechende Überprüfung eindimensionaler Simulationen des EMC3-Codes ist da- mit möglich. Aufbauend auf diesen Ergebnissen sollen nun allgemeine- re analytische Lösungen gefunden werden. [1] Y.Feng. J. Nucl. Mater. 266-269:812-818, 199. [2] S.I. Braginskii. Rev. Plasma Phys. 1:205 (1965).

P 25.2 Thu 16:30 Empore Lichthof

Impact of the Boussinesq approximation on the blob propagation in the scrape-off layer — •Alexander Ross, Andreas Stegmeir, David Coster, and Emanuele Poli — Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany

The investigation of radial transport in the scrape-off layer showed that particles and heat are transported turbulently and mainly via field-aligned filaments, appearing as blobs. These blobs are believed to greatly impact the plasma-wall interaction. Here, we want to further explore the blob transport numerically. Starting from the drift reduced Braginskii equations a two-field full-f fluid model is developed, consisting of the continuity and vorticity equations. We do not make use of the commonly used Boussinesq approximation in the vorticity equation. Instead we present a numerical scheme for the important terms and discuss the impact of the Boussinesq approximation on the transport of blobs, first in a slab geometry. The numerical schemes are implemented in GRILLIX, a plasma turbulence code using the field line map approach, which is able to treat complex geometries, especially the separatrix and X-point of diverted magnetic fusion devices. The final goal is the research of the blob propagation in a realistic geometry.

P 25.3 Thu 16:30 Empore Lichthof

Theory-based modeling of ohmic confinement parameters and impurity transport — •Ivan Erofeev, Emiliano Fable, and Clemente Angioni — Max-Planck-Institut für Plasmaphysik, Garching b. München, Deutschland

In L-mode Ohmic plasmas a transition between linear (LOC) and saturated (SOC) confinement regimes has been regularly observed as the density is raised. It is believed to be caused by a shift of the dominant turbulent mode from TEM to ITG. In some tokamaks, this is also accompanied by a flip in core plasma toroidal rotation direction from co- to counter-current. The value of the density at which this transition occurs was shown to depend on such basic regime parameters as the toroidal field and plasma current, as well as many others. In this work this dependence is studied using the ASTRA transport modeling system, extended with TGLF and NEO codes as modules. Other aspects of LOC-SOC transition including simulated turbulent mode spectra are shown. Another part of the work presented is dedicated to the modeling of the evolution of an impurity blob (on the example of Li pellet) as it penetrates the confinement region in typical deuterium plasma. One of the goals of this whole work is to validate the TGLF code against experiment in LOC-SOC relevance in the first part and on the impurity transport side in the second part, with the aim to arrive to full simulations including plasma rotation.

P 25.4 Thu 16:30 Empore Lichthof

Path integral approach to Stark-broadening of Lyman lines from hydrogen plasmas — •Nacira Bedida, Heidi Reinholz, and

Gerd Röpke — University of Rostock, Rostock, Germany

New results for Lyman lines from hydrogen plasmas are presented using the path integral method. Within the path integral approach [1], the time dependent dipole autocorrelation function is obtained in terms of Feynman propagators. Knowing the propagator in comparison to the unperturbed emitter, it is possible to develop a perturbative series. Finally, we obtain a compact formula for the intensity of Lyman lines taking an appropriate ionic micro-field distribution. Good agreement with results obtained within a quantum statistical approach to line profiles [2,3] is found, in particular at high densities and temperatures.

[1] N. Bedida et al. Contrib. Plasma Phys. 54, No 9, 783- 790 (2014); [2] S. Guenter, Habilitation thesis, Rostock University, Germany, 1995; [3] S. Lorenzen et al., Journal of Physics: Conference Series 397, 012021 (2012).

P 25.5 Thu 16:30 Empore Lichthof

Spektral-Kinetische Simulation der Planaren Multipol-Resonanz-Sonde — •Michael Friedrichs[1], Sebastian Wilczek[2], Junbo Gong[2], Ralf Peter Brinkmann[2] und Jens Oberrath[1] — [1]Institut für Produkt- und Prozessinnovation (PPI), Leuphana Universität Lüneburg, Deutschland — [2]Lehrstuhl für Theoretische Elektrotechnik, Ruhr-Universität Bochum, Deutschland

Die Messung von Plasmaparametern wie Elektronendichte und -temperatur während eines Plasmaprozesses ist eine wichtige Voraussetzung für eine Prozesssteuerung oder eine -überwachung. Die aktive Plasma-Resonanzspektroskopie (APRS) stellt eine attraktive Diagnostikmethode für eine solche Überwachung dar, bei der die Eigenschaft von Plasmen, in der Nähe der Plasmafrequenz in Resonanz zu geraten, ausgenutzt wird. Eine spezielle Bauform dieser Diagnostikmethode ist die planare Multipol-Resonanz-Sonde (pMRP). Um mit ihr aus einem gemessenen Spektrum Plasmaparameter zu berechnen, wird eine Relation zwischen Resonanzfrequenzen und Plasmaparametern benötigt. Ein möglicher Ansatz zur Bestimmung der benötigten Relation ist eine spektral-kinetische Simulation der pMRP, die in dieser Arbeit vorgestellt wird. Ähnlich wie bei Particle-In-Cell (PIC) wird bei jedem Zeitschritt aus einer Ladungsverteilung von Superteilchen das Feld und die zugehörige Kraft, sowie anschließend die resultierende Geschwindigkeit und der resultierende Ort der Teilchen berechnet. Der wesentliche Vorteil dieser Methode gegenüber PIC liegt in der gitterfreien Simulation.

P 25.6 Thu 16:30 Empore Lichthof

Electromagnetic resistive-interchange model for type-III-ELM-like limit cycles — •Federico Pesamosca[1,2], Peter Manz[2,3], and Matteo Passoni[1] — [1]Politecnico di Milano, 20133 Milano, Italy — [2]Max- Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [3]Physik-Department E28, Technische Universität München, 85748 Garching, Germany

At the transition from low to high confinement regimes in magnetically confined plasmas regular pulsations in the low kilohertz range occur which are referred to as limit cycles oscillations (LCOs). It is believed that these LCOs are a result of the interaction between zonal fows and drift-wave turbulence whose basis is described by the zero dimensional (0D) Kim-Diamond model. Recent investigations in ASDEX Upgrade have shown that LCOs are not only seen in the magnetic signal, they even show precursor activity identical to type-III ELMs which are believed to be resistive interchange dominated. Also ELMs can be described by 0D-MHD models. To enlighten the role of magnetic fluctuations in the LCO dynamics in general and those of the precursors in particular a model including both zonal fows and MHD is desirable. This has been done by deriving a 0D-model from the 3D electromagnetic turbulence model DALF3. Within the presented model the LCO dynamics has been studied for ASDEX Upgrade conditions.

P 25.7 Thu 16:30 Empore Lichthof

Eigenmode solver for electromagnetic waves in metallic structures — •Sander Coene, Burkhard Plaum, and Thomas Hirth — IGVP, Universität Stuttgart, Germany

To achieve a fusion plasma, a low-pressure gas must first be heated. In order to add energy to the plasma a waveguide and antenna set-up is used to focus an electromagnetic wave into the plasma. If one has knowledge about the eigenmodes in such a waveguide, calculations of wave propagation are immensely simplified in terms of computational time. For standard cross-section shapes (rectangular, circular, ...) analytical solutions exist, but in search of more exotic cross-section shapes that help feed into the fusion plasma, a numerical approach is needed in the form of an eigenmode solver. The development of such a solver can for instance also prove beneficial for designing imaging waveguides with an increased angular range, which are used for fusion plasma diagnostics (e.g. reflectometry and ECE imaging) or for heating (e.g. remote steering).

In these application fields, a high accuracy for the resonance frequencies is of the greatest importance. Therefore we analyze how well-established methods in current high performance computer architecture compare with more modern approaches to obtain the transversal eigenmodes.

P 25.8 Thu 16:30 Empore Lichthof

Zum Einfluss der Elektronenstoßquerschnitte auf die Stoß-Strahlungs-Modellierung eines Ar-Niedertemperaturplasmas[1] — •Jochen Wauer, Jens Harhausen, Rüdiger Foest und Detlef Loffhagen — Leibniz Institut für Plasmaforschung und Technologie, Felix-Hausdorff-Strasse 2, 17489 Greifswald

Zur Untersuchung von Niedertemperaturplasmen kann die optische Emissionsspektroskopie als etablierter Standard gelten. Neben der technischen Realisierung besteht eine hohe Anforderung an die Modellierung der aufgezeichneten Strahldichte- oder Emissionsdaten, um eine quantitative Interpretation zu ermöglichen. Die Beziehung zwischen optischen Daten und Plasmaparametern wird durch Stoß-Strahlungs-Modelle hergestellt. Hierfür werden u.a. Stoßquerschnitte für die Anregung von Neutralteilchen durch Elektronenstöße benötigt. Diese werden gegenwärtig durch quantenmechanische Berechnungen bestimmt oder aus Schwarmdaten abgeleitet. Vergleicht man Stoßquerschnitte für eine Reaktion aus verschiedenen Quellen, so können diese große Unterschiede aufweisen. Dieser Aspekt wird für einen konkreten Datensatz[2] aus einem Prozess zur plasmagestützten Deposition optischer Schichten (PIAD) untersucht. Dazu verwenden wir ein Stoß-Strahlungs-Modell mit 15 angeregten Ar-Niveaus und betrachten die Sensivität dieses Modells bezüglich der Elektron-Argon-Stoßquerschnitte aus verschiedenen Quellen.

[1]Gefördert durch das BMBF unter dem Förderkennzeichen 13N13213
[2]J. Harhausen et al., J. Phys. D: Appl. Phys. **48** (2015) 045203

P 25.9 Thu 16:30 Empore Lichthof

Fictitious time-evolution for steady state strongly non linear transport equations — •Herbert Oberlin, Marco Restelli, and Omar Maj — Max Planck Institute - IPP/NMPP, Garching bei München, Germany

The solution of nonlinear partial differential equations can pose serious challenges in the development of efficient codes for physics simulations. Standard methods usually rely on iterative schemes that, for time-evolution problems, are nested into time-stepping iterations. In strongly nonlinear cases, the convergence of the iterative nonlinear solver imposes unacceptably small time steps.

In this work, we consider the relaxation to steady-state of strongly non linear problems. In order to mitigate the effects of nonlinearities, we propose a modification of the time evolution of the equations. Through dissipation of certain metrics of the system, we force these strong nonlinear effects to play a lesser role, and induce better convergence to steady-state.

The main envisaged application is the speed up of the computational fluid dynamic kernel of the SOLPS suite of codes which simulate the outer region of the plasma column in tokamak devices.

P 25.10 Thu 16:30 Empore Lichthof

Towards TeV electron acceleration: quasi-stable injection channels in a wakefield accelerator — •Mara Wiltshire-Turkay, John Farmer, and Alexander Pukhov — Heinrich-Heine-Universität Düsseldorf, Germany

Proton-beam-driven plasma-wakefield acceleration is a promising technique to create high-energy electrons. The large accelerating gradients possible in plasma allow the transfer of energy from TeV protons to electrons, potentially increasing achievable energies by two orders of magnitude.

Via theory and simulation, we investigate the dependence of the energy gain on the point of electron injection into the wake. We find previously unobserved complex structure of the the acceptance channels for high-energy acceleration. This result is directly applicable to the optimisation of energy gain for the planned AWAKE project at CERN.

P 25.11 Thu 16:30 Empore Lichthof

Accuracy of fluid and PIC simulations for low pressure ccrf discharges* — •Markus M. Becker[1], Hanno Kählert[2], Anbang

Sun[1], Detlef Loffhagen[1], and Michael Bonitz[2] — [1]INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald — [2]ITAP, Christian-Albrechts-Universität zu Kiel, Leibnizstr. 15, 24098 Kiel

Particle-in-Cell (PIC) methods are particularly suited for the theoretical description of low pressure rf discharges [1]. Fluid models are required to reduce the computational cost if plasmas at elevated pressures and/or extended reaction kinetics are to be described. In hybrid models, kinetic and hydrodynamic methods are combined in order to take advantage of the benefits from both approaches. As a preliminary study to the development of novel hybrid models, recently developed PIC and fluid tools are presented and benchmarked against reference results for low pressure rf discharges in helium [1]. In particular, the results obtained from enhanced fluid models [2] are compared with those provided by conventional fluid descriptions and by different PIC simulation codes. It is shown that the accuracy of fluid models can be conserved at low pressures if the electron energy transport and the inertia of ions are adequately described.

This work is partly supported by the DFG via SFB-TRR24 and by the PlasmaShape project from the European Union under grant agreement no 316216.

[1] M. M. Turner *et al.*, *Phys. Plasmas* **20** (2013) 013507
[2] M. M. Becker, D. Loffhagen, *Adv. Pure Math.* **3** (2013) 343–352

*Part of the Kiel research initiative 'The Plasma Interface'.

P 25.12 Thu 16:30 Empore Lichthof

The domino effect of unstable one-dimensional bump-on-tail modes as a test for critical numerical scales — Thomas Hayward and •Philipp Lauber — Max-Planck-Institut für Plasmaphysik (IPP), 85748 Garching, DE

The so-called domino effect [BB95], though which more widely spaced modes can overlap as a result of the overlap of closely spaced modes, can lead to a significant increase in the level of mode saturation in the bump-on-tail system. As this effect depends strongly upon the overlap of fine scale structures, which can lead to the establishment of larger scale structures, it is informative to study how the numerical resolution impacts the result of this system close to the overlap threshold. We perform simulations using both particle [Deng] and grid [Kraus] based methods, investigate numerical convergence, and comment on the differences between the two approaches.

[BB95] Berk, H. L. et al. Nuclear Fusion. Vol. 35, No. 12 (1995)
[Deng] Deng, W. and Fu G.-Y. Computer Physics Communications 185, 96-105 (2014)
[Kraus] Kraus, M. PhD thesis, Technische Universität München (2013)

P 25.13 Thu 16:30 Empore Lichthof

Using IPF-FDMC full wave code as a synthetic reflectometer for studying micro-instabilities computed by ORB5 — •Francesco Carpanese, Alessandro Biancalani, Alf Koehn, and Omar Maj — Max-Planck-Institut für Plasmaphysik Boltzmannstraße 2 D-85748 Garching

The gyro-kinetic codes have reached good maturity in simulating plasma electromagnetic nonlinear micro-instabilities which are responsible for turbulent transport. Validating these codes, such as ORB5, towards experiments requires to be able to reproduce data from diagnostics which detect the micro-instabilities characteristics. The reflectometer in particular is a valuable solution to measure density perturbation and turbulent spectrum near the cut-off of the injected wave [1]. A synthetic reflectometer, to be coupled to the gyro-kinetic code, is therefore needed for simulating and interpreting the experimental diagnostic. A new full-wave code is under development, taking advantage of a novel algorithm. At the same time the 2D finite difference IPF-FDMC code has been coupled to ORB5 to simulate a reflectometer (see also [2]).

[1] Sabot, R, Plasma Phys. Controlled Fusion 48.12B (2006): B421.
[2] Conway, G. D, Plasma Phys. Controlled Fusion44.4 (2002): 451.

P 25.14 Thu 16:30 Empore Lichthof

Transport properties of dense plasma beyond Born approximation — •Sebastian Rosmej, Heidi Reinholz, and Gerd Röpke — Universität Rostock, Rostock, Deutschland

In the generalized linear response theory, transport coefficients are expressed via correlation functions. Especially the static conductivity of dense plasma is investigated. The main contribution due to electron-ion collisions is well known. Further relevant interactions have to be considered, e.g. electron-electron collisions. Within Born approximation, this was done in a recent paper [1] for arbitrary degeneracy. Assuming statically screened Coulomb potentials a correction factor is deduced. Additionally, the treatment of strong collisions is necessary in the warm dense matter regime. In [2] the T matrix effects are considered for electron-ion interactions. A new fit formula for the electron-ion transport cross section is proposed in order to reduce the numerical effort in the low density limit.

In reference to experimental results the treatment of electron-electron collisions in different approximations is evaluated and especially the influence strong collisions via T matrix is shown in more detail.

[1] H. Reinholz, G. Röpke, S. Rosmej, and R. Redmer, Phys. Rev. E 91, 043105 (2015). [2] S. Rosmej, subm. to Contrib. Plasma Phys.

P 25.15 Thu 16:30 Empore Lichthof

Quantum master equation approach for spectral line profiles in a plasma — •Chengliang Lin, Heidi Reinholz, and Gerd Röpke — Universität Rostock, Rostock, Deutschland

Within the framework of the theory of open quantum systems, the behavior of an atom in an interactive environment with particular attention to plasma surroundings is studied. A quantum master equation (QME) is derived to describe the dynamics of the atom in plasma. The contribution of the plasma environment to the QME is represented by its dynamic structure factor. For the application of the QME, the pressure broadening of spectral line profiles in a plasma is investigated. Of particular interest are the Rydberg states of the hydrogen atom. To describe the Rydberg states under the influence of a surrounding plasma, a wave packet description is introduced. The boundary between the quasi-classical and quantum mechanical representation of a bound electron is discussed. In addition, the transition rates between the bound wave packet states are calculated within this method. The resulting transition rates show a better agreement with the experimental data than the pure quantum mechanical calculation. For the further application, the inner-shell transitions (K-alpha line and Auger transition) are discussed by including both transverse and longitudinal component of the photon field as the heat bath of the investigated atom. A systematic approach to investigate the inner-shell transitions in a many-electron atom under the influence of the plasma environment is obtained.

P 25.16 Thu 16:30 Empore Lichthof

Defining and Measuring the Coupling Strength in Coulomb and Yukawa Plasmas — •Torben Ott and Michael Bonitz — Christian-Albrechts-Universität Kiel, Institut für Theoretische Physik und Astrophysik

For strongly coupled plasmas such as dusty plasmas, trapped ions, or ultracold neutral plasmas, the definition and measurement of the correlation or coupling strength is an essential question. However, when precise measurements of charge states and/or temperatures are not feasible or when the interaction between the strongly coupled species is screened, e.g., by electrons, the straightforward use of the Coulomb coupling parameter $\Gamma = Q^2/(ak_BT)$ is problematic.

In this contribution, we present two consistent and mutually compatible approaches for defining and measuring the coupling strength in Coulomb and Yukawa One-Component Plasmas based on the purely structural features of the system, thus removing the need to measure the temperature, the charge state, or the screening length of the plasma to assess its coupling state.

[1] T. Ott, M. Bonitz, Contrib. Plasma Phys. **55**, 243 (2015)
[2] T. Ott, M. Bonitz, L. G. Stanton, M. S. Murillo, Phys. Plasmas **21**, 113704 (2014)

P 25.17 Thu 16:30 Empore Lichthof

Thermodynamic Fermionic Monte Carlo Simulations of Continuous Systems without Fixed Nodes — •Tobias Dornheim, Tim Schoof, Simon Groth, and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel

Path Integral Monte Carlo (PIMC) simulations of correlated fermions at high degeneracy are generally hampered by the fermion sign problem (FSP). Here, we combine two novel methods, the Configuration [1] and Permutation Blocking PIMC [2] approach, which, due to their complementary character of the FSP, allows us to circumvent this issue. Thereby, we are able to present accurate ab initio thermodynamic data for the uniform electron gas [3,4,5] over a broad range of

parameters without the need of the fixed node approximation.

[1] T. Schoof *et al.*, Contrib. Plasmas Phys. **51**, 687 (2011)
[2] T. Dornheim *et al.*, New J. Phys. **17**, 073017 (2015)
[3] T. Schoof *et al.*, Phys. Rev. Lett. **115**, 130402 (2015)
[4] T. Dornheim *et al.*, J. Chem. Phys. **143**, 204101 (2015).
[5] S. Groth *et al.*, arXiv:1511.03598 (2015).

P 25.18 Thu 16:30 Empore Lichthof

Konsistente kinetische Simulation von Plasma und Sputtertransport in kapazitiv gekoppelten Plasmen — •Frederik Schmidt, Jan Trieschmann und Thomas Mussenbrock — Ruhr-Universität Bochum, Lehrstuhl für Theoretische Elektrotechnik, Universitätsstraße 150, 44801 Bochum, Deutschland

Sputterplasmen finden breite Anwendung zur Erzeugung funktionaler Schichten (z.B. Härtung, Korrosionsschutz). Diese Prozesse werden häufig bei Gasdrücken < 1 Pa betrieben. Für deren Verständnis – insbesondere der gekoppelten Prozesse – ist eine konsistente Betrachtung des Plasmas und des Transports dadurch gesputterter Teilchen von großer Bedeutung. Wegen großer mittlerer freier Weglängen und der nicht-thermischen gesputterten Spezies, bieten sich zur theoretischen Analyse lediglich kinetische Verfahren an.

Die Particle-in-Cell (PIC) Methode wird zur kinetischen Beschreibung des Plasmas verwendet. Darauf aufbauend wird der Sputtertransport mit Hilfe der Test Multi-Particle Methode (TMPM) bestimmt. Hierzu wird der selbstkonsistent simulierte Ionenfluss über den Fluss gesputterter Teilchen an das Modell des Teilchentransports gekoppelt. Am Beispiel eines kapazitiv gekoppelten Plasmas (CCP) werden die räumlich aufgelösten Dichten und Flüsse aller vorkommenden Spezies und deren Geschwindigkeitverteilung diskutiert. Die Ergebnisse werden ferner mit einem kinetischen Transportmodell der Neutralteilchen verglichen und diskutiert.

(Diese Arbeit wird im Rahmen des SFB/Transregio 87 durch die Deutsche Forschungsgemeinschaft gefördert.)

P 26: Poster Session-Plasma Diagnostics

Time: Thursday 16:30–19:00 Location: Empore Lichthof

P 26.1 Thu 16:30 Empore Lichthof

Improved Stereoscopy in Dusty Plasmas using Light-Field Cameras — Michael Himpel and •André Melzer — Universität Greifswald

Dusty plasmas are especially interesting for experimentalists due to the fact that the kinetic motion of the dust species is directly visible.

Thus, three-dimensional observation of the single-particle motion is desirable in most cases. Stereoscopy has already proven to be suitable for single-particle diagnostics in dusty plasmas.

In this presentation, the use of imaging by multiple light-field cameras will be discussed. The advantages and disadvantages will be shown together with preliminary results using light-field capturing.

P 26.2 Thu 16:30 Empore Lichthof

Enhanced setup facilitating emittance measurement for diagnosing ion thrusters — •Kristof Holste, Stefan Schippers, Alfred Müller, and Peter Klar — Justus-Liebig-Universität Gießen

Here we present an improved experimental setup for measuring the transverse emittance of low energy ion beams emerged, for instance, from gridded ion thrusters. Typically, the ion energy is in the order of 1 keV, the ion beams' divergence is in the order of 5-20°. The primary ion beam is decomposed into beamlets by an array of thin slits (0.2 mm slit width, 0.5 mm web thickness, 0.2 mm plate thickness). The spatial intensity distribution of the beamlets behind the slit array is measured with a wire scanner. The deviation of the beamlets' position relative to the corresponding slits corresponds to the transverse momentum distribution of the ions. Thus, the transverse phase-space area (emittance) occupied by the ions can be derived. The emittance is an important parameter for diagnosing the quality of the ion optics of an ion thruster and allows optimization of the extraction grids. Results from emittance measurements and comarisons with ions beam simulations will be presented.

P 26.3 Thu 16:30 Empore Lichthof

A New Algorithm to Determine the Total Radiated Power at ASDEX Upgrade — •Stephan Glöggler, Matthias Bernert, Thomas Eich, and The ASDEX Upgrade Team — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

Radiation is an essential part of the power balance in a fusion plasma. In future fusion devices about 90% of the power will have to be dissipated, mainly by radiation. For the development of an appropriate operational scenario, information about the absolute level of plasma radiation ($P_{rad,tot}$) is crucial. Bolometers are used to measure the radiated power, however, an algorithm is required to derive the absolute power out of many line-integrated measurements.

The currently used algorithm (BPD) was developed for the main chamber radiation. It underestimates the divertor radiation as its basic assumptions are not satisfied in this region. Therefore, a new $P_{rad,tot}$ algorithm is presented. It applies an Abel inversion on the main chamber and uses empirically based assumptions for poloidal asymmetries and the divertor radiation. To benchmark the new algorithm, synthetic emissivity profiles are used. On average, the new Abel inversion based algorithm deviates by only 10% from the nominal synthetic value while BPD is about 25% too low. With both codes time traces of ASDEX Upgrade discharges are calculated. The analysis of these time traces shows that the underestimation of the divertor radiation can have significant consequences on the accuracy of BPD while the new algorithm is shown to be stable.

P 26.4 Thu 16:30 Empore Lichthof

Investigation of the influence of plasma temperature on Doppler reflectometry — •Vandana Revathi Venkateswaran, Carsten Lechte, and Thomas Hirth — IGVP, University of Stuttgart

Doppler reflectometry is a microwave scattering diagnostic technique which employs the scattering of waves near plasma cutoffs to get information on the electron density fluctuations and also poloidal flows in toroidal fusion experiments. The scattering process has to be investigated using simulation codes in order to interpret the diagnostic results. In this case, the influence of temperature on reflectometry is studied and discussed. IPFs Finite-Difference Time Domain method based code called IPF-FD3D is used to study the fluctuations. For the warm plasmas as opposed to cold plasmas,where the plasmas have values of electron temperature similar to those of existing tokamaks relativistic effects might also be important. A mass correction makes the cold-plasma approximation in agreement with that of the fully relativistic theory (for a range of values that is the only one of interest for X-mode reflectometry in tokamaks). This makes us modify the codes related to the cold plasma theory of wave propagations applicable to cases of plasmas with characteristics similar to those of existing tokamaks [1]. The method is incorporated to study its influence on cutoffs and scattering efficiency. Initial results will be presented.

[1] E. Mazzucato, Phys. Fluids B 4, 3460 (1992).

P 26.5 Thu 16:30 Empore Lichthof

Development and Verification of an Collisional Radiative Model for Argon — •Julian Kaupe and Slobodan Mitic — 1. Physikalisches Institut, Justus-Liebig-Universität Gießen

In order to establish a set of tools for diagnostics of cold plasmas in the newly formed working groups for plasma physics at JLU Gießen a Collisional Radiative Model for Optical Emission Spectroscopy (OES) of Argon plasmas was developed and tested. This model is the first result of the development of a generalized plasma diagnostics software toolbox whose projected use will also include OES diagnostics of other rare gases and molecular gases in laboratory process plasmas, ion thrusters and complex plasma experiments at JLU Gießen.

P 26.6 Thu 16:30 Empore Lichthof

Evidence of Secondary Electron Emission during PIII Pulses by Calorimetric Probe Measurements — •Fabian Haase[1], Darina Manova[2], Stephan Mändl[2], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics, Christian-Albrechts-University Kiel, Germany — [2]Leibniz Institute of Surface Modification, Leipzig, Germany

Plasma based coating processes are a widespread field in industrial surface modification. One of these methods is plasma immersion ion implantation (PIII), a pulsed technique to alter the substrate by implanting ions into the surface, which is commonly used in industry [1]. However, many accompanying processes during PIII have not yet been fully investigated but are crucial to the outcome of the coating procedure in terms of quality and properties of the deposited films. Secondary electrons are a major, undesired component of energetic particles present in PIII. However, a direct measurement using a Faraday cup is both complex and error prone. In this work an alternative method of measuring the thermal flux associated with energetic secondary electrons is presented using a calorimetric probe [2]. Angular variations have been performed to support the assumption of a directed flux. Further investigations include studies of parameter variation, such as pulse length, pulse voltage and pulse frequency using different substrate materials (Al, Cu, stainless steel). Additionally, the spatial effect has been investigated by changing the distance to the probe.

[1] J.R. Conrad et al., J. Appl. Phys. 62 4591, 1987
[2] S. Bornholdt and H. Kersten, Eur. Phys. J. D. 67(8):167 (2013)

P 26.7 Thu 16:30 Empore Lichthof

Diamantoide als alternative Treibstoffe für Ionentriebwerke — •Patrick Dietz[1], Kristof Holste[1], Waldemar Gärtner[1], Peter Köhler[1], Christine Hofmann[2], Peter Klar[1] und Peter Schreiner[2] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]Institut für Organische Chemie, Justus-Liebig-Universität Gießen

Ionentriebwerke basieren auf der Ionisation und nachfolgenden elektrostatischen Beschleunigung eines Treibstoffs. Als Treibstoff ist prinzipiell jedes Material geeignet, jedoch ist es aus energetischer und technischer Sicht vorteilhaft, Stoffe zu verwenden, die leicht zu verdampfen und mit geringem Energieaufwand effizient zu ionisieren sind. Als Stützmasse für Ionen-Triebwerke wird zurzeit hauptsächlich das Edelgas Xenon verwendet.

Eine Alternative könnten Diamantoide darstellen. Diamantoide, z. B. Adamantan $C_{10}H_{16}$, sind auf Grund ihrer hohen Sublimationsdampfdrücke bereits bei geringen Temperaturen leicht in die Gasphase zu bringen und haben eine deutlich niedrigere Ionisierungsschwelle als Xenon (9.25 eV anstatt 12.1 eV). Auf Grund der diamantartigen Struktur der Moleküle wird von einer geringen Fragmentation der Moleküle im Triebwerksplasma ausgegangen.

Gezeigt werden Untersuchungen über das Fragmentationsverhaltens von Adamantan im Plasma eines Radiofrequenz-Ionentriebwerks mittels Massenspektrometrie des extrahierten Ionenstrahls sowie erste Ergebnisse eines experimentellen Aufbaus zur Bestimmung des Elektronenstoß-Ionisations-Wirkungsquerschnitts von Diamantoiden.

P 26.8 Thu 16:30 Empore Lichthof

Charakterisierung des Aufbaus und der Emissionsdynamik eines Metallgitter-Mikroplasma-Arrays — •Sebastian Burhenn, Sebastian Dzikowski und Volker Schulz-von der Gathen — Lehrstuhl für Experimentalphysik II, Ruhr-Universität Bochum, Deutschland

Innerhalb der letzten Jahre wurde das Teilgebiet der Mikroplasmen intensiv untersucht. Mikroplasmen zeichnen sich durch ihre kleine räumliche Ausdehnung im Bereich von wenigen 100 μm bis zu einigen mm aus. Ein Vertreter sind die Metallgitter-Mikroplasma-Arrays. Sie sind Sandwich-artig aus einer geerdeten Gegenelektrode, einem Dielektrikum und einem Metallgitter aufgebaut und werden typischerweise in einer Edelgas-Atmosphäre betrieben. Beim Anlegen einer Wechselspannung an das Metallgitter zündet das Plasma in den Kavitäten des Gitters. Die Zündbedingungen des Plasmas werden maßgeblich durch die Wahl des Dielektrikums beeinflusst. Aufgrund der hohen Spannungen von bis zu 700 V_{pp}, die lediglich auf wenigen Mikrometern angelegt werden, kann es im schlimmsten Fall zur Zerstörung des Arrays kommen. Um dies zu vermeiden wurden verschiedene Dielektrika getestet und die Bauweise des Arrays modifiziert. Mit Hilfe von phasenaufgelöster Untersuchung der Emission des Arrays in Helium konnte dann gezeigt werden, dass sich Emissionswellen mit Geschwindigkeiten von einigen km/s über die Oberfläche der Plasmaquelle ausbreiten und sich ihre Ausbreitungsgeschwindigkeit mit dem Umgebungsdruck ändert. Gefördert durch die DFG in der Forschergruppe FOR1123 "Physics of Microplasmas"(SCHU 2353/2-2).

P 26.9 Thu 16:30 Empore Lichthof

In-situ real-time monitoring of spurious modes in high power millimeter wave transmission lines using multi-hole couplers in miter bends — •W. Alexander Zach[1], Walter Kasparek[1], Carsten Lechte[1], Burkhard Plaum[1], Jörg Stober[2], Francesco Monaco[2], Harald Schütz[2], Hiroshi Idei[3], and Thomas Hirth[1] — [1]Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie IGVP, Univ. Stuttgart, Pfaffenwaldring 31, D-70569 Stuttgart, Germany — [2]Max-Planck-Institut für Plasmaphysik, EURATOM-IPP, D-85748 Garching, Germany — [3]Research Institute for Applied Mechanics, Kyushu Univ., Kasuga, 816-8560, Japan

For Electron Cyclotron Resonance Heating (ECRH) in fusion experiments, millimeter waves have to be transmitted over large distances from gyrotrons to the plasma. In the case of e.g. ASDEX Upgrade, millimeter waves with up to 1 MW of power at 140 GHz are transmitted via waveguides. Because of the high power, oversized corrugated circular waveguides are used. However, these are sensitive to alignment errors, which lead to the excitation of higher order spurious modes besides the favored hybrid mode HE_{11}. An alignment analysis would require a complete 2D field scan, which is not possible for high powers.

As an alternative, hole-array-couplers, placed in the cross section of the transmission line at a miter bend location, allow for an in-situ measurement of the power of modes, that are predominantly excited due to misalignment. Complex signals can either be processed independently or via a hard-wired interferometric setup. Simulations and experimental results are discussed.

P 26.10 Thu 16:30 Empore Lichthof

Preliminary study of ECE imaging concept for W7-X, using the Talbot effect in rectangular waguides — •Daniel Iglesias[1], Burkhard Plaum[1], Walter Kasparek[1], Matthias Hirsch[2], and Thomas Hirth[1] — [1]IGVP, Universität Stuttgart — [2]Max-Planck Institut für Plasmaphysik, Greifswald

For spatially resolved measurements of Electron Cyclotron Emission (ECE) in W7-X, an imaging antenna based on a corrugated rectangular waveguide can be used. The imaging characteristics of the antenna allow a simultaneous operation at multiple angles and frequencies. As a result it is possible to localize a set of points inside the plasma, where the ECE can be measured without the need of mobile components facing the plasma.

P 26.11 Thu 16:30 Empore Lichthof

Untersuchung eines selbst-pulsenden Atmosphärendruck-Plasmajets mit propagierender kontrahierter Entladung — •Julian Held, Daniel Schröder und Volker Schulz-von der Gathen — Lehrstuhl für Experimentalphysik II, Ruhr-Universität Bochum

Bei Atmosphärendruck betriebene Niedertemperaturplasmen sind ein viel beachtetes Forschungsgebiet auf Grund des möglichen Einsatzes in der Biomedizin. Bei diesen Plasmaquellen können jedoch Instabilitäten auftreten, die zu einem Übergang der kalten, homogenen Entladung zu einer kontrahierten Entladung führen können. Diese Entladung zeichnet sich durch eine sehr hohe Leistungsdichte aus und führt zu einem starken Anstieg der Gastemperatur, was sowohl den Jet als auch das zu behandelnde Material beschädigen kann. Um die Prozesse, die zum Wechsel in den kontrahierten Modus führen, zu untersuchen benutzen wir einen kapazitiv gekoppelten, mit 13.56 MHz angeregten Jet mit einer keilförmigen Elektrodenkonfiguration. Die kontrahierte Entladung zündet an der Stelle des geringsten Elektrodenabstands, wird durch den Gasfluss an die Spitze des Jets getrieben und erlischt dort. Dieser Vorgang wiederholt sich mit einer Frequenz im kHz-Bereich. Dieses selbstpulsende Verhalten erlaubt die Untersuchung der kontrahierten Entladung über einen langen Zeitraum ohne den Jet zu beschädigen. Der Jet wurde mit verschiedenen optischen und elektrischen Diagnostiken mit hoher Zeitauflösung untersucht, um die Entstehung der Entladung besser zu verstehen. Gefördert durch die DFG in der Forschergruppe FOR1123 "Physics of Microplasmas" (SCHU 2353/2-2).

P 26.12 Thu 16:30 Empore Lichthof

Messung zweidimensionaler Dichte- und Potentialprofile in magnetisierten Hochfrequenzplasmen — •Jonathan Schilling, Franko Greiner und Alexander Piel — Christian-Albrechts-Universität, Kiel, Germany

Durch die Verwendung von Piezo-Aktuatoren für die Positionierung einer Langmuirsonde ist es möglich, auch in starken Magnetfeldern mit Flussdichten von bis zu 4 T raumaufgelöste Sondenmessungen durchzuführen. Eine für diesen Zweck konstruierte Verfahreinheit wird vorgestellt. Diese zeichnet sich dadurch aus, dass sie zusammen mit der

Plasmakammer Suleika in der warmen Bohrung von 300 mm Durchmesser des supraleitenden Magneten Suleiman Platz findet. Somit ist es möglich, die Langmuirsonde im Plasma in einer 50 mm x 50 mm - Ebene senkrecht zu der Elektrodenoberfläche zu positionieren. 2D-Profile des Floatingpotentials und des Ionensättigungsstroms für verschiedene Leistungen der Hochfrequenzanregung und Flussdichten von 0 bis 4 T werden vorgestellt. Aus diesen Primärmessdaten werden weitere Messgrößen abgeleitet, u.a. das elektrische Feld im Plasma und hieraus die Ionendriftgeschwindigkeit. Diese Größen sind Schlüsselgrößen, um den Einschluss von Staub und das Entstehen von Voids in magnetisierten staubigen Plasmen zu verstehen.

P 26.13 Thu 16:30 Empore Lichthof

Ein System zur optischen Manipulation von Mikropartikeln im Plasma — •Viktor Schneider und Holger Kersten — Institut für Experimentelle und Angewandte Physik der Christian-Albrechts-Universität zu Kiel

Das Gebiet der Plasmen ist sowohl in der Grundlagenforschung als auch bei der technologischen Anwendung stets auf innovative Diagnostiken angewiesen. Insbesondere elektrostatische und kalorimetrische Sonden sind ein wichtiges Werkzeug in der Plasmaforschung und in der industriellen Anwendung [1].
Aufgrund ihrer Größe (nm bis μm) werden auch Mikropartikel zur Untersuchung von dynamischen Prozessen, aber auch als einzelne Sonden zur Randschichtdiagnostik eingesetzt. Nachteilig ist allerdings, dass sie sich in einem Plasma nicht beliebig manipulieren lassen.
In diesem Beitrag wird ein optisches System vorgestellt, welches den Einfang und die nichtinvasive Manipulation von Partikeln zur Plasmadiagnostik nach dem Prinzip der Laserpinzette ermöglicht. Dadurch lassen sich Mikropartikel sowohl in die Randschicht als auch in den Plasmabulk bewegen und aus der Positionsänderung in der Laserfalle Rückschlüsse auf die extern wirkenden Kräfte schließen. Weiterhin wird untersucht, ob mithilfe eines Plattenkondensators sowohl eine neue Kalibriermethode als auch eine Bestimmung der (Rest-)Partikelladung möglich ist.
[1] S. Bornholdt, et al., Complex Plasmas: Scientific Challenges and Technological Opportunities., Springer International Publishing, 2014, 197-234

P 26.14 Thu 16:30 Empore Lichthof

Thermal probe and VI-Probe measurements on a combination of HiPIMS and plasma based ion implantation — Sven Gauter[1], •Maik Fröhlich[2], Wagdi Garkas[2], Holger Kersten[1], and Martin Polak[2] — [1]Institute of Experimental and Applied Physics, Christian-Albrechts-University Kiel, Germany — [2]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany

The combination of HiPIMS and plasma based ion implantation (PBII) offers new possibilities for surface modification taking advantage of the high density of target ions and application of a synchronized high voltage bias pulse onto the substrate. A very important parameter in this combined experiment is the delay between HiPIMS pulse and PBII pulse, according to the evolution of the HiPIMS pulse.

In the present study we investigate the influence of the delay time, PBII pulse length and distance between substrate and magnetron on the substrate current as well as on the energy flux towards the substrate, measured by a highly time resolved VI-probe and by means of a calometric probe as described in [1]. The results exhibit a remarkable influence especially of the delay time and give information about the transport of the ions from target to substrate in form of a localized ion bunch, as described in [2].

[1] S.Bornholdt et al., Complex Plasmas, M.Bonitz et al. (Eds.), 197-234, 2014.

[2] W.Breilmann et al., Journal of Physics D: Applied Physics, 46(48):485204, 2013

P 26.15 Thu 16:30 Empore Lichthof

Analytical Investigation of Surface Wave and Microwave Resonances of Curling Probe — •Ali Arshadi and Ralf Peter Brinkmann — Lehrstuhl für Theoretische Elektrotechnik, Bochum, Deutschland

The term "active plasma resonance spectroscopy" (APRS) denotes a related class of plasma diagnostic methods utilizing the natural ability of plasma to resonate on or near the plasma frequency: An electrical RF signal is coupled into the plasma via a probe, the response is recorded and a mathematical model is used to determine plasma parameters.

Curling probe (CP), recently invented by Liang et al. is a novel realization of APRS concept to measure the electron density. CP can be miniaturized and be flatly embedded into the chamber wall which prevents metal contamination release and electrical disturbance. Physically, CP can be understood as a "curled" form of the hairpin probe. FDTD simulation shows two kinds of resonance: Surface plasmon resonance which induces at frequencies smaller than plasma frequency and microwave resonance which is strongly dependent on the length of CP.

Assuming that the spiralization has little electrical effect, this manuscript investigates the characteristcs of a "straightened" CP by modeling it as a rectangular slot-type resonator which is in direct contact with the plasma. The diffraction of an incident plane wave at the slot is calculated by solving the cold plasma model and Maxwell's equations simultaneously. The resonances of the probe are obtained and good agreement with the numerical results of probe inventors is demonstrated.

P 26.16 Thu 16:30 Empore Lichthof

Bestimmung der Ionenzusammensetzung in einem Niederdruck-Niedertemperatur H_2-Plasma — •Dominikus Zielke[1], Stefan Briefi[1] und Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Ein wesentlicher Aspekt bei der Charakterisierung von Molekülplasmen ist die Kenntnis der quantitativen Ionenzusammensetzung. In H_2-Niederdruck-Niedertemperaturplasmen treten die positiven Ionenspezies H^+, H_2^+ und H_3^+ auf. An einem induktiv gekoppelten HF-Plasma (Frequenz 2 MHz, maximale HF-Leistung 2 kW) mit planarer Spule werden mittels eines energieauflösenden Ionenmassenspektrometers die absoluten Dichten der jeweiligen Ionenspezies in Abhängigkeit von Druck (1 bis 10 Pa) und HF-Leistung gemessen. Die aus der relativen Zusammensetzung der Ionenspezies bestimmte effektive Ionenmasse wird als Eingangsparameter für die Auswertung von Langmuirsondenkennlinien mit den gängigen Ionentheorien verwendet. Anschließend werden die aus den verschiedenen Ionentheorien berechneten effektiven Ionendichten mit den Ergebnissen der massenspektrometrischen Messungen und mit der mittels Langmuirsonde bestimmten Elektronendichte verglichen.

P 26.17 Thu 16:30 Empore Lichthof

Diurnal dependence of foF2 variations connected with earthquakes — Elena V. Liperovskaya[1], •Claudia-Veronika Meister[2], Dieter H.H. Hoffmann[2], and Alexandra S. Silina[1] — [1]Institute of Physics of the Earth, Bol'shaya Gruzinskaya 10, 123995 Moscow — [2]Institut für Kernphysik, Technische Universität Darmstadt, Schlossgartenstr. 9, 64289 Darmstadt, and Graduate School of Excellence Energy Science and Engineering, Jovanka-Bontschits-Str. 2, 64287 Darmstadt

The diurnal variation of the characteristic frequency foF2 of the ionosphere is studied with regard to earthquakes. Used are observations of the vertical ionospheric sounding station "Tokyo" registered in the years 1957-1990. Analysed are the normalized parameter $\Delta foF2_{\mathrm{norm}} = (foF2 - \mathrm{medium}(foF2))/\mathrm{medium}(foF2)$ obtained for every hour of the day, and $\mathrm{abs}(\Delta foF2_{\mathrm{norm}})$. It is found, that about one-and-a-half months before earthquakes with magnitudes $M > 5.5$, at distances $R > R_D + 100$ km, $\mathrm{abs}(\Delta foF2_{\mathrm{norm}})$ increases in the evening, where $R_D = \exp(M)$ designates the dimension of the earthquake preparation region. The increase depends on M. Studying seismo-ionospheric effects two-three days before earthquakes, it is obtained that at night about two days before the seismic shocks $\Delta foF2_{\mathrm{norm}}$ increases with a reliability of 95 % in case of earthquakes with magnitudes $M > 5.5$ at distances $R > R_D + 100$ km. Further, a decrease of $\Delta foF2_{\mathrm{norm}}$ is observed on the day of the earthquake at daytime, for $M > 6.0$ and $R < 1000$ km.

P 26.18 Thu 16:30 Empore Lichthof

Anomalous behavior of ionospheric parameters on Kamchatka before and during seismic activities — Vadim V. Bogdanov[1], Alexander V. Kaisin[1], Aleksey V. Pavlov[1], Anastasia L. Polyukhova[1], and •Claudia-Veronika Meister[2] — [1]Institute of Cosmophysical Research and Radio Wave Propagation FEB RAS, 684034 Paratunka, Mirnaya 7, Russia, vbogd@ikir.ru — [2]Institut für Kernphysik, Technische Universität Darmstadt, Schlossgartenstr. 9, 64289 Darmstadt and Graduate School of Excellence Energy Science and Engineering, Jovanka-Bontschits-Str. 2, 64287 Darmstadt, Germany, c.v.meister@skmail.ikp.physik.tu-darmstadt.de

In the present report, the variations of ionospheric parameters and ionospheric turbulence before and during seismic events are studied

applying complex radiophysical methods and using a theoretical probability approach, suggested by the authors. The probability approach allowed to detect the growth of seismic activity in the Kamchatka region in 2013. It is found that characteristic ionospheric features as K-layer (corpuscular layer due to precipitation of particles from the radiation belts) formation, increase of the critical f_oF2-frequency and formation of F-spread as well as E_s-spread occur about one day before some seismic events on February-March (28.02.–02.03.) 2013

P 26.19 Thu 16:30 Empore Lichthof

Acceleration of Bayesian Model Based Data Analysis through Software/Hardware — Humberto Trimino Mora[1], Robert Wolf[1], •Dirk Timmermann[2], Andreas Werner[1], and Jakob Svensson[1] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [2]Universität Rostock, Rostock, Germany

Today's leading fusion experiments set new requirements for control systems as well as data analysis to achieve the desired results. Often the performance of state of the art control systems is limited, thus better solutions for the data analysis and the control of complex systems are needed. Typically, control and data analysis use straightforward processing of signals to derive the parameter of interest. Significant improvement can be reached by incorporating knowledge of the system, or the lack of it, into data analysis. Bayesian analysis provides this by empowering the analysis with a rigorous estimation of the uncertainty while introducing previous knowledge with a prior. However, this analysis currently takes long processing times which makes real time analysis and control feedback infeasible. This project attempts to accelerate this analysis towards a real time solution and presents a first proposal solution designed with highly parallelized reconfigurable hardware. The W7-X Dispersion Interferometer diagnostic model was used to implement a single free parameter hardware analysis. The trade-off between arithmetic precision and parallelization area revealed limitations and showed alternate ways to deal with this analysis. The implementation results posed the question of how to deal with the arithmetic error in the forward modeling using this analysis.

P 26.20 Thu 16:30 Empore Lichthof

A phased array antenna for Doppler reflectometry in ASDEX Upgrade — •Stefan Wolf[1], Carsten Lechte[1], Walter Kasparek[1], Pascale Hennequin[2], Garrard Conway[3], Tim Happel[3], and ASDEX Upgrade Team[3] — [1]IGVP, Universität Stuttgart, D-70569 Stuttgart, Germany — [2]Laboratoire de Physique des Plasmas, CNRS, Ecole Polytech., F-91128 Palaiseau, France — [3]Max-Planck-Institut für Plasmaphysik, D-85748 Garching, Germany

In a toroidal plasma, Doppler reflectometry (DR) allows investigating electron density fluctuations with finite $k_\perp$. The injected microwave beam's frequency determines the radial position of the probed region, its tilt angle selects the wavenumber satisfying the Bragg condition for backscattering. The rotation velocity can be calculated from the Doppler shift of the backscattered signal's frequency. By varying the injected frequency, radial profiles can be reconstructed. Varying the tilt angle resolves the $k_\perp$-spectrum of the fluctuations. For DR, a pair of phased array antennas (PAAs) has been designed, built, and installed in the ASDEX Upgrade tokamak. Beam steering is done by slightly changing the injected frequency, thus, the PAAs do not need any movable parts or electronics inside the vacuum vessel. From 75 to 105 GHz, the PAAs feature 13 frequency bands, each with an angular scan range of -20 to $+20°$. So, for each angle, there are 13 radial positions to be probed. The results from PAA characterisation, commissioning, and first DR measurements will be presented. This work was performed in the framework of the Helmholtz Virtual Institute on plasma dynamical processes and turbulence using advanced microwave diagnostics.

P 26.21 Thu 16:30 Empore Lichthof

Phase Contrast Imaging Diagnostic for the Wendelstein 7-X Stellarator — •Lukas-Georg Böttger and Olaf Grulke — Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany

The phase contrast imaging (PCI) diagnostic allows for non-invasive measurements of density fluctuations in high temperature plasmas. Since the index of refraction in a plasma is a function of the electron density, an incoming laser beam experiences a phase shift, which can be converted to intensity variations via interference after passing a phase plate. Generally speaking, the signal contains only the line-integrated information along the beam path. This limitation can be circumvented by using the fact that the density fluctuations form filamentary structures that are well aligned with the local magnetic field. If the magnetic field direction significantly varies along the beam path, optical filtering allows for localization of the density fluctuations.

In order to identify the best diagnostic position regarding localization performance three figures of merit are introduced. They allow for quantitative comparison of different lines of sight and different magnetic field configurations. The results of the optimization process and a comparison with other fusion experiments are shown in this contribution.

P 27: Low Temperature Plasmas III

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

P 27.1 Fri 11:00 b305

The breakdown process in an atmospheric pressure parallel-plate nanosecond discharge — •Bang-Dou Huang[1,2], Keisuke Takashima[3], Xi-Ming Zhu[2], and Yi-Kang Pu[1] — [1]Department of Engineering Physics, Tsinghua University, Beijing 100084, P. R. China — [2]Institute for Plasma and Atomic Physics, Ruhr-University Bochum, Bochum 44801, Germany — [3]Department of Electronic Engineering, Tohoku University 6-6-05 Aoba Aramaki, Aoba-ku, Sendai, MIYAGI 980-8579, Japan

The breakdown process in an atmospheric pressure nanosecond discharge with parallel-plate electrodes in helium/argon mixture is investigated by temporally and spatially resolved OES. The electric field is obtained from the Stark splitting of the He I 492.1 nm line. Two effective Te, i.e. Te, high and Te, low, are obtained, using the emissions from helium and argon lines and a simple time-resolved collisional-radiative model. Compared with the nominal average electric field (V/d), the field is greatly enhanced at the ionization wave front and is significantly weakened behind the wave front, as predicted by a fluid model. The value of Te, high is much larger than that of Te, low, which indicates that an elevated high energy tail in the EEPF is built up under the strong electric field during the breakdown process. Initially, the spatial distribution of Te follows that of the electric field. However, at the end of the breakdown period, the location of the highest Te is shifted away from that of the strongest electric field (in the cathode sheath). This indicates the existence of non-local effects, which is supported by the result from a simple Monte-Carlo simulation.

P 27.2 Fri 11:15 b305

Analyse der Dynamik von RF-modulierten Elektronenbeams in kapazitiv gekoppelten Plasmen — •Sebastian Wilczek[1], Jan Trieschmann[1], Ralf Peter Brinkmann[1], Julian Schulze[2], Edmund Schüngel[2], Aranka Derzsi[3], Ihor Korolov[3], Peter Hartmann[3], Zoltán Donkó[3] und Thomas Mussenbrock[1] — [1]Ruhr-Uni Bochum, Bochum, Germany — [2]West Virginia University, Morgentown, USA — [3]Wigner Research Center for Physics, Budapest, Hungary

In kapazitiven Niederdruckentladungen ist das Beschleunigen von hochenergetischen Elektronen durch die Randschichtexpansion (Entstehung von Elektronenbeams) einer der wichtigsten Heizungsmechanismen. Der Einfluss von grundlegenden Prozessparametern (z.B. Plattenabstand, Anregungsfrequenz, Druck, Elektrodenanordnung und Elektrodenspannung) kann die Dynamik dieser Elektronenbeams signifikant beeinflussen. Sowohl die Formation als auch die Reflektion an der gegenüberliegenden Randschicht kann durch eine geeignete Wahl dieser Parameter kontrolliert werden. Infolgedessen können prozessrelevante Größen, wie Elektronendichte, Ionenfluss und Verteilungsfunktionen, optimiert werden. In diesem Beitrag werden mithilfe von 1d3v Particle-In-Cell Simulationen Parameterstudien durchgeführt, welche den Einfluss der oben genannten Prozessparameter in Bezug auf die Dynamik der Elektronenbeams und weitere relevante Plasmagrößen bestimmen.

P 27.3 Fri 11:30 b305

Simulation of laser photodetachment of negative ions in

helium-oxygen barrier discharges and comparison with experiment — •Sebastian Nemschokmichal, Robert Tschiersch, and Jürgen Meichsner — Institute of Physics, University of Greifswald

Helium-oxygen discharges at atmospheric pressure are well established in applications because of their ability to produce oxygen radicals under low power consumption. The use of oxygen in a discharge always causes the formation of negative ions, but the influence of negative ions on barrier discharges is poorly investigated. Therefore, we set up a helium oxygen barrier discharge to prove negative ions in a laser photodetachment experiment.

The experiment cannot directly provide number densities of negative ions. Therefore, a supporting simulation of the laser photodetachment experiment is necessary. The presented simulation is based on the 1D fluid simulation of a helium-oxygen barrier discharge described in a further contribution. The laser photodetachment is implemented by the interaction between negative ions and a temporally and spatially dependent photon flux. Since the simulation turns out that the intrinsic negative ion density of the simulation is too low to reproduce the laser photodetachment experiment, different modifications and their capabilities of reproducing the experimental results are discussed. The comparison with the experimentally obtained dependencies of the laser photodetachment effect allows conclusions on the spatio-temporal distribution of negative ions.

P 27.4 Fri 11:45 b305

Chemistry of neutral and charged species in the effluent of the micro atmospheric pressure plasma jet in water-helium admixture — •Gert Willems, Achim von Keudell, and Jan Benedikt — Experimental Physik II, Ruhr-Universität Bochum, Germany

A thorough understanding and good control of produced neutral and charged species by cold atmospheric plasmas is essential for potential environmental and/or bio-medical applications. In this respect, mass spectrometry of these plasmas can provide absolute number densities of stable and reactive species and relative trends of charged species. Thereby giving valuable insights into the reaction chemistry. In this study we use the COST reference micro plasma jet (μ-APPJ), a radio-frequency capacitively coupled plasma source with 1 mm electrode distance, which has been operated in helium-water vapour mixture and has been studied as a potential source of hydroxyl radicals and hydrogen peroxide molecules. The water vapour concentration was up to 1.2%. The measurements of hydrogen peroxide and hydroxyl radicals from atmospheric plasma, as measured using MB-MS, will be presented. Their dependency on water vapour concentration in the carrier gas as well as distance to target have been investigated. The measured density is between 5E-13 cm-3 (2.4ppm) and 1.5E-14 cm-3 (7.2ppm) for both hydrogen peroxide molecules and hydroxyl radicals. The achieved results are in good agreement with data from Cavity-Ringdown laser absorption spectroscopy.

P 27.5 Fri 12:00 b305

3D-PIC Simulation of an Inductively Coupled Ion Source — •Robert Henrich, Michael Becker, and Christian Heiliger — Institut für Theoretische Physik, Justus-Liebig-Universität Gießen

Inductively coupled ion sources are applied to a wide range of plasma applications, especially surface modifications. The knowledge of the behavior and precise information of the plasma parameters are of main importance. These values are tedious to measure without influencing the discharge. By applying our fully three-dimensional PlasmaPIC tool we are able to reach these plasma parameters with a spatial and temporal resolution which is quite hard to achieve experimentally. PlasmaPIC is used for modeling discharges in arbitrary geometries without limitations to any symmetry. By this means we are able to demonstrate that the plasma density can have an irrotational character in ICPs. Furhtermore we will show that for gridded inductively coupled ion sources the neutral gas pressure inside the discharge chamber depends on the extraction of ions. This effect is considered in PlasmaPIC by a self-consistent coupling of the neutral gas simulation and the plasma simulation whereas the neutral gas distribution is calculated using the direct simulation Monte Carlo method (DSMC). This work has been supported by the "Bundesministerium fuer Wirtschaft und Energie". Grant 50RS1507

P 27.6 Fri 12:15 b305

Relevanz der dissoziativen Rekombination von positiven Wasserstoffionen für die Balmer-Strahlung in Niederdruck H_2-Entladungen — •Stefan Briefi[1], Dominikus Zielke[1] und Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

In Niederdruck-Niedertemperatur H_2-Plasmen sind Elektronenstoßanregungsprozesse im Wasserstoffatom und dissoziative Anregung des Wasserstoffmoleküls wesentlichen Besetzungkanäle für die oberen Zustände der Balmer-Linien. Aber auch die dissoziative Rekombination von H_2^+ kann eine wichtige – unter Umständen sogar dominante – Rolle spielen. Um die Relevanz der einzelnen Besetzungsprozesse dediziert zu bewerten, wurden Messungen der positiven Ionenspezies H^+, H_2^+ und H_3^+ mittels eines energieauflösenden Massenspektrometers in einer ICP-Entladung (planare Spule, HF-Frequenz 2 MHz, Leistung bis 2 kW) im Druckbereich zwischen 1 und 10 Pa durchgeführt. Zusammen mit der Elektronendichte und -temperatur, die per Langmuirsonde bestimmt werden, dienen die Ionendichten als Input-Parameter für das Stoß-Strahlungs-Modell Yacora H (siehe D. Wünderlich et al., JQSRT, 110, 62 - 71, 2009). Die mit diesem Modell berechneten Besetzungsdichten der elektronischen Niveaus im H Atom werden mit den Resultaten aus emissionsspektroskopischen Messungen verglichen wodurch der Beitrag der jeweiligen Besetzungkanäle für die oberen Zustände der Balmer-Linien bestimmt wird.

P 27.7 Fri 12:30 b305

High power impulse sputtering of chromium: correlation between the energy distribution of chromium ions and spoke formation — •Wolfgang Breilmann, Alexandra Eitrich, Christian Maszl, Ante Hecimovic, Vincent Layes, Jan Benedikt, and Achim von Keudell — Ruhr-Universität Bochum, Experimentalphysik II

The ion energy distribution functions (IEDF) of high power impulse magnetron sputtering (HiPIMS) plasmas show ions with kinetic energies up to 100eV, which do not exist in conventional dc magnetron sputtering discharges. The origin of these high energetic ions is a local maximum of the electric potential inside of ionization zones (IZ). These IZ, also called spokes, are structures of high plasma density, which rotate along the racetrack in ExB direction. With increasing peak current density the amount of spokes reduces until, in the case of a chromium target, they form a homogeneous discharge again. The transition from the no spokes to spokes regime and from the spokes to homogeneous regime have been observed with an energy and time resolved ion mass spectrometer and electrical probe experiments. Mass spectrometry measurements then showed the evolution of the IEDF and its dependence on the spokes regime. It was observed that a high energetic group of ions is generated when spokes occur. Furtheremore, the homogeneous regime mostly affects the low energy part of the IEDF, as it increases the potential difference between the discharge and the mass spectrometer. Thus, the homogeneous discharge is considered to be a single IZ.