Plasma Physics Division (P)

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Overview of the invited lectures and the individual sessions

(Lecture Halls HS 1010 and HS2010; Poster HS Foyer)

Invited Lectures

P 1.1	Mo	8:30– 9:00	HS 2010	**Using Fullwave Simulations to Understand the Turbulent Wavenumber Spectrum Measured by Doppler Reflectometry** — •Carsten Lechte, Garrard Conway, Tobias Görler, Tim Happel, Carolin Tröster-Schmid, The ASDEX Upgrade Team
P 3.1	Mo	14:00–14:30	HS 1010	**Numerical studies of plasma-object interactions** — •Wojciech Miloch
P 4.1	Mo	14:00–14:30	HS 2010	**Atmospheric reactive plasma jet machining technologies for ultra-precision optical surface manufacturing** — •Thomas Arnold
P 9.1	Di	8:30– 9:00	HS 2010	**Summary of the Edge Physics Results from the First Operation Phase of the Wendelstein 7-X Stellarator** — •Ralf König, W7-X team
P 9.2	Di	9:00– 9:30	HS 2010	**Physics of heat and momentum transport changes in ohmically confined tokamak plasmas** — •Rachael McDermott, Alexander Lebschy, Ivan Erofeev, Clemente Angioni, Emiliano Fable, the ASDEX Upgrade Team
P 10.1	Di	14:00–14:30	HS 2010	**Filamentary plasma eruptions: results from the nonlinear ballooning model** — •Sophia A. Henneberg, Steven C. Cowley, Howard R. Wilson
P 16.1	Mi	8:30– 9:00	HS 1010	**Influence of released surface electrons on the pre-ionization of helium barrier discharges** — •Robert Tschiersch, Sebastian Nemschokmichal, Jürgen Meichsner
P 17.1	Mi	8:30– 9:00	HS 2010	**PK-4 - Complex Plasmas under Microgravity** — •Markus Thoma
P 18.1	Mi	14:30–15:00	HS 2010	**The structure and its role in uncovering the physics of warm dense matter** — •Jan Vorberger
P 24.1	Do	8:30– 9:00	HS 1010	**Quasi-steady state plasma operation in the Be/W material mix: from the JET tokamak to ITER** — •Sebastijan Brezinsek
P 25.1	Do	8:30– 9:00	HS 2010	**Modeling streamer discharges in strong magnetic fields** — •Jannis Teunissen, Anbang Sun, Ute Ebert
P 27.1	Do	14:00–14:30	HS 2010	**Plasma discharges for the ambient processing of materials** — •James Bradley

Hauptvorträge des fachübergreifenden Symposiums SYPO

Das vollständige Programm dieses Symposiums ist unter SYPO aufgeführt.

SYPO 2.1	Mi	14:10–14:35	GW1 HS	**Herstellung von Interferenz-Schichtsystemen - vom Design zum fertigen Filter** — •Detlef Arhilger
SYPO 2.2	Mi	14:35–15:00	GW1 HS	**Praxisnahe Modellierung von Ionenstrahl-Zerstäubungsprozessen** — •Kai Starke, Benjamin Lotz, Wjatscheslaw Sakiew, Stefan Schrameyer
SYPO 2.3	Mi	15:00–15:25	GW1 HS	**Stabilisierung des Ionenstrahl-Zerstäubungs-Prozesses über adaptiv geregelte Prozessparameter** — •Florian Carstens
SYPO 2.4	Mi	15:25–15:50	GW1 HS	**Interface chemistry of thin films deposited from pulsed high power plasmas** — •Guido Grundmeier

SYPO 4.1	Mi	16:20–16:45	GW1 HS	**Diagnostics and Control Schemes for Industrial PIAD Processes** — •Jens Harhausen, Rüdiger Foest, Christian Franke, Olaf Stenzel, Jochen Wauer, Steffen Wilbrandt
SYPO 4.2	Mi	16:45–17:10	GW1 HS	**Wiederholbarkeit optischer Konstanten von plasmagestützt abgeschiedenen Oxidschichten** — •Olaf Stenzel, Steffen Wilbrandt
SYPO 4.3	Mi	17:10–17:35	GW1 HS	**Die Multipolresonanzsonde: Von der Diagnostik zur Systemanwendung** — •Moritz Oberberg, Marcel Fiebrandt, Stefan Ries, Nikita Bibinov, Peter Awakowicz
SYPO 4.4	Mi	17:35–18:00	GW1 HS	**Low stress transparent materials for optical coatings on flexible substrates** — •Melanie Gauch, Henrik Ehlers, Detlev Ristau

Sessions

P 1.1–1.6	Mo	8:30–10:15	HS 2010	**Plasma Diagnostics I**
P 2.1–2.5	Mo	8:30–10:35	HS 1010	**Helmholtz Graduate School I**
P 3.1–3.6	Mo	14:00–15:55	HS 1010	**Dusty Plasmas I**
P 4.1–4.7	Mo	14:00–16:00	HS 2010	**Plasma Technology**
P 5.1–5.10	Mo	16:30–18:30	HS Foyer	**Plasma Diagnostics**
P 6.1–6.16	Mo	16:30–18:30	HS Foyer	**Helmholtz Graduate School I**
P 7.1–7.13	Mo	16:30–18:30	HS Foyer	**Complex and Dusty Plasmas**
P 8.1–8.6	Di	8:30–10:20	HS 1010	**Plasma Diagnostics II**
P 9.1–9.4	Di	8:30–10:10	HS 2010	**Magnetic Confinement I**
P 10.1–10.6	Di	14:00–15:45	HS 2010	**Theory and Modeling I**
P 11.1–11.6	Di	14:00–16:30	HS 1010	**Helmholtz Graduate School II**
P 12.1–12.5	Di	16:30–18:30	HS Foyer	**Theory and Modelling I**
P 13.1–13.14	Di	16:30–18:30	HS Foyer	**Magnetic Confinement**
P 14.1–14.6	Di	16:30–18:30	HS Foyer	**Plasma Wall Interaction**
P 15.1–15.26	Di	16:30–18:30	HS Foyer	**Helmholtz Graduate School II**
P 16.1–16.5	Mi	8:30–10:10	HS 1010	**Plasma Diagnostics III**
P 17.1–17.6	Mi	8:30–10:25	HS 2010	**Dusty Plasmas II**
P 18.1–18.4	Mi	14:30–15:45	HS 2010	**Theory and Modeling II**
P 19.1–19.4	Mi	15:00–16:00	HS 1010	**Plasma Diagnostics IV**
P 20.1–20.2	Mi	16:30–18:30	HS Foyer	**Laser Plasmas**
P 21.1–21.4	Mi	16:30–18:30	HS Foyer	**Plasma Technology**
P 22.1–22.11	Mi	16:30–18:30	HS Foyer	**Theory and Modelling II**
P 23.1–23.16	Mi	16:30–18:30	HS Foyer	**Low Temperature Plasmas**
P 24.1–24.6	Do	8:30–10:15	HS 1010	**Plasma Wall Interaction**
P 25.1–25.7	Do	8:30–10:30	HS 2010	**Theory and Modeling III**
P 26.1–26.1	Do	11:00–11:45	HS 2010	**Plenarvortrag Annemie Bogaerts**
P 27.1–27.5	Do	14:00–16:00	HS 2010	**Low Temperature Plasmas**
P 28.1–28.6	Do	14:00–16:30	HS 1010	**Helmholtz Graduate School III**

General Assembly Section Plasma Physics

Wednesday 14:00–14:30 Lecture Hall HS2010

- Report
- Elections
- Miscellaneous

Conference Language

The default conference language of the plasma physics section of the DPG is English to allow the conference attendance of international researchers from abroad as well as from German plasma groups.

P 1: Plasma Diagnostics I

Zeit: Montag 8:30–10:15 Raum: HS 2010

Hauptvortrag P 1.1 Mo 8:30 HS 2010

Using Fullwave Simulations to Understand the Turbulent Wavenumber Spectrum Measured by Doppler Reflectometry — •Carsten Lechte[1], Garrard Conway[2], Tobias Görler[2], Tim Happel[2], Carolin Tröster-Schmid[2], and The ASDEX Upgrade Team[2] — [1]IGVP, Stuttgart University, 70569 Stuttgart, Germany — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

Doppler reflectometry is used to measure the wavenumber spectrum of the turbulent density fluctuations in fusion plasmas. Experimental Doppler spectra and density spectra from turbulence simulations show marked differences in the position and shape of the inertial range of the turbulence.

Fullwave simulations of the reflectometer show the non-linear scattering properties of the plasma at the observed density fluctuation levels and can explain these differences. In addtion, experimental Doppler reflectometry spectra from ASDEX Upgrade show a significant difference between measurements done in X and O mode polarisation, even though the underlying turbulence is the same. Turbulence simulations, together with synthetic turbulence, are used to investigate these properties of the Doppler scattering process.

P 1.2 Mo 9:00 HS 2010

Developing a Method for Measuring Plasma Radius using Schlieren Imaging — •Anna-Maria Bachmann — Max-Planck Institute for Physics, Munich, Germany

AWAKE (Advanced Wakefield Experiment) develops a new plasma wakefield accelerator using the CERN SPS proton bunch as a driver. It is propagating through a 10m long rubidium plasma, induced by an ionizing laser pulse. Since the transverse component of the wakefield has a significant value up to a radius of approximately 1mm the plasma radius must be determined experimentally, to ensure its value is larger than this value along the cell.

We use the bending of the rays of a laser pulse caused by the change of index of refraction and deflection induced by the ionizing laser pulse propagation to measure this radius. Schlieren Imaging is an optical method, which allows to increase the plasma column image contrast by blocking non-deflected rays, acting as a background, while imaging the transparent object, the plasma column in this case. The refractive index of plasma is slightly lower than 1 while the value for vapor differs strongly from 1 for light with a frequency very close to the transition frequency of the given element. Rubidium has a transition line in the visible range from the ground to the first excited state, the D2 line at 780nm. Using a tunable laser in this range, one can make the effect of the disappearing vapor in the center of the ionizing laser beam visible.

We will describe the method, explain the experimental setup and present experimental results.

P 1.3 Mo 9:15 HS 2010

Interferometer-based white light measurement of neutral rubidium density for the AWAKE experiment at CERN — •Fabian Batsch, Erdem Öz, and Patric Muggli — Max-Planck-Institut für Physik, München, Deutschland

The AWAKE experiment at CERN aims to pave the way for proton-driven plasma wakefield acceleration. One of its central parts is a unique 10 m long, temperature stabilized rubidium (Rb) vapor source. Full laser ionization of the vapor generates a 10 m long 2 mm diameter plasma channel with equal density. The optimal plasma density for wakefield acceleration is in the range of $1 \cdot 10^{14}$ to $1 \cdot 10^{15}$ cm^{-3} . Further, a density gradient along the cell (0 to 10 %) may have a positive effect on the acceleration process. The plasma density and gradient is determined by measuring optically in an automated way the vapor density at both cell ends. The diagnostic uses a coherent broadband light source, a Mach-Zehnder interferometer build out of single mode fibers and a fiber spectrograph. We apply the hook method adapted to vertical fringes. Without vapor, the interference signal intensity spectrum is sinusoidal. With vapor, anomalous dispersion occurring in the vicinity of the Rb transition lines at 780.027 nm and 794.760 nm cause a change in the distance between intensity maxima (fringes). The fringe distance becomes smaller the closer one is to the transition line and also with higher density. The Rb vapor density is obtained by fitting these curves with a function describing this change, giving a relative accuracy better 0.2 %. This diagnostic was successfully used during the first phase of the AWAKE experiment in Dec. 2016.

P 1.4 Mo 9:30 HS 2010

Kinetic Investigation of Ideal Multipole Resonance Probe — •Junbo Gong[1], Sebastian Wilczek[1], Jens Oberrath[2], Denis Eremin[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. One particular realization of APRS with a high degree of geometric and electric symmetry is Multipole Resonance Probe (MRP). The Ideal MRP (IMRP) is an even more symmetric idealization which is suited for theoretical investigations. In this work, 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 particles pusher and the field solver. However, due to the velocity difference, the electrons are treated as particles whereas the ions are only considered as stationary background. The particle pusher integrates the equations of motion for the studied particles. The Poisson solver determines the electric field at each particle position. The proposed method overcomes the limitation of the cold plasma model and covers kinetic effects like collisionless damping.

P 1.5 Mo 9:45 HS 2010

Evaluation of new faraday probe designs employing RF ion sources and ion thrusters — •Maximilian Quaas, Frank Scholze, Ronny Woyciechowski, Christoph Eichhorn, Carsten Bundesmann, and Daniel Spemann — Leibniz Institute of Surface Modifcation, Permoserstr. 15, 04318 Leipzig

Faraday probes are indispensable tools for measuring the beam current density of ion sources or thrusters. However, a reliable determination of the positive ion current is not a simple task, but requires to take several effects into account, for example, the emission of secondary electrons and sputtered ions as well as the contribution of electrons from the neutralizer, if applicable, that can alter the measured beam current significantly. In order to account for these sources of uncertainties, new faraday cup designs, typically comprising a screen and a repeller electrode in front of the charge-sensitive cup, were evaluated using SIMION simulations. These simulations allowed to optimize the geometrical dimensions of the components as well as the voltage applied to the repeller electrode to ensure that sputtered ions as well as secondary electrons, respectively, do not leave and neutralizer electrons do not enter the cup. The optimized faraday cups were manufactured, tested and evaluated using Xe ions from a gridded RF ion source. The measured beam profiles recorded for several distances from the source were compared with a reference cup and the calculated total currents compared to the beam current for different repeller voltages.

P 1.6 Mo 10:00 HS 2010

A simple equation for curling probe plasma diagnostics — •Ali Arshadi and Ralf Peter Brinkmann — Institute of Theoretical Electrical Engineering, Ruhr University Bochum, Germany

The recently invented plasma diagnostic device, curling probe (CP) is an innovative realization of ‘Active plasma resonance spectroscopy’. The CP is a spiral slot-type antenna. It has been used for accurate measurement of the electron density in low pressure plasmas for materials processing. Because of its planar and spiral structure, the CP is flatly embedded into the chamber wall that minimizes the perturbation. Since a thin layer of Quartz or Kapton covers the CP’s metal front, no metal impurity is released during the plasma processing. The CP excites the plasma by a weak RF signal and a network analyzer is used to monitor the power reflection coefficient. Two resonant microwave absorption are observed at specific frequencies between 2 and 5 GHz which are strongly dependent on the electron density and the spiral length. Neglecting the little spiralization effect, this work presents a mathematical model for a ‘straightened’ CP enabling us to determine the electron density for low and high pressure plasmas. A simple and very practical expression for the probe resonance is obtained considering the resonance of a half-wavelength standing wave along the probe length. Good agreement between our computations and the FDTD simulation is shown.

P 2: Helmholtz Graduate School I

Zeit: Montag 8:30–10:35 Raum: HS 1010

P 2.1 Mo 8:30 HS 1010

Topology optimisation of two material structures for plasma-facing component applications — •Alexander von Müller[1,2], Rudolf Neu[1,2], Udo von Toussaint[1], and Jeong-Ha You[1] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Technische Universität München, 85748 Garching, Germany

An important plasma-facing component (PFC) in future magnetic confinement nuclear fusion devices is the divertor which allows power exhaust and removal of impurities from the main plasma during operation. The most highly loaded parts of a divertor have to withstand intense particle bombardment which in turn leads to severe heat fluxes.

According to the current understanding, tungsten (W) is used as a plasma facing material while copper (Cu) is used as heat sink material in such a component. However, the combination of these materials bears difficulties due to their inherently different thermomechanical properties leading to thermal stresses during heat flux loading.

Up-to-date additive manufacturing technologies offer possibilities to materialise objects with almost any shape. Against this background, the question arises whether a topologically optimised W-Cu structure can be beneficial in order to achieve an improved PFC design.

The contribution addresses this issue by assessing the suitability of topology optimisation techniques regarding the abovementioned two material problem. An approach is presented how such an optimisation can be implemented. Eventually, the practicality of this approach is demonstrated based on a representative test case.

P 2.2 Mo 8:55 HS 1010

Plasma-driven deuterium permeation through tungsten at 300 and 450 K — •Stefan Kapser[1,2], Mitja Kelemen[3], Armin Manhard[1], Sabina Markelj[3], Klaus Schmid[1], Tiago Silva[1,4], Primož Vavpetič[3], 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 — [3]Jožef Stefan Institute and Association EURATOM-MHEST, 39 Jamova cesta, Ljubljana 1000, Slovenia — [4]Instituto de Física da Universidade de São Paulo, Rua do Matão, trav. R 187, 05508-090 São Paulo, Brazil

Deuterium permeation through tungsten under plasma exposure has been investigated for sample temperatures of 300 K and 450 K. Tungsten foils were exposed to deuterium plasma on one side, the permeating deuterium was accumulated in a getter layer on the other side. Subsequently, the deuterium amount in the getter was measured using nuclear reaction analysis (NRA). In addition, the deuterium depth distributions in the tungsten were investigated by NRA. Despite significant differences in the deuterium retention in the subsurface region of the plasma exposed tungsten, the measured permeation flux at both temperatures was similar. The experiments are interpreted based on trap-diffusion simulations. Additionally, microbeam-NRA was used to investigate the influence of the tungsten microstructure on the spatial homogeneity of the deuterium permeation flux.

P 2.3 Mo 9:20 HS 1010

Impact of 3D Magnetic Perturbations on Divertor Heat Load in ASDEX Upgrade — •Michael Faitsch, Bernhard Sieglin, Thomas Eich, Albrecht Herrmann, Wolfgang Suttrop, and the ASDEX Upgrade Team — Max-Planck-Institute for Plasma Physics, Boltzmannstr. 2, D-85748 Garching, Germany

The reduction of transient heat loads due to edge localized modes (ELM) in H-mode is required for the sustained operation of ITER/DEMO. The application of 3D magnetic perturbation (MP) fields is investigated as a method for ELM control and full ELM suppression which has recently been established on ASDEX Upgrade (AUG). However, these 3D fields lead to toroidal asymmetries of the heat load pattern in the divertor that may be problematic for future devices. AUG is equipped with a versatile coil set and a high resolution infrared (IR) camera system to characterize the impact of MPs on divertor heat loads to the highest accuracy. The 2D heat flux with constant divertor conditions in L- and H-mode is studied in AUG with slow rotating (1 Hz) $n = 1,2,3$ MP fields. In H-mode both ELM and inter-ELM data is obtained.

The resulting 2D heat flux pattern varies for distinct differential phases. The presented data indicate that at least in L-Mode enhanced cross-field transport due to the MP is negligible. With increasing density the characteristic of the 2D heat flux structure is reduced. This is accredited to the increase of the divertor power spreading S. However, ELM filaments and divertor striations lock to the perturbation leading to enhanced sputtering at distinct toroidal locations.

P 2.4 Mo 9:45 HS 1010

Divertor Heat Fluxes with Magnetic Perturbations at High Densities in the Tokamak ASDEX Upgrade — •Dominik Brida[1,2], Tilmann Lunt[1], Marco Wischmeier[1], Matthias Bernert[1], Daniel Carralero[1], Michael Faitsch[1], Till Sehmer[1], Bernhard Sieglin[1], Yühe Feng[3], Wolfgang Suttrop[1], Elisabeth Wolfrum[1], The MST1 Team[1], and The ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, D-85748 — [2]Physik Department, Technische Universität München, James-Franck-Str. 1, D-85748 Garching — [3]Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, D-17491

Magnetic Perturbations have been the subject of extensive research in the last years, due to the prospect of mitigating harmful edge localized modes (ELMs) in future divertor tokamaks, such as ITER. As an undesireable side effect MPs can create a toroidally non-uniform divertor target heat flux. This has been consistently measured, among others, in the tokamak ASDEX Upgrade (AUG) at low divertor densities. However, currently it is envisaged to operate ITER in a partially detached regime, at high divertor densities, where the impact of transport may be different.

To address this issue a comprehensive set of high density L- and H-mode deuterium discharges with MPs were carried out in AUG. It was found that the target heat flux becomes increasingly axisymmetric as the divertor detaches. Furthermore, a similar tendency has been observed in simulations with the 3D transport code EMC3-EIRENE.

P 2.5 Mo 10:10 HS 1010

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

The solution of nonlinear partial differential equations may often pose difficult challenges in the development of efficient codes for physics simulations. Standard methods usually rely on iterative schemes that, in time-dependent problems are nested into time-stepping iterations. In strongly non-linear cases, convergence of the iterative nonlinear solver imposes prohibitively small values for the time-step. When only the steady state is of interest, this amounts to wasting resources in the uninteresting transient. In this work, we propose new relaxation methods for the computation of steady-state solutions for strongly non-linear systems, based on the dissipation of specific metrics of the system which guarantee better steady-state convergence properties. The main envisaged application is the speeding up of the computational fluid dynamics kernel of the SOLPS (Scrape-Off Layer Plasma Simulation) suite of codes which simulate the outer region of the plasma column in tokamak devices.

P 3: Dusty Plasmas I

Zeit: Montag 14:00–15:55 Raum: HS 1010

Hauptvortrag P 3.1 Mo 14:00 HS 1010

Numerical studies of plasma-object interactions — •Wojciech Miloch — Department of Physics, University of Oslo, Norway

Interaction of plasma with finite-sized objects is one of main problems in plasma physics. Objects immersed in plasma will be charged by plasma and other currents, a sheath will form in their vicinity, and plasma parameters will be modified locally. Detailed understanding of the plasma-object interactions is important for a number of problems, including plasma diagnostics by probes, spacecraft performance, plasma processing, or dynamics of dust grains in complex (dusty) plasmas.

The relative motion of an object and plasma breaks the symmetry of charging, and gives rise to the wake in plasma density and potential. The object charging and wake formation are often nonlinear processes, and to study them, first principle kinetic numerical simulations should be considered. Such simulations can be carried out with the particle-in-cell (PIC) method, where trajectories of a large number of plasma particles are followed in self-consistent force fields. In this work, I focus on the object charging in flowing plasmas and wakefield effects, and present recent results from self-consistent PIC simulations. Problems that are addressed include spacecraft-plasma interaction, the role of wakes in data acquisition and instrument performance, charging of several dust grains, and the role of magnetic field in the wake formation.

Fachvortrag P 3.2 Mo 14:30 HS 1010

Structure and properties of two-dimensional binary mixtures — •Frank Wieben and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Binary mixtures can occur in various systems, e.g. fluids, colloidal suspensions and strongly coupled complex plasmas. The primary characteristic of binary systems is the decomposition of the species under certain conditions. Complex plasmas, compared to fluids or colloidal suspensions, feature a low damping of the particles which allows for the investigation of dynamical processes. Under microgravity conditions dust particles in a complex plasma form three-dimensional clouds. If a second species is injected, a fast decomposition of the species is observed, even for small size disparities. In ground based experiments two species can form a two-dimensional binary monolayer if the charge-to-mass ratios are equal. However, there are no experiments on 2D binary mixtures yet and numerical simulations on binary Yukawa systems in parabolic traps predict no decomposition of the species. In this contribution first experiments on two-dimensional binary mixtures in complex plasmas are presented. Special attention is paid to the demanding experimental generation of these systems. The experiments are compared to molecular dynamics simulations that include imperfections of real complex plasmas.

This work was supported by the Deutsche Forschungsgemeinschaft DFG in the framework of the SFB TR24 Greifswald Kiel, Project A3b.

P 3.3 Mo 14:55 HS 1010

Fine structure of a Mach cone in a zero gravity, 3d complex plasma system — •Erich Zaehringer, Mierk Schwabe, Sergey Zhdanov, Christina A. Knapek, Daniel P. Mohr, Peter Huber, and Hubertus M. Thomas — DLR German Aerospace Center, Research Group Complex Plasmas, Wessling, Germany

For a Complex Plasma, small micrometer sized particles are injected into a low temperature plasma, consisting of electrons, ions and neutral gas. Particles are getting charged by electrons and ion fluxes on their surfaces. These particles form a system with gaseous, liquid and solid properties out of several thousand charged particles. The single particle dynamics can be recorded in direct measurements due to the large size of 1 - 10 μm. Additional to measurements on plasma conditions and the particle system itself, extra particles can generate a lot of extra information about the complex plasma system.

A probe particle with supersonic speed was observed during a zero gravity experiment in the Zyflex chamber of the PlasmaLab / Eko-Plasma project, generating a fine structured Mach cone in the 3D complex plasma system. Based on that, a profile of the acoustic velocity across the cloud could be generated and perturbations were analysed. The high resolution of the data offers the application of PTV and PIV methods to measure densities, velocities and displacements, and to characterize the super-sonic motion.

This work and some of the authors are funded by DLR/BMWi (FKZ 50WM1441).

P 3.4 Mo 15:10 HS 1010

A Machine-Learning Method for Plasma Crystal Analysis — •Christopher Dietz, Tobias Kretz, and Markus Thoma — I. Physikalisches Institut, JLU Gießen

Machine-Learning is one of the most popular fields in computer science and has a vast amount of applications. We propose a method, that will use a Machine-Learning algorithm to identify crystal structures in a simulated plasma crystal. This data consists of fcc, hcp, bcc and disordered particles, which is difficult to identify using conventional methods.

The new approach works very well for highly disturbed lattices and mixed phase systems. Thus, it enables us to retrieve a more complete picture of plasma crystals.

P 3.5 Mo 15:25 HS 1010

In Operando Size Measurements of Single Microparticles in Plasmas — •Oguz Han Asnaz, Hendrik Jung, Franko Greiner, and Alexander Piel — Institute of Experimental and Applied Physics, Kiel University, Germany

In recent years ever more precise measurements of single dust particles in a plasma environment became possible. The goal of these experiments is the usage of particles as small probes for determining several plasma properties. With the gain in precision, the accuracy of manufacturer's data about the particles dimensions became a limiting factor. Therefore, in operando measurements of the microparticles are needed. In this contribution two such methods are demonstrated. Using a long distance microscope, single particles are imaged from outside the plasma chamber. In combination with phase-resolved resonance measurements [1] it is possible to determine the particle mass. Since this method can be used in operando, it is possible to analyze the long-term evolution of spherical and non-spherical particles during plasma exposure over several hours. For smaller spherical particles interferometric techniques based on Mie-scattering offer finer resolution by resolving the angular scattering pattern of the particle.

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

[1] H. Jung *et al.*, J. Plasma Phys. **82** (2016)

P 3.6 Mo 15:40 HS 1010

Single Dust Particles in a Magnetized Plasma: Stability, Charging and Interaction — •Hendrik Jung, Franko Greiner, and Alexander Piel — Institute of Experimental and Applied Physics, Kiel University, Germany

Dust in plasmas with high magnetic fields ($B > 1.0\,\mathrm{T}$) is a major topic in dusty plasma physics. The magnetization of the plasma leads to fundamental changes of the discharge properties. The limited cross field motion of the plasma constutuents has a substantial impact not only on the plasma itself but also on the charging and interaction of dust grains. The formation of filaments – structures of higher density or temperature that propagate through the magnetized discharge – play a significant role since they impede a stable confinement of the micrometer-sized dust grains and make high-precision studies of the particle system difficult.

In this contribution we show how filaments induce instabilities and heat particles. Pulsing the rf discharge suppresses filament-induced instabilities what can be utilized to get a single particle or a specific particle system to high magnetic fields where stable parameter regimes even in the continuous wave mode can be found and reliable studies of the dust system are performed. By using the well-established phase-resolved resonance method [Jung et al., JPP 82, 615820301 (2016)] the influence of the plasma magnetization on the dust charging and wake formation is investigated.

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

P 4: Plasma Technology

Zeit: Montag 14:00–16:00 Raum: HS 2010

Hauptvortrag P 4.1 Mo 14:00 HS 2010

Atmospheric reactive plasma jet machining technologies for ultra-precision optical surface manufacturing — •Thomas Arnold — Leibniz-Institut für Obrflächenmodifizierung e.V. Leipzig/TU Dresden

Atmospheric chemically reactive plasma jets are versatile tools utilized for ultra-precision surface machining. Nowadays, optical elements like lenses and mirrors require very high surface form accuracy and low waviness and micro-roughness in the range of a few nanometers or even below. At the same time, optical surface shapes differ significantly from simple basic forms like planar, spherical or cylindrical geometries. In modern optical applications e.g. for laser beam shaping, space-based astronomical telescopes, or synchrotron beam-lines optics, more and more complex aspherical or freeform surface are required. Deterministic and precise machining of optical materials like fused silica, silicon or silicon carbide by reactive plasma jets has shown a great potential over conventional mechanical-abrasive optical manufacturing since no mechanical forces are exerted to the surface and the chemical nature of plasma surface-interaction is utilized to well controlled local damage-free surface modification. Plasma jets containing halogenated precursors (e.g. CCl4, CF4) are applied in dry etching processes to remove surface material, while polymer forming precursors (e.g. CH4, hexamethyldisiloxane HMDSO) are employed for localized thin film deposition. The presentation will cover problems of plasma-surface interactions as well as technology related aspects in plasma assisted surface machining processes.

P 4.2 Mo 14:30 HS 2010

Deposition of SiO_x coatings by means of inductively coupled plasma — •Markus Brochhagen, Vincent Layes, Marc Böke, and Jan Benedikt — Experimentalphysik II, Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum

SiO_2-like films can serve as barrier coatings on polymeric substrates, where the barrier properties depend on the amount of carbon inside the layer. Such layers can be produced in a plasma process using evaporated HMDSO and admixed Argon or Oxygen. This mixture influences the amount of carbon inside the layer. The less carbon is inside the layer, the better is the barrier property of the film. The process is studied under high plasma density conditions in an ICP plasma with in-situ ellipsometry, FTIR spectrometry and XPS. Additionally the thickness is measured with a profilometer. Also the impact of argon ions and metastables is investigated in a process with prolonged Ar-plasma treatments of thin SiO_2-like layers. It is tested if carbon free films can be achieved even without O_2 admixture as it was reported for atmospheric plasmas.

This work is supported by DFG within SFB-TR 87.

P 4.3 Mo 14:45 HS 2010

CO2-based test for the detection of defects in oxygen barrier layers — •Mariagrazia Troia[1], Andreas Schulz[1], Matthias Walker[1], and Thomas Hirth[2] — [1]Institute of Interfacial Process Engineering and Plasma Technology IGVP, University of Stuttgart, Stuttgart, Germany — [2]Karlsruher Institut für Technologie KIT, Karlsruhe, Germany

Barrier layers performances are severely limited by the presence of punctual micro- and sub-micro-metrical defects. In order to determine the density of defects in barrier layers obtained through PEVCD, their origin and overall effect on oxygen transmission rate, a new non-destructive test has been developed and optimized.

Silica-like films acting as oxygen barrier layers have been deposited by means of an Electron Cyclotron Resonance low-pressure, MW-sustained plasma through gaseous feeds with different HMDSN/O2 ratios.

The coated sample is interposed between a pure CO2 atmosphere and a limewater solution: CO2 permeates preferentially through the pinholes in the barrier layers, causing the precipitation of CaCO3 crystals on top of them. Real-time analysis is performed by means of an optical microscope on top of the testing cell.

Average defect densities for different substrates and for various thicknesses and chemical compositions of barrier layers have been calculated and compared to their respective oxygen transmission rate and barrier improvement factor: the reduction of defects number shows very good accordance with the reduction in the oxygen transmission rates.

P 4.4 Mo 15:00 HS 2010

Spitze - zu - Wasser - Entladung: optische, elektrische und chemische Charakterisierung sowie Anwendungsbeispiele — •Michael Schmidt[1], Ioana Cristina Gerber[2], Torsten Gerling[1], Beke Altrock[1] und Thomas von Woedtke[1] — [1]INP Greifswald — [2]University of Iasi

Die Behandlung von Wasser mittels nicht-thermischen Plasmas führt zur Veränderung der chemischen Zusammensetzung des Wassers in Abhängigkeit von der Plasmaleistung und der Dauer der Einwirkung sowie der Art des behandelten Wassers. Vorgestellt wird eine anwendungsnah konzipierte Plasmaquelle zur Behandlung von Wasservolumina bis 1 L, basierend auf elektrischen Entladungen zwischen metallischen, hochspannungsbeaufschlagten Elektroden und einer Wasseroberfläche. Es werden optische und elektrische Untersuchungen an der Plasmaquelle sowie chemische Analysen unterschiedlicher behandelter Wasserarten diskutiert. Hierbei zeigt sich, dass sich die Leitfähigkeit und der pH-Wert bei demineralisiertem Wasser und bei Reinstwasser stark ändern, bei Leitungswasser jedoch nur geringfügig. In einer Anwendungsstudie wird die Inaktivierung unterschiedlicher Mikroorganismen, abhängig von der Art des behandelten Wassers und der Einwirkdauer, untersucht. Es kann gezeigt werden, dass alle behandelten Wasserarten antimikrobiell wirksam sind.

P 4.5 Mo 15:15 HS 2010

Decontamination of Space Equipment Using Cold Atmospheric Plasma — •Meike Müller[1], Sylvia Binder[2], Tetsuji Shimizu[2], Igor Semenov[1], Julia Zimmermann[2], Petra Rettberg[3], Gregor Morfill[2], and Hubertus Thomas[1] — [1]Deutsches Zentrum für Luft- und Raumfahrt, Institut für Materialphysik im Weltraum; Argelsrieder Feld, Wessling 82234, Germany — [2]terraplasma GmbH, Lichtenbergstraße, Garching 85741, Germany — [3]Deutsches Zentrum für Luft- und Raumfahrt, Institut für Luft- und Raumfahrtmedizin, Linder Höhe, Köln 51147, Germany

Cold atmospheric plasma (CAP) is a very effective technology for the inactivation of microorganisms, which is of crucial interest for extraterrestrial space missions. In our study, a new designed plasma-gas circulation system has been developed and tested. The investigations with bioindicators (Bacillus atrophaeus spores) show that this technology has a high biocidal effect. Therefore, several treatment volumes were tested to optimize the CAP efficacy. In addition, we plan to perform a series of measurements for chemical composition by using a FTIR spectrometer. This provides an insight into the plasma chemistry including the influence of the humidity on the inactivation of microorganisms. In this contribution, we propose a possible design of decontamination system for larger spacecraft facilities using CAP. Furthermore we will discuss the advantage of CAP technology in comparison with conventional sterilization methods.

P 4.6 Mo 15:30 HS 2010

The milli-Newton μHEMPT as Potential Main Thruster for Small Satellites — •Max Vaupel[1,2], Franz Georg Hey[1], Alexander Sell[1], Karlheinz Eckert[1], Tim Brandt[3,4,5], Claus Braxmaier[3,4], Martin Tajmar[2], Dennis Weise[1], and Ulrich Johann[1] — [1]Airbus Defence and Space, Germany — [2]Technische Universität Dresden, Germany — [3]DLR, Institute of Space Systems, Germany — [4]Center of Applied Space Technology and Microgravity, University of Bremen, Germany — [5]Institute of Experimental and Applied Physics, University of Kiel, Germany

In the last years, small satellites become more important due to the continuing miniaturisation of key technology. Due to the constraining mass requirements of small satellites, electric propulsion with its high propellant-to-thrust ratio offers several advantages. Airbus DS in Friedrichshafen performs a downscaling of the HEMPT principle to the micro-Newton regime and additionally developed a mN-μHEMPT which can be operated towards 10 mN. The mN-μHEMPT performance was characterised by direct thrust measurement as well as an indirect thrust measurement using a retarding potential analyser and Faraday cup at the AirbusDS test facility.

P 4.7 Mo 15:45 HS 2010

Characterization of two APPJs for biomedical applications — •Daniela Coenen, Julian Kaupe, Slobodan Mitic, Jan Philipps, and Detlev Hofmann — I. physikalisches Institut, Justus-Liebig-Universität, Giessen, Germany

Two atmospheric pressure plasma jets (APPJ) for biomedical applications have been designed and investigated. Firstly an APPJ for liquid spray treatment has been built to produce plasma activated liquids. Plasma quality was characterized by optical emission spectroscopy and phase resolved imaging while effect of a plasma on liquid droplets was evaluated by detection of radicals by electron-paramagnetic-resonance. The device was shown to be an efficient source for production and deposition of plasma activated liquids.

Furthermore a DBD-APPJ has been built for treatment of bacteria and viruses in solutions. Samples can be treated in a closed chamber providing conditions for systematic study of gas mixture effect on mortality of microorganisms in controllable environment. First experiments have been conducted comparing argon and helium as a carrier gas with admixtures of N_2 and synthetic air. Moreover optical and electrical diagnostics have been performed with the aim to investigate the correlation between plasma parameters and bactericidal effects. Additionally gas temperature has been estimated from rotational temperature of nitrogen second positive spectra. Using helium as carrier gas leads to higher power consumption at constant input voltages and better bactericidal effects than usage of argon. For admixtures of N_2 a significant decrease of the ion-to-neutral-ratio of N2 was observed.

P 5: Plasma Diagnostics

Zeit: Montag 16:30–18:30 Raum: HS Foyer

P 5.1 Mo 16:30 HS Foyer

Validation of current profile diagnostics at ASDEX Upgrade — •Marvin Erdmann[1,2], Alexander Bock[1], Rainer Fischer[1], Valentin Igochine[1], Alexander Mlynek[1], Matthias Reich[1], David Rittich[1], Jörg Stober[1], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Ludwig-Maximilians-Universität München, Munich, Germany

In magnetic confinement fusion, a hot plasma is confined by a magnetic field. This field balances the plasma's kinetic pressure, forming a so-called magnetic equilibrium. In the tokamak ASDEX Upgrade, the profile of the toroidal current and the related poloidal magnetic field are measured by polarimetry of a plasma-induced Faraday rotation of a DCN laser beam and by polarimetry of the Motional Stark Effect-induced polarization of the neutral beam emissions. Both diagnostics provide constraints for the equilibrium reconstruction but also suffer from calibration and background issues.

The goal of this contribution is to examine the accuracy of the equlibrium reconstruction and the agreement of the two diagnostics with the localization of Neoclassical Tearing Modes (NTMs) occuring exclusively on rational magnetic surfaces. The techniques of localizing NTMs and the validation of the two polarimetry diagnostics will be shown. Candidates for systematic uncertainties will be discussed.

P 5.2 Mo 16:30 HS Foyer

Measurement of Two-Dimensional Density and Temperature Profiles in Fully Magnetized RF Plasmas — •Jonathan Schilling, Hendrik Jung, Franko Greiner, and Alexander Piel — IEAP, Kiel University, Germany

Knowledge of the spatial structures of plasma parameters plays a key role in understanding the interplay between the plasma and its surroundings as well as embedded structures like a sputtering target or dust particles. Two-dimensional profiles of the ion density and the electron temperature at magnetic flux densities from 0 T to 4 T have been acquired using a sweeped Langmuir probe attached to a 2D positioning unit in radio frequency (rf) driven capacitively coupled parallel-plate geometry. In the present system, the connection length is in the order of centimeters as opposed to typical fusion devices where it is in the order of meters. The flux tubes can only be refilled via cross-field diffusion of charged particles which acts as a hard limit for the probe current. Since the magnetic field is aligned perpendicular to the rf electrode surface, magnetic flux tubes are electrically connected to the electrodes. This results in strong deformation of the probe characteristics and correct determination of the electron temperature is discussed.

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

P 5.3 Mo 16:30 HS Foyer

Measurements with microparticles trapped by optical tweezers with and without a plasma — •Viktor Schneider and Holger Kersten — Institute of Experimental and Applied Physics, Christian-Albrechts-University Kiel

Because of their small size (μm to nm) microparticles are used in studies of dynamic processes [1] as well as single probes in plasma sheath diagnostics [2, 3]. A disadvantage in a plasma although is, that they cannot be manipulated in their position as desired.

We present measurements with SiO_2 particles which can be manipulated without any temporal or spatial restrictions. Force measurements in presence of a plasma and without were made by using laser tweezers [4]. Based on the determined forces, the electric field in the sheath can be estimated and residual charges on the particle after turning off the plasma [5] can be obtained.

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[2] H. R. Maurer et al., Contrib. Plasma Phys. 51(2011), 218-227
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[5] L. Couëdel et al., Contrib. Plasma Phys. 49(2009), 235-259

P 5.4 Mo 16:30 HS Foyer

Coherence Imaging Spectroscopy Systems on Wendelstein 7-X for studies of island divertor plasma behavior — •Valeria Perseo[1], Ralf König[1], Christoph Biedermann[1], Oliver Ford[1], Dorothea Gradic[1], Maciej Krychowiak[1], Gabor Kocsis[2], Thomas Sunn Pedersen[1], and W7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald — [2]Wigner RCP, Budapest, Hungary

In Wendelstein 7-X (W7-X) the so called “island divertor” concept has been realized in order to exploit the intrinsic magnetic islands structure in the outer region of the plasma for impurity screening. EMC3/EIRENE simulations for W7-X and experiments for W7-AS show that particle friction can dominate over ion thermal force in a regime where divertor plasma detachment is expected, pushing the impurities towards the divertor target, thereby resulting in efficient impurity screening of the core plasma. 2D measurements of impurity flow patterns in the scrape-off layer with coherence imaging spectroscopy (CIS) systems are expected to significantly contribute to the physics understanding of this process. Since the CIS system allows 2D measurement of flow pattern and it has a high optical throughput, it is advantageous respect to a standard spectrometer in terms of amount of information about W7-X 3D geometry, signal to noise ratio and velocity and temperature resolution. The project is now in the design and set-up phase, in order to be able to use two CIS systems for investigating the island divertor plasma behavior at different magnetic configurations during the upcoming W7-X operation phase OP1.2.

P 5.5 Mo 16:30 HS Foyer

Turbulence measurements in the Scrape-Off-Layer of Wendelstein 7-X — •Carsten Killer[1], Olaf Grulke[1], Dirk Nicolai[2], Guruparan Satheeswaran[2], Klaus-Peter Hollfeld[3], Bernd Schweer[2], Olaf Neubauer[2], and W7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald, Germany — [2]Forschungszentrum Jülich, IEK4-Plasmaphysik, Jülich, Germany — [3]Forschungszentrum Jülich, ZEA-1, Jülich, Germany

Turbulent transport in the Scrape-Off-Layer (SOL) is expected to be crucial for the upcoming divertor operation of Wendelstein 7-X. Electric probes are an established tool for both SOL profile characterization and turbulence measurements and are consequently also employed in W7-X. A fast reciprocating probe carrier mounted at the outboard mid-plane allows to scan the entire SOL up to the last closed flux surface. In this contribution, scenarios of probe measurements with respect to turbulence in the SOL of W7-X are explored. Fundamental parameters such as the SOL width and pressure decay length are deduced from profiles of plasma potential, density and temperature which are obtained utilizing sweeping Langmuir probes. A dedicated probe head designed for turbulence studies (comprising radial and poloidal probe arrays and a Mach probe) allows to investigate spectra and the radial-poloidal structure of fluctuations, poloidal and radial electric fields, parallel and perpendicular plasma flows and particle transport. The connection of the probe pins along a magnetic flux tube to other SOL diagnostics allows for benchmarking of results and for studies of the parallel structure and dynamics of turbulent plasma fluctuations.

P 5.6 Mo 16:30 HS Foyer

A new laser blow off system on the W7-X stellarator. — •Th. Wegner[1], B. Geiger[1], R. Burhenn[1], S. Knauer[2], R. Foest[3], and V. Winters[4] — [1]Max-Planck-Institute for Plasma Physics, Greifswald, Germany — [2]Institute of Physics, Greifswald, Germany — [3]Leibniz Institut for Plasma Science and Technology , Greifswald, Germany — [4]University of Wisconsin, Madison, Wisconsin, USA

The impurity confinement in stellarators can lead to impurity accumulation and early pulse termination by radiation collapse. In particular, the impurities in the plasma influence the power balance by increasing the radiation losses and the dilution of the plasma. The investigation of the impurity transport is a demanding task for steady-state operation. Hence a new laser blow off (LBO) system on the W7-X will be used to insert impurities to the plasma edge in a controlled manner. Therefore, a Nd:YAG laser beam is guided through an optical system to the coated glass target which is positioned inside the torus. By using a movable lens and mirror, the position of the laser spot on the glass target as well as its diameter can be varied. Hence, single atoms, clusters, ions as well as electrons can be ablated depending on the coating, the thickness and the laser energy density on the glass target. In OP 1.2, the glass targets will be positioned by means of a multi-purpose manipulator. The transport of the impurity can be studied using different diagnostics, e.g., emission spectroscopy. This contribution reports on the design status of the LBO system and the quantitative tests regarding the ablation of the coatings which will be used in OP 1.2.

P 5.7 Mo 16:30 HS Foyer

Development and implementation of an average Z_{eff} measurement for ASDEX Upgrade plasmas — •T. Welzel[1,2], A. Kappatou[2], R. McDermott[2], U. Stroth[2,1], R. Dux[2], R. Fischer[2], T. Pütterich[2], and The ASDEX Upgrade Team[2] — [1]Physik-Department E28, Technische Universität München, D-85748 Garching, Germany — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching, Germany

The effective charge Z_{eff} is an indicator of the plasma purity. Knowledge of Z_{eff} is important to many physics investigations, however, it is not routinely measured on ASDEX Upgrade. This work aims to develop and implement a fast, automatic and reliable routine measurement of average Z_{eff}. There are two different ways to determine this value. At ASDEX Upgrade, Z_{eff} can be inferred from the individual measurements of the dominant impurities in the plasma. Another approach is to determine the average effective charge via background bremsstrahlung emission measurements, which depend upon the wavelength, electron temperature and density as well as on Z_{eff}. Using other diagnostics to measure the electron density and temperature, Z_{eff} can be calculated. However, the bremsstrahlung emission measurements can be disturbed for example by light reflected on the tokamak wall. The main focus of this work lies in determining suitable measurements of the bremsstrahlung, which will then be used to provide a routine measurement of the average Z_{eff} in ASDEX Upgrade. The Z_{eff} values derived with this method are benchmarked against those obtained by directly measuring the impurity densities in the plasma.

P 5.8 Mo 16:30 HS Foyer

Removal of irritant gas emissions via a dielectric barrier discharge — •Marina Unseld[1,2], Sebastian Dahle[1,2], and Wolfgang Maus-Friedrichs[1,2] — [1]TU Clausthal, Institut für Energieforschung und Physikalische Technologien, Leibnizstraße 4, 38678 Clausthal-Zellerfeld — [2]TU Clausthal, Clausthaler Zentrum für Materialtechnik

We present the use of a dielectric barrier discharge (DBD) for the removal of irritant gases. To study the detailed plasma mechanisms, an experimental set-up was constructed that provides a significant concentration of the irritant gas. The gas stream is analyzed with and without plasma treatment using a commercial system based on a quadrupole mass spectrometer. Comparing results of a direct DBD application, treatments in the afterglow and the sole use of UV radiation gives way to identify the plasma species responsible for the reaction. The DBD is applied to the irritant molecule 1-Sulfinylpropane, which is produced from isoalliin by the enzyme alliinase.

P 5.9 Mo 16:30 HS Foyer

Argon Implantation in Composite Magnetron Targets — •Sascha Monje and Vincent Layes — Ruhr-Universität Bochum, Lehrstuhl für Physik reaktiver Plasmen, Bochum, Deutschland

The implantation of argon in different magnetron targets during reactive and non-reactive HPPMS processes was analyzed by doing an „in-vacuo“ characterization of the targets surface composition using x-ray photoelectron spectroscopy. The used targets were circular Al and Cr targets (50mm diameter), as well as Al@Cr and Cr@Al composite targets, which are built of normal Cr (Al) Targets with a cylindrical Insert of Al (Cr) placed in the middle of the racetrack. The non-reactive investigation was performed in the argon dominated and the selfsputtering dominated Mode. The reactive measurements were done only in argon dominated mode due to limitations of the power supply. The characterization of the plasma discharge was done using a CCD-camera and optical emission spectroscopy (OES) to get basic knowledge for the interpretation of the XPS-Measurements. The XPS-investigation was conducted after in-vacuo transfer of the magnetron target to the XPS-chamber. The distribution of redeposited species on the target surface was evaluated and showed a correlation between the redeposited species from the Insert and the concentration of implanted argon. Furthermore, the reactive measurements showed a direct correlation between surface oxidation and argon implantation. The work was supported by the C7 Projekt of the SFB TR 87.

P 5.10 Mo 16:30 HS Foyer

Investigation of Microarray Plasmas with an adjacent dielecric — •Sebastian Dzikowski[1], Ronan Michaud[2], Remi Dussart[2], and Volker Schulz-von der Gathen[1] — [1]Lehrstuhl für Experimentalphysik II, Ruhr-Universität Bochum, Germany — [2]GREMI, University of Orleans, France

Microplasma pixel devices are interesting for applications such as surface modification. A representative is the metal grid array, which is a stable alternative to silicon-based arrays. They consist of a dielectric, a grounded and a powered electrode with symmetrically arranged cavities. Typically, microplasma arrays are operated close to atmospheric pressure with noble gases like argon and helium. By applying a bipolar triangular voltage waveform with an amplitude of 700 V peak-to-peak and a frequency of 10 kHz, the discharge is ignited in the cavities having a diameter of about 200 and depth of 50 μm. For future applications, such as coating and catalysis, the interaction between the array and a dielectric surface positioned at close distance ($< 100\ \mu$m) is of great importance. Here, we present the phase dependent expansion of the emission out of the cavities by application of phase resolved optical emission spectroscopy. Optical emission spectroscopy allowed the analysis of argon and nitrogen line ratios for both array configurations.

Supported by the DAAD in the frame of projekt 57134635 "CoSi2Me"

P 6: Helmholtz Graduate School I

Zeit: Montag 16:30–18:30 Raum: HS Foyer

P 6.1 Mo 16:30 HS Foyer

Electron Cyclotron Emission Diagnostic Calibration and First Heatwave Analysis Results at Wendelstein 7-X — •Udo Hoefel[1,2], Hans-Jürgen Hartfuss[1], Matthias Hirsch[1], Sehyun Kwak[1], Gregor Pechstein[2], Stefan Schmuck[3], Torsten Stange[1], Jakob Svensson[1], Gavin Weir[1], Robert Wolf[1,2], and the W7-X team[1] — [1]IPP, Greifswald, Germany — [2]TU Berlin, Berlin, Germany — [3]Culham Science Centre, Abingdon OX14 3DB, United Kingdom

Wendelstein 7-X (W7-X) is equipped with a 32 channel electron cyclotron emission (ECE) radiometer (with 16 additional high spatial resolution channels), that requires for the localisation of the radiative temperature measurement absorption and reemission respectively an optically thick plasma. The absolute calibration is done via a hot/cold source and a corresponding model in the MINERVA framework is used in a first effort to infer the effective sensitivities with rigorously determined uncertainties.

The exclusive heating throughout the first operation phase (OP1.1) was a flexible 140 GHz electron cyclotron resonance heating (ECRH) system that allowed plasma scenarios with modulated power which were used for preliminary electron heatwave studies with both power deposition on and off the magnetic axis. This allows for a first comparison of electron heat diffusivities as obtained from heat pulse analysis and power balance analysis.

P 6.2 Mo 16:30 HS Foyer

Influence of pedestal top properties on ELM mitigation and first insights into the pump-out effect — •Nils Leuthold[1], Wolfgang Suttrop[1], Rainer Fischer[1], Athina Kappatou[1], Andrew Kirk[2], Rachael McDermott[1], Alexander Mlynek[1], Martin Valovic[2], Matthias Willensdorfer[1], the ASDEX Upgrade Team[1], and the EUROfusion MST1 Team[3] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]CCFE, Culham Science Centre, Abingdon, Oxon, OX14 3DB, U.K. — [3]See http://www.euro-fusionscipub.org/mst1

Edge Localized Modes (ELMs) are triggered by the steep edge gradients, which get formed in the high confinement mode of a tokamak device. They expell particles and energy in a burst like manner. While controlable ELMs provide a useful tool to avoid impurity accumulations, it is essential to find ways to mitigate or suppress ELMs in the next step fusion device ITER in order to reduce the harmful energy fluence to the first target. One encouraging method is the application of a magnetic perturbation (MP) field, but along with the ELM mitigation/suppression by the MPs comes also the so called "density pump-out" effect. It is triggered by the MPs and causes a degradation of the plasma confinement by expelling a significant amount of the particle inventory. The influence of the electron density and collisionality at the top of the H-mode pedestal on the energy losses caused by ELMs is shown as well as a first insight into the pump-out effect. An approach to test various theories regarding the pump-out effect on ASDEX Upgrade is presented.

P 6.3 Mo 16:30 HS Foyer

Low-Z impurity transport studies using CXRS at ASDEX Upgrade — •Cecilia Bruhn[1,2], Rachael McDermott[1], Alexander Lebschy[1,2], Ralph Dux[1], Athina Kappatou[1], Volodymyr Bobkov[1], Roman Ochoukov[1], Jakob Ameres[2,1], Clemente Angioni[1], Marco Cavedon[1], Thomas Pütterich[1], Eleonora Viezzer[3,1], and the Asdex Upgrade Team[1] — [1]Max-Planck-Insitut für Plasmaphysik, Garching, Germany — [2]Technische Universität München, Garching, Germany — [3]University of Seville, Seville, Spain

To achieve optimum fusion performance, future fusion reactors need to control the build up of high- and low-Z impurities in the plasma core. Thus, it is important to develop and validate our theoretical understanding of impurity transport. Recent experimental work on this topic at ASDEX Upgrade (AUG) has focused primarily on steady-state profiles, which deliver the ratio of the diffusive and convective transport coefficients. However, from a time dependent density profile the transport coefficients can be separately determined by solving an inverse problem. At AUG, a sinusoidal modulation of the boron density can be achieved by modulating the power from the ion cyclotron resonance frequency (ICRF) antennas. This signal can then be monitored with the charge exchange recombination spectroscopy (CXRS) diagnostics, which can make complete measurements of the boron density profiles with high spatial and temporal resolution. We will present a database of measured transport coefficient profiles, their dependencies on local plasma parameters and a first comparison to neoclassical theory.

P 6.4 Mo 16:30 HS Foyer

Dependence of Oxidation on the Grain Orientation of Tungsten — •Karsten Schlüter and Martin Balden — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

Tungsten (W) is planned to be a plasma facing material of future fusion reactors. It can be oxidized in case of a loss of coolant with simultaneous air ingress. In such an incident, activated tungsten oxide could sublimate leading to a potential safety issue if the tungsten oxide is released into atmosphere. Oxidation processes are complex and for a deeper understanding, this study focuses on oxidation in relation to the grain orientations.

The grain orientations on a W sample were analyzed using electron backscatter diffraction. Subsequently, the sample was oxidized in a thermobalance, measuring the time dependent weight increase. The grain dependent oxidation rates were determined by measuring the thickness of the oxide layer of single grains by scanning electron microscope and confocal laser scanning microscope. W grains with {100} orientation have the highest and a two times higher oxidation rate in a range of 720 K to 870 K than to the lowest oxidation rates, e.g. like the oxidation rate of the {111} orientation. The derived oxidation rates are consistent with gravimetric measurements.

P 6.5 Mo 16:30 HS Foyer

Study of the gas balance of Wendelstein 7-X — •Georg Schlisio[1], Uwe Wenzel[1], Thomas Sunn Pedersen[1], Tom Wauters[2], and W7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald — [2]KMS/RMA, Brussels, Belgium

The Wendelstein 7-X (W7-X) stellarator experiment is currently being prepared for its plasma operation phase OP1.2 with an island divertor. In the first operation phase (OP1.1) in 2016 the device was operated in a limiter configuration. We studied the gas balance during OP1.1 by balancing the neutral particle input and output. The components in the plasma vessel interact with the neutral gas, i.e. by wall pumping or outgassing. The neutral gas pressure and its constituents have a strong influence on the plasma performance. In order to gain a quantitative understanding of the gas balance, we are studying and modeling the sources and sinks.

To assess the gas removal rate, given by $Q = p \cdot S$ (p pressure, S pumping speed), an accurate calibration of the neutral pressure gauges is required. For OP1.2 an effective calibration scheme is presented that allows fast calibration of all pressure gauges simultaneously. Data collected in OP1.1 is analyzed to better understand neutral gas effects such as wall pumping, outgassing and runtime effects. We found that the gas balance was dominated by the effect of net outgassing. We studied the dependence on the magnetic configuration and on the heating power. We present an outline of the plans for assessing the gas balance in OP1.2, with pulse lengths of tens of seconds. We also present elements of a gas balance model being developed for OP2 (30min pulses).

P 6.6 Mo 16:30 HS Foyer

First numerical results towards a 3D MHD equilibrium solver via artificial relaxation mechanisms — •Camilla Bressan[1,2], Michael Kraus[1,2,3], Philip James Morrison[1,4], Omar Maj[1], and Eric Sonnendrücker[1,2] — [1]Max-Planck-Institute for Plasma Physics, Garching, Germany — [2]Technical University of Munich, Mathematics Department, Garching, Germany — [3]Waseda University, Tokyo, Japan — [4]The University of Texas at Austin, Physics Department and Institute for Fusion Studies, USA

First numerical experiments on a novel method to compute ideal MHD equilibria are presented. The method is based on metriplectic dynamics, initially proposed by Morrison (Physica D,18,410-419(1986)), and relies on the Hamiltonian structure of the MHD equations. Essentially, it consists in a relaxation method which is capable of dissipating selected functionals and norms of the MHD variables. As all relaxation methods, the approach does not suffer from topological restrictions (determined by the assumption of nested flux surfaces employed e.g. in the VMEC code), and yet it allows more control over the relaxation mechanism, through the choice of the dissipated functional.

The work presented applies the method in simple 2D models and represents a first step to prove its validity. We claim that this could be a good candidate for an efficient 3D equilibrium code which can address Stellarators as well as Tokamaks whose 3D effects (namely islands and ripples) are increasingly important.

P 6.7 Mo 16:30 HS Foyer

Optimal and Robust Multigrid Solver for Elliptic Problems with Application to Anisotropic Diffusion — •Mustafa Gaja[1], Ahmed Ratnani[1], Emmanuel Franck[2], Mariarosa Mazza[1], Jalal Lakhlili[1], and Eric Sonnendruecker[1] — [1]Max Planck Institute For Plasma Physics, Germany — [2]Inria Nancy Grand Est and IRMA Strasbourg, France

We investigate devising a robust and an optimal multigrid (MG) solver for the linear system arising from applying Isogeometric Analysis using B-Splines as basis functions for elliptic problems. The Laplacian and the Mass operators (H1 and L2 projectors, respectively) are inverted using MG as a solver and the acquired Toeplitz matrices from applying the Generalized Locally Toeplitz (GLT) theory as a preconditioner. The latter is used to construct an efficient preconditioner that eliminates the pathology ensuing from using high order B-Splines discretization. The goal is to have building blocks that are used for more complicated systems, thanks to physics based preconditioning and splitting schemes. We present the obtained results and show how we apply the method for anisotropic diffusion and present the corresponding results.

P 6.8 Mo 16:30 HS Foyer

A Phase Contrast Imaging Diagnostic for Turbulence Measurements in the Wendelstein 7-X Stellarator — •Lukas-Georg Böttger[1,2], Olaf Grulke[1], and Eric Matthias Edlund[3] — [1]Max-Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [2]Technical University of Denmark, 2800 Kgs. Lyngby, Denmark — [3]Massachusetts Institute of Technology, Cambridge, MA, USA

The phase contrast imaging (PCI) diagnostic allows for a non-invasive imaging of electron 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 by utilising a phase plate. Initially, the image contains only the line-integrated information along the beam path. However, if the magnetic field direction significantly varies along the beam path, a spatial resolution can be obtained by optical filtering.

The diagnostic is designed to operate in the range from large scale ion temperature gradient (ITG) to smaller scale trapped electron mode (TEM) and electron temperature gradient (ETG) turbulence. Simulations for ITG and TEM turbulence in W7-X geometry were performed (e.g. Helander et al., Nucl. Fusion 55 (2015) 053030) and show, inter alia, much more poloidally localised turbulent structures than in Tokamaks. Hence, the specific diagnostic location strongly influences the observations. Based on the simulations we discuss possible measurement results as a preparation for the upcoming operation phase OP 1.2 and give an update of the diagnostic design and testing process.

P 6.9 Mo 16:30 HS Foyer

Combining electromagnetic gyro-kinetic particle-in-cell simulations with collisions — •Christoph Slaby, Ralf Kleiber, and Axel Könies — Max-Planck-Institut für Plasmaphysik, D-17491 Greifswald, Germany

It remained an open question whether for electromagnetic gyro-kinetic particle-in-cell simulations pitch-angle collisions and the recently introduced pullback transformation scheme [A. Mishchenko et al., Physics of Plasmas **21**, 092110 (2014) and R. Kleiber et al., Physics of Plasmas **23**, 032501 (2016)] are consistent.

This question is answered by comparing the PIC code EUTERPE with an approach based on an expansion of the perturbed distribution function in eigenfunctions of the pitch-angle collision operator (Legendre polynomials) to solve the electromagnetic drift-kinetic equation with collisions in slab geometry.

It is shown how both approaches yield the same results for the frequency and damping rate of a kinetic Alfvén wave and how the perturbed distribution function is substantially changed by the presence of pitch-angle collisions.

First results concerning the non-linear saturation of a toroidicity-induced Alfvén eigenmode driven by energetic ions indicate that the saturation level is very sensitive to the collision frequency. The scaling is compared with analytical predictions.

P 6.10 Mo 16:30 HS Foyer

Parametric Decay Instability during Collective Thomson Scattering on ASDEX Upgrade — •Søren Kjer Hansen[1,2], Stefan Kragh Nielsen[2], Alf Köhn[1], Jörg Stober[1], and The ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, D-85748 Garching bei München, Germany — [2]Department of Physics, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark

A parametric decay instability (PDI) is a three-wave interaction where a strong electromagnetic (pump) wave decays into two electrostatic daughter waves. The present work is motivated by observation of such a PDI during collective Thomson scattering (CTS) experiments at the ASDEX Upgrade (AUG) tokamak [Nielsen et al., 2016]. Similar behaviour has been observed during CTS experiments at the LHD stellarator [Kubo et al., 2016]. The PDI, which has been investigated at AUG, is one in which the X-mode pump wave decays into a high-frequency electron Bernstein wave and a low-frequency warm lower hybrid wave. We have obtained estimates of the gyrotron power necessary to excite the PDI and the frequency shift of the electron Bernstein wave relative to the pump wave [Hansen, 2016], generalising the earlier results of [Porkolab, 1982]. Applying these results to an AUG experiment (shot 28286) yielded a gyrotron power threshold well below the one used in the experiment and a frequency shift similar to the one observed, thus validating the existence of a PDI.

P 6.11 Mo 16:30 HS Foyer

An approach to an electronic stability control for gyrotrons — •Fabian Wilde[1], Stefan Marsen[1], Ioannis Pagonakis[2], Konstantinos Avramidis[2], Torsten Stange[1], Heinrich Laqua[1], and John Jelonnek[2] — [1]Max Planck Institute for Plasma Physics (IPP), Wendelsteinstr. 1, D-17489 Greifswald, Germany — [2]Institute for Pulsed Power and Microwave Technology (IHM), Karlsruhe Institute of Technology (KIT), Kaiserstr. 12, D-76131 Karlsruhe, Germany

Wendelstein 7-X (W7-X) uses electron cyclotron resonance heating (ECRH) by 140 GHz high-power microwave sources (gyrotrons) as primary heating method. Therefore a fast, electronic stability control for gyrotrons, allowing operation at highest possible output powers with maximum efficiency, is desireable. Such a control unit needs to implement a stabilization scheme using a reliable precursor for mode loss and a fast, automated mode recovery, if it fails.

Consequently shot spectrograms of the stray radiation were examined to identify a suitable precursor. A preliminary candidate appeared above 142 GHz, hence a D-band RF diode together with a high-pass filter was used to quantify the parasitic activity. A preliminary statistical analysis of 3000 shots yields a reasonable distribution for the probability of failure, nevertheless, a better precursor could be obtained using a 140 GHz notch filter to take into account the azimuthal neighbour mode. First experiments with a FPGA-based prototype, implementing the automated mode recovery, will be conducted soon. Multi-mode simulations, taking beam charge neutralization into account, will be used to describe a physical gyrotron reliability model.

P 6.12 Mo 16:30 HS Foyer

SOLPS Modeling of Partially Detached Plasmas in ASDEX Upgrade — •Ferdinand Hitzler[1,2], Marco Wischmeier[1], Felix Reimold[3], Xavier Bonnin[4], Arne Kallenbach[1], the ASDEX Upgrade Team[1], and the EUROfusion MST1 Team[5] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Technische Universität München, Garching, Germany — [3]Forschungszentrum Jülich, Jülich, Germany — [4]ITER Organization, St. Paul-lez-Durance, France — [5]See http://www.euro-fusionscipub.org/mst1

Power exhaust in future fusion devices like ITER is a challenging issue which has to be addressed carefully. For an unmitigated power flux the power load limits for the divertor components of around $10\,\mathrm{MWm^{-2}}$ would be exceeded considerably. In order to be able to sustain operation under reactor conditions the power load at the divertor plates has to be reduced significantly. This reduction can be achieved via detachment, a divertor regime which is observed at high plasma densities and low divertor temperatures.

The goal of this contribution is the investigation of divertor detachment using the SOLPS code package for interpretative simulations. Since ITER is foreseen to be operated in a partially detached regime in H-mode, the main focus of this work is the transition from the high recycling to the partially detached regime. The width of this transition, the operational window, and possible advantages and disadvantages of different degrees of detachment are discussed. A code validation will be performed via comparison of the modeling results with experimental data from ASDEX Upgrade in nitrogen and argon seeded H-mode.

P 6.13 Mo 16:30 HS Foyer

Analysis and Modelling of JET Neon Seeded Discharges With High Radiative Power Fraction — •Stephan Glöggler[2,3], Marco Wischmeier[2], Matthias Bernert[2], Giuseppe Calabrò[4], Alexander Huber[5], Christopher Lowry[6], Matthew Reinke[7], Sven Wiesen[5], and JET Contributors[1] — [1]EUROfusion Consortium, JET, Culham Science Centre, Abingdon, UK — [2]IPP, Garching, Germany — [3]Physik-Department E28, TUM, Garching, Germany — [4]ENEA for EUROfusion, Frascati, Italy — [5]FZ Jülich GmbH, Jülich, Germany — [6]European Commision, Brussels, Belgium — [7]ORNL, Oak Ridge, USA

In future fusion devices as ITER and DEMO the power flux onto the divertor target plates will have to be reduced by deliberate seeding of impurities. In DEMO a major fraction of the induced radiative power losses must originate inside the last closed flux surface. As radiative power losses within the confined plasma might reduce the plasma confinement and impact the discharge stability it is crucial to determine and understand the underlying physical processes in high radiative discharges.

At JET neon seeded discharges were carried out and the influence of the seeding at high heating powers on the pedestal and the divertor profiles is examined. An inter-relation of these profiles with the radial radiation distribution is analyzed. Numerical simulations with the code package SOLPS-ITER (plasma fluid code B2.5 coupled with the Monte Carlo neutral code EIRENE) of these discharges are performed to complement the experimental findings.

P 6.14 Mo 16:30 HS Foyer

Non-Maxwellian fast particle effects in gyrokinetic GENE simulations — •Alessandro Di Siena[1], Tobias Goerler[1], Hauke Doerk[1], Jonathan Citrin[2,3], Thomas Johnson[4], Mireille Schneider[3], and Emanuele Poli[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]FOM Institute DIFFER, PO Box 6336, 5600 HH Eindhoven, The Netherlands — [3]CEA, IRFM, F-13108 Saint Paul Lez Durance, France — [4]VR Association, EES, KTH, Stockholm, Sweden

The understanding of the stabilising mechanism of fast particles on the main plasma turbulence is an essential task for a future fusion reactor, where the energetic particles can constitute a significant fraction of the main ions. While the consideration of equivalent Maxwellian distributed fast ions in the simulations has greatly improved the agreement with the experiment, the fast ion electromagnetic stabilization seems to be somewhat overestimated. However, it is well known that to rigorously model highly non thermalised particles, a non-Maxwellian background distribution function is needed. To this aim, a previous study on a particular JET plasma has been revised and analysed with the gyrokinetic code GENE. In order to study the impact of non-Maxwellian distribution functions on the plasma turbulence, the fast particle distributions have been modelled with a number of different analytic choices, as well as numerical distributions imported from the modelling tools NEMO/SPOT and SELFO. The analytical distributions best approximating the numerical ones are identified and linear and nonlinear results are shown.

P 6.15 Mo 16:30 HS Foyer

Bayesian inference of electron temperature and density from JET high resolution Thomson scattering and interferometer data — •Sehyun Kwak[1,2], Jakob Svensson[2], Sergey Bozhenkov[2], Joanne Flanagan[3], Mark Kempenaars[3], Young-chul Ghim[1], and JET Contributors[3] — [1]Dept. of Nuclear and Quantum Engineering, KAIST, Daejeon, South Korea — [2]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [3]Culham Centre for Fusion Energy, Abingdon, UK

A Bayesian model for inferring electron temperature and density profiles from a combination of the high resolution Thomson scattering (HRTS) and interferometer systems at JET has been developed. The HRTS system measures spectra of Thomson scattered light, which depends on the local temperature and density. The interferometer measures line integrated density along a number of lines of sight. As the spatial channels and lines of sight of the HRTS and interferometer systems are differently located the temperature and density profiles need to be mapped to normalised flux coordinates (here using the EFIT code) so that the forward model predicts both HRTS and interferometer data simultaneously given the profiles. The prior temperature and density profiles are modelled as Gaussian processes with spatially varying smoothness properties (determined by hyperparameters). The posterior distribution of the temperature and density profile as well as their hyperparameters is explored by a Markov chain Monte Carlo (MCMC) scheme. Since the model includes both HRTS and interferometer systems, the HRTS calibration is done automatically.

P 6.16 Mo 16:30 HS Foyer

Kinetic Simulations of 1D SOL Plasmas with KIPP-SOLPS Coupling Code — •Menglong Zhao, Alex Chankin, and David Coster — Max-Planck-Institut fuer Plasmaphysik, Boltzmannstraße 2, Garching

In order to investigate the kinetic effects in a systematic way, the 1D2V kinetic Vlasov-Fokker-Planck (VFP) code KIPP has been coupled to SOLPS to treat electron parallel transport kinetically. KIPP-SOLPS coupling code allows us to incorporate kinetic electrons into the already sophisticated fluid model (B2) self consistently. The simulation results of KIPP-SOLPS with pure deuterium and with carbon impurity in 1D geometry with stagnation point upstream and target downstream will be presented. These results are then compared to the results of only SOLPS simulation with or without heat flux limiter. Finally the cases with only SOLPS but including modified heat transmission coefficient are compared with KIPP-SOLPS coupling cases.

P 7: Complex and Dusty Plasmas

Zeit: Montag 16:30–18:30 Raum: HS Foyer

P 7.1 Mo 16:30 HS Foyer

Nonlinear collisional plasma wakes of small particles — •Sita Sundar, Hanno Kaehlert, Jan-Philip Joost, Patrick Ludwig, and Michael Bonitz — Christian Albrechts Universitaet Kiel Germany - 24098

Dynamical screening and wake effects in complex plasmas have been the subject of many early investigations, including experimental [1] as well as theoretical work. However, it was shown using Linear Response(LR) theory [2] that the characteristic features of the wake potential for non-Maxwellian plasma are qualitatively different from Maxwellian streaming ions. Here, the electrostatic potential of a dust grain in streaming ions in the presence of collision frequency, ν is computed using three-dimensional particle-in-cell(PIC) code 'COPTIC' [3]. We compare our numerical results with the wake potential obtained from the LR formalism for Maxwellian and non-Maxwellian cases in linear as well as nonlinear regime. We discuss the physics of distribution function, flux etc. around the grain and present a parametric study of collision frequency vs. wake peak position, peak potential etc. for the non-Maxwellian streaming plasmas.

References:

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

[2] J.-P. Joost, P. Ludwig, H. Kaehlert, C. Arran, and M. Bonitz, Plasma Physics and Controlled Fusion 57, 025004 (2015).

[3] I. H. Hutchinson, Physics of Plasmas 18, 032111 (2011).

P 7.2 Mo 16:30 HS Foyer

Milli-gravity experiments with an improved PK-4 setup — •Michael Kretschmer, Markus Thoma, Christopher Dietz, and Benjamin Steinmüller — Justus-Liebig-Universität, Giessen, D

Plasmakristall 4 (PK-4) is a complex plasma laboratory installed onboard the International Space Station ISS since 2014. It is mainly used for studying complex plasmas in the fluid state by creating a dc discharge inside a glass tube with a low-pressure gas where microparticles are injected in. An engineering model of PK-4 resides at the university of Giessen (PK-4 GI). Unless the ISS unit, this setup can easily be altered and improved. It has been adapted for a parabolic flight campaign (PFC) with the A310 ZERO-G aircraft.

Additionally, PK-4 GI has been equipped with a new camera that allows the recording of the particles' motion with much higher resolution compared to the original camera. During the PFC with 124 parabolas, providing a g level of ±50 m-g, two main objectives were planned:

- Investigation of the phase transition of an electro-rheological (ER) plasma. In general, an ER liquid changes its mechanical properties, e.g. viscosity, when a voltage is applied. With PK-4 GI we can study this on the single-particle level.

- Demixing of two liquid phases. By injecting a mixture of particles with two different sizes into the plasma we can observe how the particles demix, from the individual to the collective particle scale.

- Wave phenomena are widely observed in complex plasmas. During the experiments described above we keep an eye also on this topic.

P 7.3 Mo 16:30 HS Foyer

Diagnostic of nanodust and nanodusty plasma — •Franko Greiner[1], Sebastian Groth[1], Benjamin Tadsen[1], Iris Pilch[2], Jonathan Schilling[1], and Alexander Piel[1] — [1]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität Kiel — [2]Functional Materials Group, IFM, Linköping University, Sweden

A plasma containing submicron-sized particles is an interesting object from both basic plasma physics and plasma technology point of view. The density of the nanoparticles strongly depends on the ability of the discharge to confine particles and its interplay with the repelling forces between the particles. To diagnose the plasma, information on the size of the particle, their size- and spatial distribution, and their density are needed. With all this information dust density waves (DDW) can be used to diagnose the plasma. The advantage of the DDW diagnostic is that it is noninvasive and the waves can easily be studied by means of video microscopy. We discuss several findings and compare with results from other diagnostics like microwave interferometry and electrostatic probes.

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

P 7.4 Mo 16:30 HS Foyer

Fast Langmuir probe measurements during nanoparticle growth in a CCRF plasma — •Erik von Wahl[1], Yerbolat A. Ussenov[2], T. S. Ramazanov[3], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics (IEAP), Kiel University, Germany — [2]National Nanotechnology Laboratory of Open type (NNLOT), Al - Farabi KazNU, Almaty, Kazakhstan — [3]Institute of Experimental and Theoretical Physics (IETP), Al-Farabi KazNU, Almaty, Kazakhstan

The oldest and well established technique to measure electron temperatures and electron densities in a plasma is the Langmuir probe, introduced by Mott-Smith and Langmuir.

However, in dust forming plasmas the current onto the probe may be distorted by charged dust particles and non-conductive contamination due to film forming radicals and ions. One approach to overcome this problem is by shielding the probe tip from its environment. In the present study ion bombardment by a negatively biased probe was used instead to keep it clean. Additionally, the V-I-characteristics were obtained by an advanced and fast voltage sweep pattern for the probe bias. By keeping the duration of positive bias shorter than the inverse of the nanoparticle's plasma frequency $\tau_d = 1/\omega_{pd}$ the negatively charged dust particles are not able to overcome the on average negative probe potential and, thus, cannot contaminate the probe.

Measured changes in electron density and temperature are presented during the entire growth cycle of nanoparticles. An upper limit for the dust plasma frequency will also be presented.

P 7.5 Mo 16:30 HS Foyer

Characteristics of the charge density distribution around a test charge in streaming plasmas — •Zhandos Moldabekov[1,2], Patrick Ludwig[1], Sita Sunda[1], Ingmar Schnell[1], and Michael Bonitz[1] — [1]Christian-Albrechts-Universität zu Kiel, Germany — [2]Al-Farabi Kazakh National University, Almaty

Interaction between dust particles in complex plasmas can significantly deviate from the simple Yukawa (Debye) type potential due to streaming of plasma particles. Recent progress on this problem has been achieved for both unmagnetized and magnetized plasmas. In the unmagnetized case, the deviation of the dust charge potential from the equilibrium result can be understood by the ion focusing effect of the negatively charged dust particle. Particularly, this is the case for the experiments on study of the complex plasma properties in the different types of gas discharges. Therefore, the development of the physical picture of the dust particles dynamics in such stationary nonequilibrium plasma requires the careful evaluation of the charge distribution of the focused ion cloud at different regimes of the plasma parameters. We take the ion acceleration by an external electric field explicitly into account, which leads to a non-Maxwellian velocity distribution. The results are compared to PIC and fluid simulations. Further attention is devoted to the construction of the analytical model within a multipole expansion approximation for the description of the lateral grain-grain interaction, i.e. perpendicular to the direction of the ion flow.

P 7.6 Mo 16:30 HS Foyer

Optical charge analysis of nanoparticles in RF discharges — •Harald Krüger and André Melzer — Institute of Physics, University Greifswald

Nanoscaled dust particles of aluminum oxide (Al_2O_3) in RF discharges can exhibit a charge-dependent resonance in Mie scattering in the infrared spectral range [1]. Measurements of this dependence will be used to determine the charge of the particles trapped in a dusty plasma.

In initial experiments the resonance has been detected. Besides the mere existence, the expected shifts of the resonance by a few wave numbers could not be measured with the resolution of the used FTIR spectrometer. Therefore the spectrum of the charged particles will be recorded in more detail using a high-resolution FTIR spectrometer.

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

P 7.7 Mo 16:30 HS Foyer

Electric Field Reconstruction and Particle Trapping in Nonlinear Dust-Density Waves — •Stefan Schütt[1], Michael Himpel[1], Alexander Piel[2], and André Melzer[1] — [1]Institute of Physics, University Greifswald — [2]IEAP, University Kiel

Under laboratory conditions, micrometer-sized particles in a dusty plasma sediment in the lower discharge sheath. Under weightlessness, however, extended dust clouds can be generated and self-excited dust-density waves spanning over several wavelengths can be observed.

The dynamics of the dust particles is directly accessible by means of video microscopy. Using the reconstructed trajectories of individual particles, the potential in the wave field can be determined over a large spatial range. The decomposition into a modulation and a linear background component allows to determine the average electric field in the plasma. In this contribution, the application of this method to data obtained on parabolic flights is presented and the results are compared to numerical simulations.

In strongly non-linear dust-density waves, particles get trapped in an equilibrium of friction force and the modulated component of the electric field force. This can lead to a strongly deformed velocity distribution compared to linear waves. Molecular dynamics simulations of strongly coupled, driven waves are presented and compared to the experimental findings.

P 7.8 Mo 16:30 HS Foyer

Modification of microparticles due to intense laser radiation — •Dietmar Block, Jan Schablinski, and Frank Wieben — Institut for Experimental and Applied Physics, Kiel University, Germany

Recent experiments have demonstrated that it is possible to build an optical tweezer for dusty plasmas. It allows to trap and manipulate single particles from a 2-d plasma crystal. However, as soon as a particle is trapped it is exposed to intense laser radiation. To investigate the influence of intense laser radiation on the particle, the trapping and detrapping processes are studied with high spatial and temporal resolution. Our measurements show, that the trapped particle properties are different and that this change is reversible once the particle is detrapped.

P 7.9 Mo 16:30 HS Foyer

Simulation of ion wake effects in dusty plasmas — •Alexander Piel — IEAP, Kiel University

The focussing of supersonic ion flows by negatively charged dust particles and the associated accumulation of positive charge in the wake of the particle is a well known phenomenon [1]. In experiments, attractive forces between dust particles are often attributed to the attraction by the wake charge. In this contribution, results from a fast molecular dynamics code are presented that analyze the interparticle forces in detail. It is shown that net attractive forces are only found when the second particle is located transverse to the direction of the flow. The force is greatest in the plane of the maximum of the wake potential. Contrariwise, two flow-aligned particles only show repulsive forces. Further, the ion charge collection in two-particle systems is studied. The results are discussed w.r.t. the asymmetric interaction observed in resonance experiments [2].

These investigations were funded by DFG TR-24 project A2.

[1] D. Block et al, Contrib. Plasma Phys. 52, 804 (2012) [2] H. Jung et al, Phys. Plasmas 22, 053702 (2015)

P 7.10 Mo 16:30 HS Foyer

(In-)Compressibility of crystalline particle flows — •Jochen Wilms and Alexander Piel — Institute of Experimental and Applied Physics, Kiel University, Germany

Dust trapping of free-floating torus-shaped dust clouds in magnetized anodic plasmas has been studied extensively over the past few years. In an upright, ring-shaped confinement the particles are driven in azimuthal direction by the Hall component of the ion drag.[1] Because of acceleration and deceleration due to gravity a stationary but inhomogeneous flow pattern establishes. This flow shows many interesting properties, e.g., we observed shock-like phenomena, a crystallization of the flow, bifurcations and inverse bifurcations.[2] The laboratory experiments are accompanied by detailed 3D molecular-dynamics simulations which make measures accessible, which are beyond the possibilities of the real experiment. Recent results of these numerical experiments have shown that a toroidal dust flow in the incompressible fluid limit can evolve shock-like events which are similar to hydraulic jumps in open channel flows.[3] In this contribution we will discuss the hydrodynamics and the thermodynamics of flow properties and the hydraulic jump at the individual particle scale. Furthermore, we will examine on the microscopic level how a compressible medium like a dust cloud can act quasi-incompressible.

Funded by DFG in the framework of SFB-TR24, Project A2.

[1] I. Pilch et al., Physics of Plasmas **15**, 103706 (2008)
[2] J.Wilms et al., Physics of Plasmas **22**, 063701 (2015)
[3] A. Piel and J. Wilms, Physics of Plasmas **23**, 073701 (2016)

P 7.11 Mo 16:30 HS Foyer

The influence of pressure for the state of aggregation in complex plasmas — •Benjamin Steinmüller, Christopher Dietz, Michael Kretschmer, and Markus Thoma — I. Physikalisches Institut, JLU Gießen

The influence of neutral gas pressure for crystallization of extended three dimensional complex plasmas is investigated. The experiments are performed in a cylindrical parallel-plate radio frequency chamber under gravity conditions. To quantify the crystallization a new analysis method is proposed. This method is an extension of the scalar product of the local bond order parameter with the benefits from Minkowski structure metric. Both methods display the same behavior: At low pressure the complex plasma is in the solid state, while at high pressure it is in the liquid state. Former ground based experiments exhibited the opposite behavior.

P 7.12 Mo 16:30 HS Foyer

Kugelblitze - Evidenz und Interpretation — •Herbert Boerner — Mainz

Die Natur von Kugelblitzen ist ein kontroverses Thema der atmosphärischen Physik. Obwohl Berichte über Beobachtungen mehrere Jahrhunderte zurückreichen, ist sogar die Existenz der Kugelblitze keineswegs generell akzeptiert. Daher gibt es bisher auch keinen Konsensus über die Physik dieser leuchtenden Objekte. Dieser Vortrag diskutiert die vorliegende Evidenz in Form von Berichten, Fotografien und Videos. Mögliche Fehlinterpretationen von Beobachtungen und alternative Erklärungen wie Sinnestäuschungen werden diskutiert. Der Schwerpunkt wird hierbei auf neuere Beobachtungen gelegt. Abschließend werden die Chancen und Bedingungen für zukünftige kontrollierte Beobachtungen diskutiert, insbesondere im Hinblick auf die weite Verbreitung von Blitzortungssystemen und Videokameras.

P 7.13 Mo 16:30 HS Foyer

Korrelation von Kugelblitzbeobachtungen und positiven Wolke-Erde Blitzen — •Herbert Boerner — Mainz

Kugelblitze werden fast ausschließlich in Gewittern beobachtet, wobei diese Objekte eher selten oder sogar sehr selten auftreten. Überraschenderweise gibt es jedoch einige wenige Beobachtungen die von einer hohen Anzahl von solchen Objekten berichten, was auf besonders günstige Bedingungen für die Erzeugung hindeutet. Ein erster Hinweis auf eine mögliche Korrelation von Kugelblitzen und positiven Blitzen ergibt sich aus der Tatsache, dass in Wintergewittern mehr dieser Objekte beobachtet werden als man es von der geringen Zahl der Blitze erwarten würde. Ein besonders gut dokumentierter Fall aus Neuruppin (1994) stützt diese Vermutung. In dem Vortrag wird eine Reihe von solchen Beobachtungen analysiert um diese Korrelation zu verifizieren. Dazu werden die Eigenschaften von negativen und positiven Wolke-Erde Blitzen mit den Details der verschiedenen Beobachtungssituationen verglichen und eine Hypothese zu dem Erzeugungsmechanismus dieser Objekte vorgestellt.

P 8: Plasma Diagnostics II

Zeit: Dienstag 8:30–10:20 Raum: HS 1010

Fachvortrag P 8.1 Di 8:30 HS 1010

Characterizing atmospheric pressure plasma jets using cavity-enhanced absorption spectroscopy — •Jean-Pierre van Helden[1], Stephan Reuter[1], Ana Lawry Aguila[2], Michele Gianella[2], and Grant Ritchie[2] — [1]Leibniz Institute for Plasma Science and Technology (INP Greifswald), Greifswald, Germany — [2]Department of Chemistry, Physical and Theoretical Chemistry Laboratory, University of Oxford, Oxford, UK

Cold non-equilibrium atmospheric pressure plasma jets are increasingly applied in material processing and plasma medicine. Hence, it is essential to diagnose the fluxes of the species generated by these plasma sources to identify relevant fundamental processes and to improve process efficiency. Especially, high precision measurements of reactive molecular precursors, free radicals and short lived species are of crucial importance. However, their small dimensions make the detection of generated transient species a challenge. We have overcome these limitations by using optical cavities to achieve effective absorption path lengths of up to 100 meters in mm sized plasma jets [1]. Here we report on the detection of the hydroperoxyl radical, HO2, in the effluent of a plasma jet by the use of optical feedback cavity-enhanced absorption spectroscopy (OF-CEAS). The achieved detection levels indicate that such a spectrometer will find broad application in future studies of the chemical network in the effluents of plasma jets and provides a new way of testing and improving our modelling of these complex plasma environments. [1] M. Gianella, S. Reuter, A. Lawry Aguila, G.A.D. Ritchie, and J. H. van Helden, New J. Phys. 18 (2016) 113027.

Fachvortrag P 8.2 Di 8:55 HS 1010

A Calorimetric Study of Secondary Electrons in Sputtering and Nitriding PIII Processes — •Fabian Haase[1], Stephan Mändl[2], Darina Manova[2], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics, CAU Kiel, Germany — [2]Leibniz Institute of Surface Modification, Leipzig, Germany

Reactive deposition processes are commonly used in industry to achieve high quality coatings. Modern technologies including magnetron sputtering and HIPIMS crucially depend on plasma properties including SEE from surfaces exposed to the plasma or energetic ion bombardment. The latter one can actually lead to changes in surface composition due to preferential sputtering or ion implantation. This variation is usually not accessible by conventional measurements of secondary electron coefficients. In this work, an approach using a passive calorimetric probe to investigate the effect of different substrate surface states is presented using a PIII setup where energetic ions are accelerated to the substrate. In preparatory studies the energy flux from the substrate during a PIII pulse was determined which conclusively left only SEE as the only viable candidate for intense energy influx. In the present study we measured several materials and alloys (e.g. Al, AlMg3, Mg, MgAl9Zn1, Cu, Zn, Mo, Ti and stainless steel 304) starting from a fully oxidized substrate using Ar sputtering into a clean metal state and afterwards nitriding towards a fully nitrided substrate. Kinetics on the de-oxidizing and nitriding as well as relative secondary electron emission coefficients for the materials were obtained.

P 8.3 Di 9:20 HS 1010

Phase resolved polarization measurements in a capacitively coupled rf-plasma in hydrogen — •Philipp Ahr, Tsanko V. Tsankov, Dirk Luggenhölscher, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, 44801 Bochum, Germany

Anisotropy in the electron excitation in a plasma leads to a measurable polarization of the gas emitted light. The effect is strongest for lines with $\Delta j = 1$. The electron beams in CCP offer such anisotropy in the excitation and provide new means for plasma diagnostics.

Here, the polarization ratio P of the Balmer-α line and of the molecular Fulcher-α band in hydrogen plasma is measured over the time by phase resolved optical emission spectroscopy (PROES). Due to the low dissociation degree the Balmer-α emission is mainly from dissociative excitation of the hydrogen atoms. The measurements are done for different values of the neutral gas pressure and the substrate bias. Different structures are observed in the space-time diagrams of the polarization. These are shown to be directly connected to the known electron dynamics in the plasma. However, also additional temporal structures in the polarization are obtained. A simple model is developed to estimate the observed polarization ratio in the discharge.

P 8.4 Di 9:35 HS 1010

Correlation of spatially resolved in-vacuum XPS characterisation and optical diagnostics for composite magnetron targets in HiPIMS plasma — •Vincent Layes[1], Sascha Monjé[1], Carles Corbella[1], Volker Schulz-von der Gathen[1], Achim von Keudell[1], and Teresa de los Arcos[2] — [1]Experimental Physics II Ruhr-University Bochum. Universitätstr. 150, 44780 Bochum, Germany — [2]Technical and Macromolecular Chemistry, Paderborn University, Warburgstr. 100, 33098 Paderborn, Germany

In-vacuum characterisation of magnetron targets after high power pulsed magnetron sputtering (HiPIMS) has been performed using X-ray photoelectron spectroscopy (XPS). Al-Cr composite targets (circular, 50 mm diameter) in two different geometries were investigated: an Al target with a small cylinder of Cr inserted at the racetrack position, and a Cr target with a small disk of Al inserted at the racetrack position. The HiPIMS discharge and the target surface composition were characterised for three different power conditions. The HiPIMS plasma characterisation was done using optical emission spectroscopy (OES) and fast imaging by a CCD camera; the surface characterisation was done after in-vacuum transfer of the magnetron target to the XPS. This parallel evaluation has provided information about: (i) lateral transport and redeposition of sputtered species on the target, (ii) oxidation state of the target surface as function original composition, position and HiPIMS plasma conditions, and (iii) correlation between local surface conditions and plasma characteristics.

P 8.5 Di 9:50 HS 1010

Electric field measurement in diffuse helium-nitrogen barrier discharge by Stark polarization spectroscopy — •Sebastian Nemschokmichal, Robert Tschiersch, and Jürgen Meichsner — Institute of Physics, Ernst-Moritz-Arndt-University of Greifswald

Discharges in helium with molecular admixtures like nitrogen or oxygen are important for applications at atmospheric pressure because of their ability to produce radicals at low power requirements. For a better understanding of these discharges and to optimize applications, numerical simulations and their comparison with crucial discharge parameters of the experiment are necessary. One important discharge parameter is the electric field strength, which can be determined by Stark polarization spectroscopy at 492.2 nm and from the intensity ratio of the two singlet lines at 667.8 nm and 728.1 nm [1]. The combination of both methods allows a precise absolute calibration by the Stark polarization spectroscopy and a good spatial and temporal resolution by the intensity ratio method. For this contribution, these methods are applied to a diffuse dielectric barrier discharge driven by a square wave voltage in helium with 500 ppm nitrogen admixture at a gap distance of 3 mm. In contrast to previous investigations of such discharges, a photomultiplier is used instead of an ICCD camera to improve the temporal resolution and to avoid the blurring by the jitter in discharge breakdown. In addition, it is planned to compare the spatio-temporally resolved electric field strength with 1D fluid simulations.

[1] Ivković et al. J. Phys. D: Appl. Phys. 47 (2014) 055204

P 8.6 Di 10:05 HS 1010

Deposition of a-C:H layers using an atmospheric pressure He/Acetylene plasma jet — •Theresa Urbanietz, Katja Rügner, Gert Willems, Achim von Keudell, and Jan Benedikt — Institut für Experimentalphysik II, Ruhr-Universität Bochum, 44780 Bochum, Germany

The deposition and treatment of a-C:H films by means of an atmospheric pressure microplasma jet with helium/acetylene mixtures has been studied by in situ FTIR spectroscopy. It is shown that the deposition rate has a saturating behaviour with increasing admixture of acetylene and reaches a maximum deposition rate of 15 nm min^{-1}. The additional admixture of nitrogen leads to a three times faster deposition rate and an appearance of nitrogen double and triple bounds in the film. The treatment is done by alternating application of a helium/acetylene plasma and a helium/nitrogen plasma to the same deposition area. This is achieved by applying two plasma jets on a rotating substrate. In contrast to the addition of nitrogen the treatment with helium/nitrogen plasma shows an etching effect caused by nitrogen atoms and an appearance of single nitrogen bounds in the film. A treatment with a pure helium plasma in direct contact with the surface has no significant effect on the film. The analysis of the plasma with mass spectrometry shows the polymerization of C_2H_2 to C_4H_2 and C_6H_2 with the help of C_2H.

P 9: Magnetic Confinement I

Zeit: Dienstag 8:30–10:10 Raum: HS 2010

Hauptvortrag P 9.1 Di 8:30 HS 2010

Summary of the Edge Physics Results from the First Operation Phase of the Wendelstein 7-X Stellarator — •Ralf König and W7-X team — Max-Planck-Institute for Plasma Physics, Wendelsteinstr.1, 17491 Greifswald, Germany

Wendelstein 7-X (W7-X) is the largest and most optimised superconducting stellarator world-wide, which aims at demonstrating high heating power steady state plasma operation. In its first operation phase (OP1.1), most of the in-vessel graphite wall armor had not yet been installed and instead of the 10 discrete island divertor modules only 5 inboard limiters were used. Plasma purity and wall outgassing were continuously improved by ECRH and GDC wall conditioning. Low ECR heated plasmas of up to 6 s (0.6 MW, 1 gyrotron) were created, as were shorter-lived higher power discharges (4.3 MW, 6 gyrotrons). Te > 8 keV, Ti > 1.5 keV and ne = 3 10^{19} m^{-3} were achieved simultaneously. The power loads to the limiters reached up to 5 MW/m^2 in steady state (< 60% ECRH input power), with toroidal asymmetries up to a factor 2. The SOL widths were on the order of 1-2 cm. Langmuir probe arrays integrated into one limiter showed significant top/bottom asymmetries in Te and ne, as did IR camera measurements in the power load distribution across the limiters, which suggest ExB drifts at the plasma edge. IR camera observations revealed indications for enhanced transport due to frequent bursts with poloidal mode numbers of about 15 seen on the limiter surface, while fast video camera images show filamentary structures elongated along the magnetic field lines, which rotated poloidally, consistent with the ExB drift velocity.

Hauptvortrag P 9.2 Di 9:00 HS 2010

Physics of heat and momentum transport changes in ohmically confined tokamak plasmas — •Rachael McDermott[1], Alexander Lebschy[1,2], Ivan Erofeev[1], Clemente Angioni[1], Emiliano Fable[1], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Technische Universität München, Garching, Germany

In Ohmically confined tokamak plasmas the energy confinement time is observed to increase linearly with the plasma density up to a critical density above which it saturates. These two regimes, below and above this critical density, are referred to as linear and saturated Ohmic confinement (LOC and SOC) and are ubiquitous to tokamak experiments. In the same general parameter regime, dramatic changes in the core plasma toroidal rotation are also observed, with the rotation actually flipping sign from the co-current to the counter-current direction. These changes in both energy and momentum transport have long been ascribed to changes in the plasma turbulence, which is expected to transition from trapped electron mode (TEM) driven to ion temperature gradient (ITG) driven as the electron density, and hence collisionality, is increased. While recent modelling work does display a gradual TEM-ITG transition throughout the plasma as the density grows, the critical densities of the LOC-SOC transition and the rotation reversals do not correspond to any sudden modification of the global turbulence regime. Rather, the LOC-SOC transition can be related to the increase in ion turbulent transport, which is higher when ITG is dominant.

Fachvortrag P 9.3 Di 9:30 HS 2010

Control of Edge-Localized Mode in Magnetically Confined Fusion Plasmas — •Yunfeng Liang — Forschungszentrum Jülich GmbH, Jülich, Germany

A great challenge for fusion energy research and technology is to confine burning plasma while maintaining tolerable steady state and transient heat and particle fluxes on plasma-facing components. When tokamak plasmas operate in a high-confinement (H-mode) regime, a significant increase in the plasma energy confinement time is observed. However, as a consequence, a steep plasma pressure gradient and an associated increased current density at the plasma edge could exceed a threshold value to drive magnetohydrodynamic instabilities referred to as edge-localized modes (ELMs). ELMs lead to quasiperiodic expulsions of large amounts of energy and particles from the confined region, which in turn could result in serious damage to plasma-facing components. The next generation fusion machines, like ITER and DEMO, will need a reliable method for controlling or suppressing large ELMs.

In this paper, several newly developed ELM control methods on EAST and JET tokamaks including low n (1, 2) resonant magnetic perturbations (RMP) [Phys. Rev. Lett. 117, 115001 (2016), Phys. Rev. Lett. 105 , 065001 (2010)], Lower Hybrid Waves (LHW) [Nature Physics, 9, 817-821 (2013), Phys. Rev. Lett. 110, 235002 (2013)], Li pellets injection and Li powder [Phys. Rev. Lett. 114, 055001 (2015)] will be presented. In addition, the role of magnetic topology in accessing ELM suppression will be discussed.

P 9.4 Di 9:55 HS 2010

Comissioning of the soft X-ray tomography system (XMCTS) in the Wendelstein 7-X stellarator — •Christian Brandt, Henning Thomsen, Torsten Broszat, Ralph Laube, Mirko Marquardt, Mathias Schülke, Thomas Sieber, Sven Weissflog, and and the W7-X Team — Max-Planck-Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

The soft X-ray multi-camera tomography system (XMCTS) has been assembled and installed inside the W7-X vacuum vessel. The commissioning is scheduled for the upcoming operation phase (OP1.2a). Twenty pinhole cameras aligned on a poloidal circumference measure the plasma radiation in the soft X-ray range (> 1 keV) with 18 lines-of-sight each (360 in total). The preamplifier electronics is located directly behind the silicone photodiode arrays within the actively water-cooled camera housings. By tomographic reconstruction the radiation distribution of the poloidal cross section inside the LCFS will be obtained with a spatial resolution of ≈ 2 cm. The foreseen sample frequency of 2 MHz enables the detection of MHD modes up to 800 kHz. In addition the XMCTS will provide insights into the spatiotemporal dynamics of impurities and the quality of the plasma confinement (Shafranov shift). Ongoing work is the preparation of the control and data acquisition systems. The data rate will be 1.6 GB/s and for the later planned long pulse plasmas $\approx$ 3 TB per 30 minutes.

P 10: Theory and Modeling I

Zeit: Dienstag 14:00–15:45 Raum: HS 2010

Hauptvortrag P 10.1 Di 14:00 HS 2010

Filamentary plasma eruptions: results from the nonlinear ballooning model — •Sophia A. Henneberg[1], Steven C. Cowley[2,3], and Howard R. Wilson[4] — [1]Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, 17489 Greifswald — [2]Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford OX1 3NP, UK — [3]Corpus Christi College, Oxford OX1 4JF, UK — [4]York Plasma Institute, University of York, Heslington, YO10 5DD, UK

Two distinct studies are investigated exploiting the nonlinear model for ideal ballooning modes with potential applications to Edge Localized Modes (ELMs). The nonlinear model for tokamak geometries was developed by Wilson & Cowley 2004 and consists of two differential equations which characterize the temporal and spatial evolution of the plasma displacement.

In the first study, the interaction of multiple filamentary eruptions is addressed in magnetized plasma in a slab geometry. Equally sized filaments evolve independently in both the linear and nonlinear regime. However, if filaments are initiated with slightly different heights from the reference flux surface, they interact with each other in the nonlinear regime: Lower filaments are slowed down and then completely suppressed while the higher filaments grow faster due to the nonlinear interaction.

In the second study, this model of nonlinear ballooning modes is examined quantitatively against experimental observations of ELMs in MAST and JET-like geometries. The results suggest experimentally relevant results can only be obtained using modified equilibria.

P 10.2 Di 14:30 HS 2010

Influence of plasma backgrounds including neutrals on SOL filaments using 3D simulations — •David Schwörer[1,2], Nick Walkden[2], Huw Legatte[1], Fulvio Militello[2], and Miles M. Turner[1] — [1]Dublin City University, Dublin, Ireland — [2]Culham Centre for Fusion Energy, Culham, 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). In order to design next generation machines, understanding this non diffusive transport mechanism is beneficial to predict wall fluxes.

We have carried out non-linear, three-dimensional simulations, including neutral-plasma interactions, using the STORM module for BOUT++. The heat and particle influx is varied, generating self-consistent 1D profiles that reproduce both low and high recycling regimes. Filaments where seeded on the backgrounds, and the resulting filament motion was studied. Additional to density and temperature scans, a scan in filament size was performed. This increases the understanding of filaments and their scaling with plasma background, in the experimentally relevant regime. These filaments radial velocity showed a linear increase in mid-plane background temperature T, lying between the $T^{\frac{1}{2}}$ scaling for inertial limited and the $T^{\frac{3}{2}}$ scaling for sheath limited filaments. The suitability of the target temperature as well as the average temperature instead of the upstream temperature as scaling quantity have been studied. With the exception of low temperatures, an increased density results in a decreased radial velocity.

P 10.3 Di 14:45 HS 2010

The Uniform Electron Gas at Warm Dense Matter Conditions — •Simon Groth[1], Tobias Dornheim[1], Travis Sjostrom[2], and Michael Bonitz[1] — [1]Christian-Albrechts-Universität zu Kiel, D-24098 Kiel, Germany — [2]Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

The availability of an accurate parametrization of the exchange correlation energy of the uniform electron gas (UEG) on the basis of ground state quantum Monte Carlo simulations has been crucial for the success of density functional theory (DFT) calculations within the local density approximation. However, it is widely agreed [1] that the description of recent experiments with inertial confinement fusion and laser-excited solids within the DFT framework requires to go beyond the ground state. While an explicitely thermodynamic DFT approach is long known, it relies on an accurate parametrization of the exchange correlation free energy of the UEG at warm dense matter conditions. Here we present our novel parametrization that is based on our ab initio simulations [2,3] and perform benchmarks against various other parametrizations.

[1] V. Karasiev et al. Phys. Rev. E 93, 063207 (2016)
[2] T. Schoof et al., Phys. Rev. Lett. 115, 130402 (2015)

[3] T. Dornheim et al. Phys. Rev. Lett. 117, 156403 (2016)
This work is supported by DFG project BO1366-10 and via SFB TR-24 Project No. A9.

P 10.4 Di 15:00 HS 2010

Study on the effect of impact ionization by the proton bunch on plasma density — •Gabriel Fior, Patric Muggli, and Allen Caldwell — Max-Planck-Institut für Physik, Munich, Germany

The Advanced Wakefield Experiment (AWAKE) at CERN is a proof-of-principle of plasma wakefield acceleration. The proton bunch travels through a 10m cell containing rubidium vapor, which is ionized by a laser pulse thus creating plasma. While the proton bunch travels inside the plasma self-modulation instability (SMI) occurs, and micro bunches of the order of the plasma wavelength scale (1mm) are formed. The focus of AWAKEs first phase is to investigate SMI.

Since the SMI heavily depends on the plasma density, it must be very well defined. Impact collisions between the incoming protons and rubidium atoms lead to additional electronic density via ionization. The focus of this work is to investigate and assess how large is this contribution.

Theoretical calculations, combined with Monte Carlo simulations, were carried out to characterize the collisions taking place during the experiment.

In the collisions between the protons and the rubidium, we account both for direct ionization, caused by the protons, as well as the secondary ionization, arising from secondary electrons. Therefore we can determine the electron density generated from the impact collisions and assess the impact on the SMI.

A brief explanation on the AWAKE experiment will be given, along with more details about the simulations and the results.

P 10.5 Di 15:15 HS 2010

Electrical conductivity of partially ionized noble gases — •Sebastian Rosmej, Heidi Reinholz, and Gerd Röpke — Universität Rostock, Institut für Physik, 18051 Rostock, Deutschland

The conductivity of partially ionized noble gases is considered within the Linear Response Theory in a chemical picture. The different scattering mechanisms (electron-ion, electron-electron and electron-atom) contribute to the electrical resistivity. Correlation functions are evaluated including strong collisions via the T matrix approximation for different densities and temperatures. Especially the influence of electron-electron and electron-atom collisions is presented. The interaction between free electrons and atoms for isolated systems is modeled by an optical potential, screening effects caused by the plasma environment are included. The low-density Spitzer limit as well as the Ziman limit for high degeneracy are reproduced. Further analytical limits are given. Our theoretical results are compared with MD simulations and experiments.

P 10.6 Di 15:30 HS 2010

Theoretical investigation of power balance of a miniature microwave ICP-plasmajet — •Michael Klute[1], Horia-Eugen Porteanu[2], Wolfgang Heinrich[2], Peter Awakowicz[3], and Ralf Peter Brinkmann[1] — [1]Institute of Theoretical Electrical Engineering, Ruhr University Bochum, Germany — [2]Microwave Department, Ferdinand-Braun-Institut Berlin, Germany — [3]Electrical Engineering and Plasma Technology, Ruhr University Bochum, Germany

Microwave-driven plasmas-jets offer attractive properties for various technical applications. They are usually operated in a capacitive mode. However experimental experience show a number of disadvantages for capacitive energy-coupling. Therefore in large scale plasmas inductive energy-coupling is preferable. Recently Porteanu et al.[1] proposed a small scale plasma-jet operated as an inductive discharge. The key characteristic of the suggested plasma-jet is the implementation of an LC-resonance-circuit into a cavity resonator. In this work the proposed plasma-jet is examined theoretically. A global model for the electromagnetic fields and energy balance is presented. Consequent mathematical analysis of the electromagnetic fields leads to a description based on a sum of different modes. It is found that the modes of zero and first order can be identified with inductive and capacitive coupling. In a second step the matching network and its frequency depended characteristic are taken into account. Finally an investigation of stable working points and possible hysteresis effects is done. [1]H. E. Porteanu et al. Plasma Sources Sci.Technol.22, 035016(2013)

P 11: Helmholtz Graduate School II

Zeit: Dienstag 14:00–16:30 Raum: HS 1010

P 11.1 Di 14:00 HS 1010

Kinetic waves in non-Maxwellian plasmas — •Patrick Astfalk[1,2], Seth Dorfman[2], and Frank Jenko[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstrasse 2, 85748 Garching, Germany — [2]Department of Physics and Astronomy, University of California, Los Angeles, CA 90095, USA

Due to low collisionality, particle velocity distributions in space plasmas can develop and maintain nonthermal features. This makes linear wave analysis particularly challenging since it invalidates the use of simple Maxwell-Boltzmann distributions and necessitate the use of sophisticated numerical tools. Nonthermal deviations from an isotropic Maxwell-Boltzmann distribution can, on the other hand, provide a source of free energy and drive a rich variety of velocity space instabilities. We use a recently developed fully kinetic dispersion relation solver which can process arbitrary distributions obtained from spacecraft measurements and simulation data to carry out a realistic investigation of velocity space instabilities in the solar wind and Earth's magnetosphere such as the ion firehose instability and the right-hand resonant ion beam instability. We compare the results to other solvers based on bi-Maxwellian and anisotropic kappa distributions, and we extend the analysis to quasilinear theory to study the instabilities' saturation due to resonant pitch-angle scattering.

P 11.2 Di 14:25 HS 1010

Doppler reflectometry power response regimes: modelling and experiments — •J.R. Pinzon[1,2], T. Happel[1], P. Hennequin[3], E. Blanco[4], T. Estrada[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]Laboratoire de Physique des Plasmas, Ecole Polytechnique, France — [4]Laboratorio Nacional de Fusion, CIEMAT, 28040 Madrid, Spain.

The experimental characterization of turbulence in fusion plasmas is relevant for confinement studies and the development of a fusion reactor. Doppler reflectometry (DR) is a microwave diagnostic technique used for the characterization of density turbulence in fusion plasmas. It can provide perpendicular wavenumber($k_\perp$)-spectra of the turbulence, velocity of the plasma and, using two reflectometer channels, the radial correlation length L_r of the turbulence. However it is well known, from theory and simulations, that a non-linear response of the diagnostic is involved, which makes data analysis and interpretation challenging.

The power response in Doppler reflectometry is studied using 2D full wave simulations and the physical optics model. Apart from the already known linear and saturation regimes, a new enhanced non-linear power response is observed. Results from the modelling are compared with experiments from the ASDEX Upgrade Tokamak. The impact of the previous regimes in $k_\perp$-spectra and L_r measurements is studied.

P 11.3 Di 14:50 HS 1010

Radio frequency heating induced edge plasma convection — •Wei Zhang[1,2], Wouter Tierens[1], Diogo Aguiam[3], Vladimir Bobkov[1], David Coster[1], Helmut Fuenfgelder[1], Jonathan Jacquot[1], Jean-Marie Noterdaeme[1], Roman Ochoukov[1], Antonio Silva[3], the ASDEX Upgrade Team[1], and the EUROfusion MST1 Team[1] — [1]Max Planck Institute for Plasma physics, Garching, Germany — [2]University of Ghent, Ghent, Belgium — [3]University of Lisbon, Lisbon, Portugal

Plasma heating with radio waves in the Ion Cyclotron Range of Frequency (ICRF) is one of the standard heating methods in tokamaks. The parallel electric field of the ICRF waves enhances the edge plasma potential nonlinearly through radio frequency sheath rectifications. Subsequently this large inhomogenous potential drives $E \times B$ convection in the plasma edge. In this contribution, the plasma density convection induced by 2-strap and 3-strap antennas with different antenna feeding configurations are investigated in the ASDEX Upgrade tokamak. Experimentally, the $E \times B$ convection is measured with the poloidal distributed reflectometers embedded in the 3-strap antenna. Theoretically, this $E \times B$ convection is simulated by running the EMC3-EIRENE, RAPLICASOL and SSWICH codes in an iterative and self-consistent way. Qualitative agreements are found between the simulations and experiments. It is indicated that the sheath rectifications and density convection induced by 3-strap antennas with optimized feeding configuration are smallest, and those induced by 2-strap antennas are usually largest.

P 11.4 Di 15:15 HS 1010

Characterization of ELM associated phenomena by magnetic pick-up coils on ASDEX Upgrade — •Felician Mink[1,2], Elisabeth Wolfrum[1], Florian M Laggner[1], Ulrich Stroth[1,2], and The ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [2]Physik Department, E28, TUM, 85748 Garching, Germany

In highly confined tokamak plasmas periodically appearing edge localized modes (ELMs) are accompanied by mode-like magnetohydrodynamic (MHD) activities with defined toroidal mode numbers.
Here magnetic pick-up coil arrays are used to determine poloidal and toroidal mode numbers m and n of these inter-ELM modes and to calculate the variation of their amplitude with the poloidal angle, i.e. the ballooning. The radial position and the rotation velocity of the modes are estimated from m and n values and the measured frequency. Plasma parameters are varied in order to get an insight into the drive of these inter-ELM modes.
Several coexisting branches of modes at slightly different positions in the pedestal region are rotating with the $v_{E\times B}$ dominated plasma velocity. Branches with low toroidal mode numbers, $n = 1 - 5$, appear further outside and stronger ballooned than modes with intermediate ones, $n = 7 - 12$. Mode numbers vary slightly with changing plasma parameters, but the strong ballooning is still only related to the low n modes, which are also conserved during the crash. These mode characteristics are in contradiction with the often mentioned kinetic ballooning modes.

P 11.5 Di 15:40 HS 1010

Plasma turbulence studies in the scrape-off layer — •Alexander Ross, Andreas Stegmeir, David Coster, Karl Lackner, and Sibylle Günter — Max-Planck-Institut für Plasmaphysik (IPP), Boltzmannstraße 2, 85748 Garching bei München

The investigation of plasma edge turbulence is of major importance for future fusion devices. The full-f drift reduced Braginskii model is well suited for the collision dominated SOL, as it does not make any assumptions about the size of the fluctuations. GRILLIX, a plasma turbulence code using the field-line map approach, is being extended by this four-field model, consisting of equations for the density, vorticity, parallel momentum and electron temperature. Statistical diagnostics, e.g. the probabilty distribution function are presented for a slab geometry. The final goal is the investigation of the thermal model in a diverted geometry.

P 11.6 Di 16:05 HS 1010

Theory-based modeling of L-mode plasma intrinsic rotation in ASDEX Upgrade — •Ivan Erofeev, Emiliano Fable, Clemente Angioni, William Hornsby, Rachael McDermott, and the ASDEX Upgrade Team — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

Many tokamak plasmas have been found to develop finite toroidal rotation velocity from rest without external sources of torque, and L-mode plasmas tend to flip the rotation direction in the core twice - from co- to counter-current and back again - as the density grows. This phenomenon is known as intrinsic rotation and is believed to be caused by a component of the stress tensor not related to either viscosity or pinch. This residual stress appears as a consequence of the poloidal symmetry violation.

In this work we investigate the effect of non-zero, poloidally averaged, parallel wavenumbers of plasma microinstabilities like TEM and ITG modes, which arise from finite tilting angles of the turbulent structures. We perform simulations of L-mode plasma experiments in ASDEX Upgrade with the ASTRA code, coupled to the TGLF transport model, and the drift-kinetic solver NEO. We estimate the values of the tilting angles and the average parallel wavenumbers from TGLF linear turbulent spectra, which are necessary to match the experimental toroidal velocity profiles. We then compare the results to global gyrokinetic simulations with the GKW code.

P 12: Theory and Modelling I

Zeit: Dienstag 16:30–18:30 Raum: HS Foyer

P 12.1 Di 16:30 HS Foyer

Ab Initio Quantum Monte Carlo Simulation of the Warm Dense Electron Gas — Tobias Dornheim[1], Simon Groth[1], •Travis Sjostrom[2], and Michael Bonitz[1] — [1]Christian-Albrechts-Universität zu Kiel, D-24098 Kiel, Germany — [2]Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

The uniform electron gas (UEG) at finite temperature is of high interest for warm dense matter research, most notably as an input for thermal density functional theory. Until recently, the most accurate data [1] had been obtained using Quantum Monte Carlo (QMC) in the fixed node approximation (RPIMC) and by subsequently extrapolating the results for the finite model system to the thermodynamic limit (TDL) by adding a finite-size correction. However, the quality of these results has been called into question: (I) RPIMC constitutes an uncontrolled approximation that induced errors of $\sim 10\%$ for the finite model system [2] and (II) the employed finite-size correction is only appropriate in parts of the warm dense regime. Here we show how to perform ab initio QMC simulations of the UEG without the fixed node approximation [3] and present a new approach to subsequently extrapolate the results to the TDL without any systematic errors [4].
[1] E. Brown et al., PRL **110**, 146405 (2013)
[2] T. Schoof et al., PRL **115**, 130402 (2015)
[3] T. Dornheim et al., PRB **93**, 205134 (2016)
[4] T. Dornheim et al., PRL **117**, 156403 (2016)
Supported by DFG project BO1366-10 and via SFB TR-24 Project No. A9.

P 12.2 Di 16:30 HS Foyer

Theoretical foundations of quantum hydrodynamics for dense plasmas — •Zhandos Moldabekov and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel, Leibnizstraße 15, 24098 Kiel, Germany

Dense quantum plasmas are of high current interest in astrophysics and many laboratory experiments. The theory of these systems is complicated, therefore a simplified approach based on Quantum hydrodynamics (QHD) has become popular [1]. However, often QHD is used outside the range of applicability and even with incorrect explicit expressions. The key ingredients of QHD for fermions are the Fermi pressure and the Bohm potential. We have recently shown [2] that to compute the screened potential in a plasma the prefactor of the Bohm term has to be corrected yielding good agreement with the static long-wavelength limit of the random phase approximation [3]. Here we analyze how the QHD equations can be further improved in order to better reproduce a broader wavenumber-frequency range. The nonlocal Bohm potential, in linear response, has been derived. The exchange-correlation potential in linear response, in terms of the dynamic local field correction, for the QHD application has been obtain. This allows to use the results of the previous studies of the dynamic local field correction in the QHD theory.

[1] G. Manfredi, F. Haas, Phys. Rev. B 64, 075316 (2001) [2] D. Michta et al., Contrib. Plasma Phys. 55, 437 (2015) [3] Z. Moldabekov et al., Phys. Plasmas 22, 102104 ((2015)

P 12.3 Di 16:30 HS Foyer

Diagnostik und Modellierung eines Mikrowellen-Plasmabrenners bei Atmosphärendruck — •Sandra Gaiser[1], Andreas Schulz[1], Matthias Walker[1] und Thomas Hirth[2] — [1]Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie, Universität Stuttgart — [2]Karlsruher Institut für Technologie

Für die Untersuchung und Optimierung eines bei Atmosphärendruck betriebenen Mikrowellen-Plasmabrenners wurden mit Hilfe des Programmes COMSOL Multiphysics® Simulationsmodelle erstellt. Die

Ergebnisse der Simulationen konnten mit experimentellen Daten verglichen werden.

Das Plasmamodell enthält Bilanzgleichungen für die Elektronen- und Schwerteilchendichten sowie für die Elektronenenergie. Dazu kommt ein Satz von Elementarreaktionen zur Beschreibung eines Argon-Plasmas. Des Weiteren wurde das Drude-Modell verwendet, um dem Plasma eine frequenzabhängige Leitfähigkeit und Permittivität zuzuweisen und damit seine elektrischen Eigenschaften zu berücksichtigen. Dies ermöglicht es, die Auswirkung einer sich ändernden Elektronendichteverteilung auf das elektrische Feld im Plasmabrenner zu untersuchen.

Ein Vergleich der berechneten maximalen Elektronendichte mit gemessenen Werten zeigte bereits eine gute Übereinstimmung von Simulation und Experiment. Qualitative Untersuchungen des Plasmas bestätigten zudem einen aus den Simulationsergebnissen abgeleiteten Zusammenhang zwischen der Lage des Plasmas im Brenner und einer einhüllenden Gasströmung.

P 12.4 Di 16:30 HS Foyer

Effect of mode structure variation on fast particle transport in hybrid-kinetic simulations — •Thomas Hayward-Schneider and Philipp Lauber — Max-Planck-Institut für Plasmaphysik, Garching, Germany

Perturbative modelling of Alfvén eigenmodes (AEs) using the nonlinear perturbative drift-kinetic initial value code Hagis and the linear gyrokinetic eigenvalue code Ligka is introduced. We present the steps to couple these two codes, with a goal of non-/semi- perturbative, nonlinear simulations of AEs. Towards this aim, we show a benchmark of a prescribed, time-dependent mode structure in Hagis. We introduce ITER scenarios for study, and observe that the AE resonance locations are highly sensitive to the magnetic profiles.

P 12.5 Di 16:30 HS Foyer

Molecular Dynamics Simulations Of Laser Ablation and Plasma Formation — Eugen Eisfeld and •Johannes Roth — Universität Stuttgart

Laser ablation is studied with classical molecular dynamics simulations. The interaction of ultrashort laser pulses with a metallic material is modeled using a hybdrid two-temperature model with separate temperatures for the electrons and the lattice. We have implemented an ionization model based on the Thomas-Fermi theory as well as wide-range models for the complex permittivity, the electronic heat conductivity and the electron-phonon coupling parameter, similar to the work of Povarnitsyn [1] which describes the transition from the metal to the plasma state.

The laser absorption is calculated by solving the Helmholtz wave equation instead of the simple Lambert-Beer law. The improved results are compared to simulations carried out with hydrodynamic simulations.

[1] Povarnitsyn et al., Appl. Surf. Sci. 258 (2012) 9480.

P 13: Magnetic Confinement

Zeit: Dienstag 16:30–18:30 Raum: HS Foyer

P 13.1 Di 16:30 HS Foyer

High-efficiency injection of positrons into a magnetic dipole trap — •Markus Singer[1], James R. Danielson[2], Marcel Dickmann[1], Uwe Hergenhahn[3], Juliane Horn-Stanja[3], Haruhiko Saitoh[3,4], Eve V. Stenson[3], Matthew R. Stoneking[5], Thomas Sunn Pedersen[3,6], and Christoph Hugenschmidt[1] — [1]Technische Universität München — [2]University of California, San Diego — [3]Max-Planck Institut für Plasmaphysik — [4]University of Tokyo — [5]Lawrence University, Wi, USA — [6]Ernst-Moritz-Arndt University Greifswald

Electron-positron plasmas represent a unique state of matter as pair-plasmas. The mass symmetry of the particles lead to fundamentally different physical phenomena compared to conventional electron-ion plasmas. Despite great theoretical interest these plasmas have not been magnetically confined yet. The goal of APEX (A-Positron-Electron-eXperiment) projects is the creation of magnetically confined electron-positron plasmas, by injecting positrons from the world*s most intense positron source NEPOMUC (NEutron-induced POsitron Source MUniCh) into a magnetic dipole trap, which will also allow the simultaneous confinement of electrons. The current prototype trap mainly consists of a cylindrical permanent magnet which is placed in the center of a segmented ring electrode. Positrons are guided into the dipole by E x B plates which induce a drift motion across closed magnetic field lines.In recent experiments, by tailoring electrostatic fields in the trap, the injection efficiency could be increased up to 100%. The results from these experiments will be presented and compared to simulations.

P 13.2 Di 16:30 HS Foyer

Global model for radio frequency magnetron sputtering — •Dennis Engel, Dennis Krüger, and Ralf Peter Brinkmann — Institute of Theoretical Electrical Engineering, Ruhr University Bochum, Germany

During the last decades magnetron sputtering gained a high technological significance. It is used wherever high quality thin films are needed. Due to the high complexity, the active control of this process is current subject of research. Active control allows to keep the plasma in a stable working condition. An efficient model in terms of computation time is required. This work shows one possible model, based on a lumped circuit model for a capacitively coupled radio frequency discharge [1]. The necessary changes to this model regarding the magnetic field are shown. The newly proposed model is used to investigate the influence of various input parameters on the sheath voltage and the discharge current. These parameters can be the magnetic field strength, the neutral gas pressure or the applied voltage.

[1] T. Mussenbrock et al., PSST **16**, 377-385 (2007)

P 13.3 Di 16:30 HS Foyer

Compression of the radial positron profile in a magnetic dipole trap by rotating electric fields — •J. Horn-Stanja[1], U. Hergenhahn[1], T. S. Pedersen[1,2], H. Saitoh[1,3], E. V. Stenson[1], M. R. Stoneking[4], M. Dickmann[5], C. Hugenschmidt[5], M. Singer[5], and J. R. Danielson[6] — [1]Max-Planck-Institute for Plasma Physics — [2]Ernst-Moritz-Arndt University Greifswald — [3]University of Tokyo — [4]Lawrence University — [5]Technische Universität München — [6]University of California, San Diego

An electron-positron plasma is, in contrast to a conventional electron-ion plasma, characterized by the mass balance of the oppositely charged components. Although offering a fundamentally different playground for plasma physics, the experimental investigation of these plasmas is still in its infancy. The APEX project aims to create the first magnetically confined electron-positron plasma by first accumulating positrons from the world's most intense positron source NEPOMUC in novel linear trapping devices (the Positron Accumulation eXperiment PAX) and second injecting them into a magnetic dipole trap which allows to confine them simultaneously with electrons.

Recent experiments with a prototype dipole trap operated at the NEPOMUC source proved the interaction of rotating electric fields with positrons in a magnetic dipole field. In a broad frequency range around 150kHz a compression of the radial positron profile was observed. In this contribution, results from these experiments as well as from simulations on the interaction of rotating electric fields with positrons in this dipole trap will be presented.

P 13.4 Di 16:30 HS Foyer

Numerical Investigation of Microwave Propagation at the Stellarator TJ-K — •Lennart Bock, Gabriel Sichardt, Eberhard Holzhauer, Carsten Lechte, and Mirko Ramisch — Institute of Interfacial Process Engineering and Plasma Technology, University Stuttgart

The plasma of the stellarator TJ-K allows electron cyclotron radiation to propagate through the whole torus via multiple reflections and to be detected with a dedicated diagnostics. In a first step, 2D full wave simulations were used to analyze microwave propagation in both, toroidal and poloidal cross section. The solving algorithm implements the Finite Difference Time Domain method and assumes a fixed ion background. Plasma density profiles and magnetic background fields were chosen representative for TJ-K. The simulation incorporates the geometry of the receiver system including an antenna at the outer port and a reflecting mirror on the inside wall of the torus. Different geometrical configurations were simulated to optimize the weighting function of the receiving system. Furthermore, the importance of the resonator geometry of TJ-K with its highly reflective walls was investigated. In a next step, the simulation was extended to 3D and implemented in the IPF-FD3D code in order to cover the full toroidal geometry of TJ-K for a full extent analysis of the weighting function. The stellarator's realistic magnetic background field was implemented and the density profile was modeled to be constant on the flux surfaces. This contribution compares 2D with 3D results and is considered essential for the interpretation of experimental results from the measuring system.

P 13.5 Di 16:30 HS Foyer

Development status of a levitated dipole experiment for pair-plasma production — •Haruhiko Saitoh[1], Juliane Horn-Stanja[1], Eve V. Stenson[1], Uwe Hergenhahn[1], Thomas Sunn Pedersen[1], Markus Singer[2], Matthew R. Stoneking[3], and Nagato Yanagi[4] — [1]Max-Planck-Institut für Plasmaphysik — [2]Technische Universität München — [3]Lawrence University, USA — [4]National Institute for Fusion Science, Japan

Magnetic dipole is a simple and most common field configuration in the Universe, which generates a variety of plasma phenomena in a strongly inhomogeneous magnetic field. One of scientific applications of the dipole field is its usage as a trapping geometry for electron-positron pair-plasmas. For this purpose, we, the APEX (A Positron Electron Experiment) collaboration [1], is developing a compact levitated dipole device, APEX-D, to be operated at the NEPOMUC slow positron facility [2]. In order to minimize perturbations to plasmas, the superconducting dipole field coil (F coil, "F" for floating) of APEX-D will be magnetically levitated in a vacuum chamber. We plan to fabricate a Bi-2223 high-temperature superconducting (HTS) F coil that is magnetically levitated by using a feedback-controlled levitation coil (L coil), after inductive excitation of a persistent current in the F coil. We report design studies and status of development on the APEX-D project.

[1] T. Sunn Pedersen et al., New J. Physics **14**, 035010 (2012).
[2] C. Hugenschmidt et al., New J. Physics **14**, 055027 (2012).

P 13.6 Di 16:30 HS Foyer

Shearing rate dependence of turbulent transport — •Til Ullmann and Mirko Ramisch — Institute of Interfacial Process Engineering and Plasma Technology, University of Stuttgart

In toroidally confined fusion plasmas, poloidal $E \times B$ shear flows play a crucial role in the reduction of radial turbulent transport Γ. Theoretical predictions exist for the functional dependence of Γ on the shearing rate on a rational surface and close by. In order to test the transport's shearing rate scaling, plasma biasing via a ring electrode is used at the stellarator TJ-K for controlling the shearing rate Ω of imposed stationary flows. The applicability of this method could already be demonstrated: Ω generally increases with bias voltage. In a next step, the cross-field transport is calculated from data of a poloidal 64-pin probe array alternately measuring potential and density fluctuations. The background flow shear is deduced from radial profiles of the plasma potential as measured with a moveable emissive probe. Spectral contributions to turbulent transport are correlated with the shearing rate and compared to theoretical predictions.

P 13.7 Di 16:30 HS Foyer

Surface Temperature Measurement of In-Vessel Components Using Infra Red Spectroscopy — •Raheesty Devi Nem, Bernhard Sieglin, Albrecht Herrmann, and ASDEX Upgrade Team — IPP, Boltzmannstraße 2, 85748 Garching bei München

Neutral beam injection (NBI) is one of the auxiliary heating method used on ASDEX Upgrade. If the neutral beam is not absorbed by the plasma, it can deposit a high heat load with a heat flux density of up to $\approx 40\ \frac{\mathrm{MW}}{\mathrm{m}^2}$ on the first wall. For the machine protection, the **H**eat **S**hield **T**hermography (HST) is used to observe the strike points of the beam. The current HST system uses two colors pyrometers at wavelengths of about $0.9\,\mu$m and $1.6\,\mu$m to evaluate the surface temperature. Volume radiation influences the measurement, resulting in an overestimation of the surface temperature. As a consequence, the NBI is switched off unnecessarily. The aim of this work is to improve the HST by using infra red spectroscopy to disentangle thermal radiation from volume radiation. The basic principles for the surface temperature evaluation using IR thermography is shown. The calibration process of the IR spectrometer in laboratory is discussed. The spectrometer has been commissioned in the lab and tested at the high heat flux test facility GLADIS. The experimental setup and the results from GLADIS are shown. In addition the uncertainties of the spectroscopic measurement are discussed using synthetic data. An outlook to the commissioning of the new HST system on ASDEX Upgrade during the start of the 2017 campaign is given.

P 13.8 Di 16:30 HS Foyer

On the comparison of energy confinement in stellarators and tokamaks — •Ulrich Stroth[1,3], Birkenmeier Gregor[3,1], Fuchert Golo[2], Schneider Philip[1], ASDEX Upgrade team[1], and Wendelstein 7-X team[2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching — [2]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald — [3]Physik-Department E28, Technische Universität München, 85747 Garching

With the ASDEX Upgrade (AUG) tokamak and the successful start of the stellarator Wendelstein 7-X (W7-X), the MPI for plasma physics operates two major fusion facilities. This motivates a direct comparison of the confinement quality of two fundamentally different magnetic configurations. While experimentally [1] and theoretically [2] it has been shown that turbulent transport can be expected to be rather different in character, the global energy confinement time of both stellarators and tokamaks can be described with the same scaling expression if appropriate parameters are chosen [3]. A physically relevant comparison of confinement has to concentrate on the transport coefficients. This can be achieved by eliminating from the scalings trivial parameter dependencies such as on plasma volume and surface or by directly comparing transport analyses of dimensionally similar discharges from both devices. The presentation discusses the different techniques for a direct confinement comparison and presents first applications to experimental data from AUG and W7-X.

[1] G. Birkenmeier et al., PRL **107**(2011),025001; [2] P. Helander et al., PPCF **54**(2012),124009; [3] U. Stroth, PPCF **40**(1998),9

P 13.9 Di 16:30 HS Foyer

Preparation of an experimental plasma stability survey in Wendelstein 7-X plasmas — •Henning Thomsen[1], Tamara Andreeva[1], Christian Brandt[1], Joachim Geiger[1], Axel Könies[1], Ulrich Neuner[1], Carolin Nührenberg[1], Kian Rahbarnia[1], Jonathan Schilling[2], and W7-X Team[1] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Christian-Albrechts-Universität zu Kiel, IEAP, Leibnizstr. 11, 24114 Kiel, Germany

The Wendelstein 7-X stellarator (W7-X) ended its first operational phase in March 2016. The preparations for the next experimental phase (which is planned to begin in summer 2017) have been started. Currently ongoing upgrades of the first wall and the microwave heating system enable the realization of higher plasma performance in W7-X. Additionally, the plasma diagnostic capabilities are extended. In view of the detection of the magneto-hydrodynamic (MHD) properties, the most important supplements are the installation of the X-ray multi camera tomography system (allowing the reconstruction of a poloidal flux surface) and the integration of a set of Mirnov coils (magnetic probes for the detection of MHD modes). These improvements provide the possibility to investigate the MHD stability of the Wendelstein 7-X stellarator plasmas and the validation of this design optimization goal for different magnetic configurations. In this contribution we present the planning for the proposed measurements during the next experimental campaign, based on the results obtained during the first experimental phase as well as the new diagnostic and device capabilities.

P 13.10 Di 16:30 HS Foyer

Completion of magnetic diagnostics at Wendelstein 7-X stellarator — •K Rahbarnia[1], T Andreeva[1], B B Carvalho[2], M Endler[1], D Hathiramani[1], J Geiger[1], S Lazerson[3], U Neuner[1], J Svensson[1], H Thomsen[1], A Werner[1], M Zilker[1], and W7-X Team[1] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Instituto de Plasmas e Fusao Nuclear Instituto Superior Tecnico, Lisbon, Portugal — [3]Princeton Plasma Physics Laboratory, Princeton, NJ 08540, USA

During the first operation phase (OP 1.1) of Wendelstein 7-X about 50% of the magnetic sensors, i.e. diamagnetic loops, Rogowski and saddle coils were commissioned. The measured diamagnetic energies and plasma currents are in reasonable agreement with theoretical predictions and results of other diagnostics (Thomson scattering, Bolometry) with respect to absolute values, confinement times and global energy balance. The completion of the equilibrium diagnostics in OP 1.2 (start summer 2017) allows a precise reconstruction of magnetic equilibria complemented by calculations using STELLOPT. Based on the diamagnetic flux measurement an interlock signal is generated to avoid damage of machine and diagnostics due to continued heating after a sudden plasma breakdown. Previous fluctuation measurements during OP 1.1 using 4 Mirnov coils clearly showed mode activity in the low kHz-range ($\sim$ 7 kHz) as well as potential alfvénic behaviour in the 100 kHz-range. The completion of the Mirnov diagnostic (125 sensors) allows more detailed investigations and cross-comparisons to other fluctuation diagnostics, like reflectometry and soft X-ray tomography.

P 13.11 Di 16:30 HS Foyer

Influence of the Neutral Velocity Distribution on the Results of Pedestal Transport Modeling — •Johannes Gnilsen[1], Florian Laggner[1], Sebastian Keerl[1], Elisabeth Wolfrum[2], Emiliano Fable[2], Gregor Birkenmeier[2], and Eleonora Viezzer[3] — [1]Institut für Angewandte Physik, TU Wien, 1040 Vienna, Austria — [2]Max-Planck- Institut für Plasmaphysik 85748 Garching, Germany — [3]Department of Atomic, Molecular and Nuclear Physics, Universidad de Sevilla, 41012 Spain

High confinement mode operation in tokamak plasmas is accompanied by periodically appearing collapses of the edge transport barrier (pedestal) and a burst-like ejection of particles and energy, called edge localized modes (ELMs). After each ELM, both, the electron density and temperature recover and the pedestal builds up again. The temporal evolution of the density recovery is modeled using the transport code ASTRA, which solves the continuity equation for the tokamak geometry. Experimentally measured profiles are modeled interpretatively by adapting the profile of the diffusion coefficient. At the plasma edge the ionization of neutrals causes a significant source of plasma particles, which strongly contributes to the density build-up. This work will investigate the influence of assumptions made on the neutral velocity distribution on the diffusion coefficients derived from ASTRA modeling. Diffusion coefficients obtained from simulations with purely thermal neutrals will be compared to results using distributions with higher velocities, which stem from e.g. Franck-Condon decay or direct reflection from high-Z walls.

P 13.12 Di 16:30 HS Foyer

Origin of radiative fluctuations close to the X-point during detachment in ASDEX Upgrade — •Peter Manz[1], Steffen Potzel[1], Marco Wischmeier[1], Sergei Krasheninnikov[2], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]University California San Diego, La Jolla, USA

The dynamics of radiative fluctuations in the divertor region close to the X-point during the fluctuating state of detachment are studied in ASDEX Upgrade. In this state the inner divertor is detached and the outer divertor is still attached. The X-point fluctuations appear at a frequency of a few kHz, which is at rather low frequency for plasma instabilities, but also at a rather high frequency for equilibrium related phenomena. Two possibilities will be discussed. The first one equates the X-point fluctuations with the dynamics of the ionization front. Fluctuations arise due to geometric restrictions on the propagation of the ionization front. The divertor nose constitutes an obstacle for the perpendicular neutral flux from the target to the region above the X-point. Passing into this shadow the ionization front fades away. A cyclic reformation of the ionization front propagating from below to above the X-point occurs. Another possibility for the X-point fluctuations is the current convective instability caused by the large temperature difference between the inner and outer divertor and a radial gradient in the resistivity.

P 13.13 Di 16:30 HS Foyer

Non-local turbulent plasma transport in fusion plasmas — •Klara Höfler[1,2], Pascale Hennequin[3], Tim Happel[1], and Ulrich Stroth[1,2] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Physik Department E28, TUM, Garching, Germany — [3]Laboratoire de Physique des Plasmas, Ecole Polytechnique, Palaiseau, France

The understanding of particle and energy transport in magnetically confined plasmas is one of the key topics in fusion research. In general both collisional and turbulent transport are described in terms of Fick's law through a diffusion coefficient and a local temperature or density gradient. There exist observations, however, where transport at one location depends on the gradients at a different position. Such a non-local description would dramatically change our physical understanding of transport in fusion plasmas. In this master thesis, turbulence measurements from different microwave diagnostics on the ASDEX Upgrade tokamak will be used and changes in the fluctuation characteristics will be correlated with profile changes. Previous observations of non-local transport will be summarized and the plans for experiments on ASDEX Upgrade as well as the relevant diagnostics will be presented.

P 13.14 Di 16:30 HS Foyer

Scaling of Zonal Flow Power with Shearing Rate — •Rafael Carmona Cabezas, Til Ullmann, and Mirko Ramisch — Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie, Pfaffenwaldring 31, Stuttgart, Deutschland

In toroidal magnetic plasma confinement, zonal flows (ZF) play an important role in regulating drift-wave turbulence and, thus, edge cross-field transport. These flows are driven by gradients in turbulent Reynold stress, which is related with an average vortex tilt in the turbulent fluctuations. Thus, an already present background shear flow is expected to favour the ZF drive by tilting eddies.

In this work, the dependence of ZF amplitude on background ExB flow shear is investigated. To this end, the shearing rate of radially localized and stationary poloidal ExB flows are controlled via external plasma biasing. Different types of biasing electrodes are employed. Radial profiles of the ExB flow are measured by means of a movable emissive probe. At the same time, fluctuations in plasma density and potential are acquired using a poloidal 64-Langmuir probe array situated on one magnetic flux surface. The amplitude of the poloidally averaged potential fluctuations has proven useful as a good approximation for the time-varying ZF. This way, ZF power is detected, experimentally, and correlated with background flow shear.

P 14: Plasma Wall Interaction

Zeit: Dienstag 16:30–18:30 Raum: HS Foyer

P 14.1 Di 16:30 HS Foyer

The effect of secondary electron emission on discharge properties in an rf-plasma — •Felix Georg, Thomas Trottenberg, and Holger Kersten — Institut für experimentelle und angewandte Physik, Kiel, Deutschland

A diagnostic combining a retarding field analyzer, a passive thermal probe and Langmuir probe techniques is presented. The setup is used to combine and compare measurements of these techniques to study the plasma-wall interaction for different materials.

In the plasma chamber two horizontal electrodes made of stainless steel are placed. The lower one is powered by an rf voltage with 13.56 MHz. The two electrodes are embedded into two MACOR contrivances which can be horizontally adjusted. Different materials (metal, metal oxide) can be placed onto the driven electrode. Thus, the interaction of the rf-plasma with the surface can be observed in special regard to varying secondary electron emission.

The electron density and energy distribution as well as the ion energy distribution have been independently measured. Additionally, the energy influx can be determined. By comparison of the three electric probe measurements the effect of the secondary electron emission of specific surfaces can be identified.

P 14.2 Di 16:30 HS Foyer

A molecular dynamics modeling of electron emission from metal surfaces induced by gas-surface interactions — •Alexey Filinov[1,2,3], Michael Bonitz[1], and Detlef Loffhagen[2] — [1]Institut für Theoretische Physik und Astrophysik, CAU Kiel, Leibnizstr. 15, D-24098 Kiel, Germany — [2]INP Greifswald e.V., Felix-Hausdorff-Straße 2, 17489 Greifswald, Germany — [3]Joint Institute for High Temperatures RAS, Izhorskaya Str. 13, 125412 Moscow, Russia

The interaction of a dilute monatomic gas with a solid surface is investigated by Molecular Dynamics (MD) simulations. The main goal is to provide a microscopic description of the electronic stopping-power effects and secondary electron emission. The gas-surface interaction (for Ar atoms and ions) is treated via the effective pair potential determined from the non-local van-der-Waals approach [1]. Different energy dissipation channels in the adsorption process are included. The electron-hole pair excitations are considered via the model of electronic friction [2]. The phonon excitations are treated via the Langevin MD simulations. We analyze how the electron emission current depends on the effective electron temperature (determined by the energy losses) and the work function of a metal modified by a surface electric field and positive ions slowly moving at atomic distances to the surface.

[1] R. Grenier et. al., J. Chem. Phys. A 119, 6897 (2015). [2] J.I. Juaristi et. al., Phys. Rev. Lett. 82, 1048 (1999).

P 14.3 Di 16:30 HS Foyer

Investigation of Plasma Detachment Characteristics and Dynamics at the ASDEX Upgrade Tokamak — •Amazigh Zerzour, Matthias Bernert, Daniel Carralero, Ulrich Stroth, and The ASDEX Upgrade Team — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

Future tokamaks like ITER and DEMO will experience heat fluxes of about 300 MWm^{-2} onto the divertor if not mitigated. This poses a major threat to the device as material heat load limits are expected to be in the range of 5 MWm^{-2}. An efficient solution to this is the detachment of the plasma from the divertor, a state in which the plasma temperature drops to values of several eV at the divertor, allowing for recombination and charge exchange processes in the divertor volume. However, future tokamaks are foreseen to operate in the High Confinement Mode (H-Mode) which features cyclic instabilities, so-called Edge Localized Modes (ELMs), periodically driving high heat fluxes onto the divertor. Heat loads during ELMs can last long enough to effectively reattach the plasma to the divertor. We therefore investigate H-mode plasmas at various densities and power fluxes to characterize the detachment cycles in between ELMs. Understanding the characteristics and dynamics of the detachment regimes, not only in between ELMs, and their influence on the bulk plasma is of crucial importance for the successful operation of future tokamaks.

P 14.4 Di 16:30 HS Foyer

A multipurpose room-temperature solid-state pellet launcher for ASDEX Upgrade — •Raphael Hoepfl[1,2], Martin Balden[1], Thomas Haertl[1], Otto J. W. F Kardaun[1], Peter T. Lang[1], Rudolf Neu[1,3], Bernhard Ploeckl[1], Volker Rohde[1], Datong Wu[2], and ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching — [2]Munich University of Applied Sciences, Lothstr. 34, 80335 München — [3]Technische Universität München, Boltzmannstr. 15, 85748 Garching

Recently, a system for the injection of lithium (Li) pellets into the Tokamak ASDEX Upgrade was developed. It is capable to launch mm-sized pellets at speeds up to 600 m/s with 2 Hz repetition rate. Now, the system was revised to act as a multipurpose unit for injecting different types of room-temperature solid-state pellets. As a first application, wall conditioning is envisaged. Encouraged by the favorable behavior observed during plasma start up gained by small amounts of Li, the idea is to inject solid-state boron (B) for wall conditioning. Usually the latter is performed burning a 4 hour long glow discharge in a He B_2H_6 mixture depositing about 10^{23} B atoms, conducted typically monthly after about 350 plasma discharges. Presently, boron nitride (BN) is selected as pellet material. The co-injection of nitrogen should be tolerable as it is introduced anyway regularly for radiative cooling and performance investigations. About 10^{20} B atoms per pellet and 10^{21} per discharge could be delivered, possibly sufficient for supplementary wall conditioning. Currently, BN raw material from different sources covering a variety of sizes, consistency and purity are investigated.

P 14.5 Di 16:30 HS Foyer

Untersuchung der Rückhaltemechanismen von Wasserstoff in Beryllium Wolfram Verbindungen — •Michael Eichler, Timo Dittmar und Christian Linsmeier — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany

In den experimentellen Fusionsreaktoren JET und zukünftig auch ITER besteht die erste Wand im Hauptraum aus Beryllium (Be). In Bereichen der höchsten Wärmelasten (Divertor) wird zusätzlich Wolfram (W) verwendet. Als Brennstoff werden die Wasserstoffisotope Deuterium (D) und Tritium (T) eingesetzt. Durch den Kontakt der Reaktorwand mit den D- und T-Ionen wird unter anderem das Oberflächenmaterial erodiert und an anderen Stellen deponiert. Dadurch entstehen Be-W Verbindungen. Da das radioaktive T während des Reaktorbetriebs in der Wand eingelagert wird, ist die Untersuchung des Wasserstoffinventars, insbesondere der Rückhaltemechanismen in Be-W Legierungen von besonderem Interesse. Dazu wird das Ultra Hoch Vakuum Experiment namens ARTOSS vorgestellt, welches alle relevanten Oberflächenanalytiken vereint und somit die in situ Präparation und Analyse entsprechender Materialien unter wohldefinierten Bedingungen ermöglicht. Der Ionenbeschuss im Reaktor wird hier mit einer Ionenquelle simuliert. Mit Spannungen bis maximal 20 kV werden D- und Wasserstoffionen in Be-W Verbindungen implantiert. Ausserdem werden erste Untersuchungen mittels Röntgenphotoelektronenspektroskopie (XPS), thermischer Desorptionsspektroskopie (TDS) und nuklearer Resonanzanalyse (NRA) gezeigt.

P 14.6 Di 16:30 HS Foyer

Protection of the first wall of Wendelstein 7-X with neural nets. — •Daniel Böckenhoff and Marko Blatzheim — Max-Planck-Institut für Plasmaphysik, Greifswald, Deutschland

Wendelstein 7-X (W7-X) is the first fully optimized stellarator. One of its main objectives is to demonstrate steady state capability of the confinement concept. The plasma-wall contact is going to be realized with so called divertors that intersect the plasma. Various mechanisms, like the development of plasma currents, lead to a change in the magnetic topology as well as plasma parameters over time. Therefore the heat load pattern on the divertors is dynamic. To ensure the safety of the first wall and protect the plasma from impurities, heat load pattern control is essential for long term operation.

Since the physics of the underlying processes is highly complex, we seek plasma control based on artificial neural networks. Inputs are in particular infrared pictures of the heat load pattern. The first important step towards this goal is to train the neural net to reconstruct the magnetic edge topology from a series of given patterns and predict the further evolution. Moreover, a study of the optimal input quantities and their preprocessing is crucial and will be presented herein.

P 15: Helmholtz Graduate School II

Zeit: Dienstag 16:30–18:30 Raum: HS Foyer

P 15.1 Di 16:30 HS Foyer

Estimation of heating rate values with the multiple airglow chemistry model — •Olexandr Lednyts'kyy and Christian von Savigny — University of Greifswald, Greifswald, Germany

The Multiple Airglow Chemistry (MAC) model based on more than 60 aeronomical reactions was developed to reflect the photochemistry of the identified electronic states of molecular oxygen (O_2). The MAC model was applied in the MLT (upper mesosphere and lower thermosphere) region to calculate heating rate profiles in the MLT and to compare them with the reference profiles extracted from SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) infrared radiometer data. The reference profiles consider heating rates of seven reactions that are important in the energy budget of the mesopause region. The MAC model enables us to estimate the contribution of other processes to the heating of the MLT at night as well. Odd hydrogen and odd oxygen species prevail in the chemical heating in the MLT. Particularly, hydroxyl radical, atomic oxygen and O_2 contribute to the quenching heating.

P 15.2 Di 16:30 HS Foyer

Neural Net Applications for Plasma Edge Analysis in Wendelstein 7-X — •Marko Blatzheim[1,2], Daniel Böckenhoff[1], Hauke Hölbe[1], Thomas Sunn Pedersen[1], and Roger Labahn[2] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Deutschland — [2]Universität Rostock, Rostock, Deutschland

Neural nets are powerful tools and due to recent improvements in computer performance and more complex mathematical approaches they are the state of the art in various applications, e.g. pattern recognition, machine translation or human-level control. Wendelstein 7-X (W7-X) is a fully optimized stellarator with the main goal to demonstrate steady state capability of fusion reactors. The plasma edge targets so-called divertors which ensure to avoid damage at other first-wall components and to reduce plasma impurities. Therefore, they themselves are exposed to a high heat load which can be observed by infrared cameras. We are using neural nets with the purpose to analyze images of the plasma-divertor-interaction in real time. Convolutional neural nets are trained using simulated plasma data. They are a promising approach to predict different plasma properties. In the future these neural nets will be trained to evaluate possible critical states and find parameter configurations to avoid them.

P 15.3 Di 16:30 HS Foyer

Power loads and power decay lengths in the limiter phase of Wendelstein 7-X — •Holger Niemann[1], Marcin Jakubowski[1], Ralf König[1], Thomas Sunn Pedersen[1], and Glen Wurden[2] — [1]Max-Planck Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald — [2]Los Alamos National Laboratory, Los Alamos, USA

Wendelstein 7-X (W7-X), an advanced stellarator with five-fold symmetry, started its initial plasma operation phase(OP1.1) in December 2015. In OP1.1 the plasma-wall interaction was realized with 5 graphite limiters installed on the inboard side of the plasma vessel. 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 surface temperature on the limiters was investigated with two IR cameras: a microbolometric camera (8-14 μm, spatial resolution 5 mm) observes the left side of the limiter in modulel 5 from the top and a high resolution IR camera (3-5 μm, spatial resolution 1 mm) observes three tiles above the midplane of limiter 3. The heat flux density is evaluated with the THEODOR code from evolution of the surface temperature data. Both cameras observed heterogeneous structure of power loads. The flux tube with longest connection length (about 80 m) carries highest heat flux to the limiter. The calculated heat flux density for the longest connection length given by the THEODOR code is up to 5-6 MW/m 2 . From the perpendicular power flux the parallel power flux and the power decay length is calculated. This gives a power decay length up to 1-2 cm.

P 15.4 Di 16:30 HS Foyer

Experimental investigation of Ion Cyclotron waves interplay with magnetic perturbations and MHD phenomena. — •Guillermo Suarez Lopez[1,2], Roman Ochoukov[1], Matthias Willensdorfer[1], Roberto Bilato[1], Hartmut Zohm[1,2], ICRF Team[1], and ASDEX-U Team[1] — [1]Max Planck Institute for Plasma physics, Garching b. Munchen, Germany — [2]Ludwig Maximillians University, Munich, Germany.

The excitation of compressional plasma waves at the ion cyclotron frequency is an effective technique for heating plasmas up to fusion temperatures. The main drawback of the technique comes from the necessity of placing embedded launchers (antennas) close to the plasma edge, due to the evanescent nature of these waves in low density plasmas, such as the ones present in the edge region of a tokamak device. The total distance along which the excited waves are evanescent up to the propagation layer, the R-cutoff, determines the amount of power lost in the decay and the coupling efficiency, that is, the fraction of non-reflected power coupled from the transmission line to the plasma. This distance can be indirectly modified in a non-axisymmetric fashion by the application of magnetic perturbation fields for other purposes, such as ELM mitigation, or plasma intrinsic phenomena such as MHD modes. Under these conditions, the antenna coupling efficiency can undergo significant variations. This study addresses experimentally the impact of non-axisymmetric plasma profiles on ion cyclotron heating coupling efficiency by means of antenna embedded reflectometry, ion-cyclotron probes, and plasma profile measuring diagnostics.

P 15.5 Di 16:30 HS Foyer

Comprehensive benchmark of the ONIX code for simulating negative ion extraction from an ITER relevant ion source. — •Ivar Mauricio Montellano[1], Serhiy Mochalskyy[1], Adrien Revel[2], Dirk Wünderlich[1], and Ursel Fantz[1] — [1]Max- Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]LPGP, Univ. Paris-Sud, 91400 Orsay, France

The ITER NBI system is based on powerful large-scale RF sources for negative hydrogen or deuterium ions. In order to improve the insight into the complex physics of the low pressure, low temperature plasma close to the extraction system of the ion source the application of self-consistent models is mandatory. The 3D PIC code ONIX is capable to simulate the volume close to one extraction aperture of the ITER prototype source. So far, ONIX has been applied in order to reproduce the generation and extraction of negative hydrogen and of co-extracted electrons. Of particular importance is the ratio of extracted ion current to co-extracted electron current which has to be kept below one in the experiment. However, some experimental results as the presence of a significant amount of surface produced negative ions in the plasma volume cannot be reproduced by the code. This discrepancy initiated a thorough benchmarking process. Addressed during the benchmarking are the boundary conditions in the beam direction and numerical aspects, such as the ratio of the Debye length to the grid cell size used by the code. Presented are benchmark results as well as a comparison between plasma properties calculated for the prototype source using the former and the improved version based on the benchmarking results.

P 15.6 Di 16:30 HS Foyer

Doppler Coherence Imaging of impurity ion flows in the ASDEX-Upgrade divertor and plasma flows in VINETA.II — •Dorothea Gradic[1], Oliver Ford[1], Tilmann Lunt[2], Robert Wolf[1], and ASDEX-Upgrade Team[2] — [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, measurement of ion dynamics is of great importance to study the plasma behavior in magnetic fields such as the exhaust particle flows in the divertor areas. The Doppler coherence imaging spectroscopy (CIS) is a relatively new technique for the observation of plasma bulk ion flows. It is a passive optical diagnostic which produces 2D images of line-integrated measurements of the ion flow or ion temperature.

The main physics objective of this study is the research of ion dynamics in the small, low-temperature linear plasma experiment VINETA.II and the medium-sized tokamak ASDEX- Upgrade. This work focuses on the general characteristics of impurity ion flows in the poloidal field divertor and on bulk plasma ion flow in VINETA.II. Doppler CIS measurements from both experiments will be presented. A comparison with flows simulated by the 3D edge modeling code EMC3-Eirene is included for the ASDEX-Upgrade divertor measurements.

P 15.7 Di 16:30 HS Foyer

Numerical studies of the scrape-off layer connection length in Wendelstein 7-X (W7-X) — •Priyanjana Sinha, Hauke Hölbe, and Thomas Sunn Pedersen — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald

The goal of the present study is based on the development of special magnetic configurations with extremely short and extremely long connection lengths. This will demonstrate the flexibility of the W7-X coil system and help to understand the impact of the connection length on the scrape-off-layer (SOL) physics.

The connection length is the distance along B in the SOL between two points of contact with the solid surface. In low-shear stellarators like W7-X we can get very long connection lengths, almost one order of magnitude longer than in a tokamak of a similar size.Thus, the cross-field transport, which helps spread out the heat load on the divertor target plates, plays a relatively large role in stellarators compared to tokamaks, and one may expect wider strike lines on the divertor of a stellarator.

We present here a numerical study of the achievable connection lengths for the 9 vacuum reference configurations of W7-X which were used previously for divertor optimization. We also present a configuration with extra high values of connection lengths for those field lines in the SOL that carry significant amounts of outflowing plasma to the divertor surface. For this study a field line tracer using the magnetic field obtained by solving the vacuum Biot-Savart equation is used and is combined with a 3D model of the PFC based on CAD data.

P 15.8 Di 16:30 HS Foyer

Development of Charge Exchange Recombination Spectroscopy in the Near Scrape-off Layer at ASDEX Upgrade — •Ulrike Plank[1,2], Thomas Pütterich[1,2], Marco Cavedon[1], Michael Griener[1], Eleonora Viezzer[3], Ulrich Stroth[1], and The ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]Faculty of Physics, Ludwig Maximilian University of Munich, Schellingstr. 4, 80799 Munich, Germany — [3]Dpt. of Atomic, Molecular and Nuclear Physics, University of Seville, Avda. Reina Mercedes, 41012 Seville, Spain

The radial electric field E_r at the plasma edge is known to influence the access and quality of the high confinement mode in magnetically confined fusion plasmas. Traditional charge exchange recombination spectroscopy (CXRS) on fully stripped ions (e.g. B^{5+}) measures E_r up to the last closed flux surface (LCFS). A new CXRS diagnostic is now developed at ASDEX Upgrade which determines E_r in the near scrape-off layer (SOL) by CX measurements on partially stripped species (e.g. B^{3+}) which exist in the radial vicinity of the LCFS. This system will complement measurements of probes in the SOL and of Doppler reflectometry across the edge region. The new CXRS diagnostic utilizes a piezo gas valve injecting deuterium into the edge plasma. This allows local measurements on thermal CX reactions and makes the diagnostic independent of the neutral beam injection. Details of the construction and the calibration methods as well as first measurements will be presented.

P 15.9 Di 16:30 HS Foyer

Development of a spectroscopic system to investigate fast-ion populations in the plasma periphery of ASDEX Upgrade — •Anton Jansen van Vuuren[1,2], Benedikt Geiger[1], Asger Jacobsen[1], and The ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Ludwig-Maximilianis-Universität München, Munich, Germany

Detailed knowledge of fast-ions in fusion plasmas is needed since these supra-thermal particles are responsible for plasma heating, current drive, and at the plasma edge for possible damages to plasma facing components. One tool to investigate fast-ion populations is the fast-ion D-alpha (FIDA) diagnostic. While this spectroscopic technique has been frequently used to investigate the core plasma specially at ASDEX Upgrade, it has not been regularly used to measure fast ions at the plasma edge. This region is of interest since the effects of magnetic error fields, the toroidal field ripple as well as MHD instabilities strongly influence the fast ion confinement at the edge. A newly designed and built spectrometer installed to observe edge intersecting lines of sight during the 2017 campaign at ASDEX Upgrade will be presented along with an assessment of the initial results. The assessment will include a comparison between measured spectra and FIDASIM modeled spectra.

P 15.10 Di 16:30 HS Foyer

Semi-Lagrangian drift-kinetic simulations: field-aligned interpolation and splitting in complex geometries — •Edoardo Zoni[1,2], Yaman Güçlü[1], Michel Mehrenberger[3], and Eric Sonnendrücker[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Germany — [2]Zentrum Mathematik, TU München, Germany — [3]Institut de Recherche Mathématique Avancée, Université de Strasbourg, France

Global turbulence simulations of magnetic fusion devices based on the solution of the gyrokinetic Vlasov-Maxwell equations are computationally very expensive because the thermal ion Larmor radius must be resolved.

The computational burden may be reduced by aligning one grid coordinate with the local magnetic field line, along which the gradients are known to be small. Unfortunately, this methodology poses restrictions on the poloidal mesh, and cannot easily handle complex magnetic field configurations found in diverted Tokamaks and Stellarators.

An alternative and more flexible approach was developed by Ottaviani and Hariri, where local field-aligned differentiation (or interpolation) was performed between adjacent poloidal planes.

Such a method was adapted to the semi-Lagrangian context and combined with dimensional splitting of the transport equation by Latu et al.. We now extend it to general curvilinear coordinates.

We describe here the mathematical formulation and the details of our field-aligned interpolation algorithm. Our code is verified with a linear dispersion analysis for the ITG instability in screw-pinch configuration.

P 15.11 Di 16:30 HS Foyer

Inference of plasma parameters from an X-ray imaging diagnostic using neural networks — •Andrea Pavone, Jakob Svensson, and Andreas Langenberg — Max-Planck-Institute for Plasma Physics, Wendelsteinstraße 1, 17491 Greifswald, Germany

The W7X X-ray Imaging Crystal Spectroscopy system collects X-rays emitted in the interaction between electrons and ion impurities in the plasma. The light is collected along several lines of sight in the beam shaped poloidal cross-section of the torus. A forward model for this diagnostic is implemented in the Minerva framework, a Bayesian modelling framework which in this case allows the inference of plasma profiles via a nonlinear tomographic inversion of the measured images. This approach makes use of algorithms such as Markov Chain Monte Carlo (MCMC) and Maximum a Posteriori (MAP), which require the forward model to be run several time before a solution is found. This makes the data analysis relatively slow. Neural networks are an emerging class of algorithms for adaptive basis function regression. The regression is done by fitting the network model to a training set of images and corresponding profiles. Once the network is trained, it can be used on real data to provide real time analysis of measurements. This approach is easily generalizable to any diagnostic implemented in the Minerva framework. The neural network architecture will be described, together with the choices related to the creation of the training set, and results from the application to measured data. Finally, a comparison with the standard Bayesian inference strategy implemented within the Minerva framework is provided.

P 15.12 Di 16:30 HS Foyer

Deuterium retention in tungsten damaged by MeV ions — •Barbara Wielunska[1,2], Matej Mayer[1], and Thomas Schwarz-Selinger[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr.2, 85748 Garching — [2]Physik Departement, E28, TUM, 85748 Garching

Tungsten is a promising candidate material for the wall of a future fusion reactor due to its low erosion yield and low hydrogen solubility. However, fusion neutron irradiation will cause defects in the material which can strongly increase hydrogen retention. Therefore it is important to study the mechanism of defect creation and hydrogen retention in tungsten. Neutron irradiation is often simulated by different ion species. It is not yet clear which ion species cause comparable damage cascades as neutrons. Therefore samples of hot rolled, polished tungsten were implanted with different ion species (p, D, He, Si, Fe, Cu, W) at energies between 0.3 and 20 MeV to damage levels of 0.04 and 0.5 dpa. To study the hydrogen retention in defects, the samples were exposed to a low temperature deuterium (D) plasma to decorate the defects. To obtain the D depth distribution nuclear reaction analysis using the reaction D(3He, p)α was performed. Trapped D was released by controlled heating of the sample and monitoring the amount of released D (thermal desorption spectroscopy). D release differs depending on the implanted ion species which might be a result of the different damage cascades. The results of these studies will be presented.

P 15.13 Di 16:30 HS Foyer

An aligned discontinuous Galerkin method for a non-coercive elliptic operator — •Benedict Dingfelder[1], Florian Hindenlang[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 straightforwardly discretized by finite elements (FE). In their simplest form, they collapse to a heterogeneous anisotropic diffusion equation with a semidefinite diffusion tensor. The form we consider is given by

$$-\nabla \cdot \left(bb^\top \cdot \nabla\phi \right) = \omega^2 \phi \qquad \text{in } \Omega \tag{1}$$

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 (DG) method with locally aligned cells and basis is presented which improves the numerical accuracy by roughly four digits in comparison to existing methods with the same computational complexity. The results can be used in more complex applications.

P 15.14 Di 16:30 HS Foyer

THEODOR in a Bayesian Framework: a probabilistic evaluation of heat flux density profiles — •Dirk Nille, Udo v. Toussaint, and Bernhard Sieglin — Max-Planck-Institute for Plasma Physics, Boltzmannstr. 2, D-85748 Garching, Germany

The ill-posed problem of estimating parameters from quantities which are subject to diffusion is of central importance for various transport models in physics. In fusion research a precise determination of the heat flux density onto the surface of a solid material is crucial, as plasma power exhaust is a major challenge in the development of a future fusion power plant.

This is done by solving the heat diffusion equation in the target material with the surface temperature as boundary condition, given by measurements. Infrared thermography provides spatially and temporally resolved data for this purpose. Solving the heat diffusion equation is tackled for decades by deterministic codes like THEODOR. Developed for the fast evaluation of data no statistical analysis was performed. Error bars are obtained from the standard deviation during quasi-static conditions.

Using adaptive kernel to model the heat flux density distribution onto the surface and taking into account the known distribution of the measured photon flux yields reconstructions of better quality and known uncertainty. Therefore the numerical method of THEODOR is used in a forward model.

P 15.15 Di 16:30 HS Foyer

Cross-polarization scattering of diffracting microwave beams in ITER — •Lorenzo Guidi[1,2], Omar Maj[1], Hannes Weber[1], Alf Köhn[1], Antti Snicker[1], and Emanuele Poli[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]Technische Universität München, Numerical Methods for Plasmaphysics (M16), Boltzmannstr. 3, 85748 Garching, Germany

Density fluctuations in the edge region may severely affect the quality of electron-cyclotron beams in ITER, with potentially detrimental effects on their intended applications, e.g., stabilization of MHD modes. Density fluctuations may lead in particular to: i) a broadening of the beam, with consequent loss of precision on the deposition region; ii) an energy transfer from, e.g., the injected O-mode to the X-mode, with a consequent loss of power and a possible contribution to stray radiation.

The code WKBeam describes electron-cyclotron beams in a tokamak plasma, accounting for the beam broadening by density fluctuations i) and it has been extended to include cross-polarization scattering ii). It relies on a solid mathematical model - the wave kinetic equation - derived with techniques from semiclassical analyis. The solution is obtained through a rigorously derived Monte-Carlo numerical scheme. We present some benchmark results with the full-wave code IPF-FDMC, together with preliminary results for ITER. In fact, while for existing tokamaks cross-polarization scattering is actually negligible, for some ITER scenarios this effect might be of a certain relevance. In particular, we observe a high sensitivity of our results to the model used for the fluctuations in the scrape-off-layer.

P 15.16 Di 16:30 HS Foyer

Quantitative study of kinetic ballooning mode theory in simple geometry — •Ksenia Aleynikova, Alessandro Zocco, and Per Helander — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

At high beta plasmas are expected to have electromagnetic microturbulence due to the kinetic ballooning mode (KBM) instability, which can generate anomalous losses of heat and particles. The stability of such plasmas has first been successfully studied within the ideal magnetohydrodynamic (MHD) model with use of the ballooning transformation [1].

In this work we study and extend the theory of kinetic ballooning modes proposed by Antonsen and Lane [2], and Tang, Connor and Hastie [3].

For large gradients and large inverse aspect ratio, a variational formulation of the eigenvalue problem for KBMs based on diamagnetically modified MHD, derived from Refs. [2-3], provides sufficient quantitative agreement with GK simulations performed with both GS2 and GENE codes. For small pressure gradients, a new finite beta formulation of the "intermediate frequency theory" of Ref. [3] is proposed. Such new theory also provides good quantitative agreement with numerical simulations.

[1] Connor J. W., Hastie R. J. and Taylor J. B. Phys. Rev. Lett. 40 (1978) [2] Thomas M., Antonsen Jr. and Lane B. Phys. Fluids 23, 1205 (1980) [3] W. M. Tang , J. W. Connor, and R. J. Hastie, Nucl. Fusion 20, 1439 (1980)

P 15.17 Di 16:30 HS Foyer

Real Time Defects Detection System for the Protection of Plasma Facing Components(PFCs) in Wendelstein 7-X — •Adnan Ali[1,3], Marcin Jakubowski[1], Henri Greuner[2], Rudolf Neu[2,3], Thomas Sunn Pedersen[1], and W7-X Team[1] — [1]Max Planck Institute for Plasma Physics,Wendelsteinstrasse 1, 17491 Greifswald — [2]Max Planck Institute for Plasma Physics,Boltzmannstrasse 2, 85748 Garching — [3]TUM, Department of Mechanical Engineering, Boltzmannstrasse 15, 85748 Garching

One of the 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/m2. In order to protect the divertor elements from overheating and to monitor power depositions,infrared endoscopes will be installed and real-time system is designed for online analysis. Important prerequisite for safe operation of a steady-state device is automatic detection of the hot spots and other abnormal events. The earlier algorithm designed for early detection of defects e.g. hotspots, surface layers and delaminations during the discharge is improved to be compatible with the real time system acquiring the images. It enables automatic detection of the critical events and broadcast them to the main Discharge Control System. This allows dynamic control of the scenario of the discharge in order to assure safe operation of W7-X. The initial tests of the overall system was conducted in GLADIS.

P 15.18 Di 16:30 HS Foyer

Radial basis functions for the Vlasov equation — •Anna Yurova[1,2], Katharina Kormann[1,2], and Caroline Lasser[2] — [1]Max-Planck-Institut für Plasmaphysik — [2]Technische Universität München

Solving the full kinetic equations can help in understanding possible shortcomings of gyrokinetics. We consider a reformulation of the classical semi-Lagrangian method using a representation of the distribution function in a radial basis.

Using Radial Basis Functions (RBF) discretization for the Vlasov equation allows for more flexibility in the choice of the computational domain and can have spectral accuracy. We choose Gaussians which allow for exact integration and resemble the structure of the solution in velocity space. Therefore, it is possible to simulate an unbounded domain in velocity instead of cutting it as it is currently done in existing mesh-based methods.

We investigate the inherent ill-conditionioning of the linear system arising from the RBF-discretization. This ill-conditioning is linked to the width of the Gaussian function. We study different choices of the width of our radial basis in order to establish the optimal setup for our problem.

P 15.19 Di 16:30 HS Foyer

Determining fundamental transport parameters of hydrogen isotopes in tungsten — •Georg Holzner[1,2], Thomas Schwarz-Selinger[1], and Udo von Toussaint[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 — [2]Fakultät für Maschinenwesen der Technischen Universität München, Boltzmannstr. 15, 85748

Future fusion devices will use the hydrogen isotopes deuterium and tritium as fuel. The first-wall material probably will be tungsten for which retention and transport of hydrogen isotopes needs to be predicted. The key quantity for transport is the diffusion coefficient. The generally accepted value for diffusion of protium in tungsten stems from Frauenfelder derived in the late 60s. Experimental values determined since scatter by several orders of magnitude, trapping effects are presumably the reason. However, recent simulations even question the Frauenfelder value. Furthermore that experimental value was not derived for deuterium. The objective is to measure the solubility of protium and deuterium in tungsten at temperatures between 1400 and 3000K. At these temperatures trapping effects are vanishing and pure diffusion is the governing transport effect. From solubility the diffusion coefficient can be derived. Hence, an Ultra High Vacuum (UHV) experiment needs to be planned and established. An induction furnace in combination with a water cooled quartz glass container is used for conditioning by gas loading at pressures of up to one atmosphere. Following the spectra of the gas species in solution is measured by Thermal Desorption Spectroscopy (TDS).

P 15.20 Di 16:30 HS Foyer

High Current Ion Source for in-situ Sputter Yield Measurements — •Rodrigo Arredondo Parra[1,2], Martin Oberkofler[1], and Klaus Schmid[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, D-85748, Garching, Germany — [2]Technische Universität München, Boltzmannstr. 2, D-85748, Garching, Germany

HSQ-II (HochStromQuelle II) is a high current DuoPIGatron type ion source. It is an upgraded version of the decommissioned HSQ-I and mainly used for the measurement of sputter yields and retention with focus on wall materials for fusion devices. The ion beam is accelerated by voltages between 2 kV and 10 kV and mass-filtered in a magnetic sector field. A monoenergetic beam of a single species (e.g. D_3^+) is used for irradiation of samples in the separate implantation chamber at a base pressure of 10^{-8} mbar. The ion beam profile has been characterized after the dipole magnet and dedicated ion optics simulations to maximize the flux to the target are underway. Optimizing gas inflow and beam focusing grid voltage, for the measured beam footprint of approximately 0.5 cm^2, ion flux densities of up to $4 * 10^{15}$ ions/cm^2/s have been achieved. By applying suitable decelerating potentials at the target, final energies of the impinging particles between 200 eV/D and several keV/D can be achieved. The sample can be rotated for irradiation at oblique angles and heated for sample exposure at elevated temperatures. The sample weight can be assessed in situ by means of a magnetic suspension balance, allowing for in-situ sputter yield measurements. The first application of the machine will be the study of sputter yield on rough surfaces.

P 15.21 Di 16:30 HS Foyer

Investigation of deuterium interaction with lattice defects in tungsten — •Mikhail Zibrov[1], Matej Mayer[1], Armin Manhard[1], and Dmitry Terentyev[2] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]SCK CEN, Mol, Belgium

Although the database on hydrogen (H) isotopes behaviour in tungsten (W) is rather wide, some of the fundamental aspects of the hydrogen-defect interaction are not well understood yet. The aim of this study is to investigate the H interaction with various lattice defects in W by using specially prepared samples having one dominant and well-known defect type.

In order to create mainly vacancies, single crystalline W samples were damaged by 200 keV protons to low damage levels. Then the samples were annealed at temperatures in the range of 500-1300 K to study the stages of vacancy clustering. In order to introduce mainly dislocations, recrystallized W samples were subjected to tensile plastic deformations at elevated temperatures to different levels. All the samples were then exposed to a low-flux low-energy D plasma in order to decorate the defects with deuterium (D) without producing additional damage. The D inventory in the samples was then characterized by nuclear reaction analysis (NRA) and thermal desorption spectroscopy (TDS). It was observed that single vacancies contribute to a peak near 600 K in the TDS spectra. Annealing at temperatures above 700 K led to agglomeration of vacancies in vacancy clusters, which was manifested by a disappearance of the peak near 600 K and appearance of a new peak near 750 K.

P 15.22 Di 16:30 HS Foyer

Investigation of mode coupling during the ELM cycle on ASDEX Upgrade by magnetic bicoherence spectra — •Georg Harrer[1], Elisabeth Wolfrum[2], Peter Manz[2], Felician Mink[2], Friedrich Aumayr[1], and The ASDEX Upgrade Team[2] — [1]Institut für Angewandte Physik, TU Wien, Wiedner Hauptstr. 8-10/134, 1040 Vienna, Austria — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

Edge localized modes (ELMs) occur as repetitive bursts of magneto-hydrodynamic activity in high-confinement regimes of tokamak fusion plasmas. ELMs lead to a sudden release of pedestal stored energy and cause high heat fluxes to the first walls. Also, during the inter-ELM phase, mode-like activities can be observed and they can cause additional transport across the separatrix. Simulations suggest that non-linear couplings of these modes might play an important role for the ELM onset. Bicoherence analysis delivers a method to diagnose and display these couplings. In this work an algorithm combining bicoherence and ELM-synchronization has been developed. The algorithm was tested with a non-linear coupling model and improved by dithering and windowing functions. Different phases of the ELM cycle were examined. In most of these phases no coupling was found. Just before some ELMs three wave coupling was found which seems to be connected to the appearance of double peak ELMs.

P 15.23 Di 16:30 HS Foyer

First steps in analyzing the role of the outer divertor in the L-H transition power threshold in ASDEX Upgrade — •Ou Pan, Tilmann Lunt, Daniel Carralero, Andrea Scarabosio, Marco Wischmeier, Ulrich Stroth, and ASDEX Upgrade Team — Max-Planck-Institute for Plasmaphysics, Boltzmannstr. 2, 85748 Garching, Germany

The transition from L-mode to H-mode occurs generally above a certain heating power threshold ($P_{L\text{-}H}$). The widely used ITPA scaling for $P_{L\text{-}H}$ in deuterium plasmas depends on the line-averaged density, magnetic field and the surface area of the separatrix. However, in ASDEX Upgrade, $P_{L\text{-}H}$ shows a significant dependence on the material of the plasma facing components (PFCs). The threshold in full tungsten (W) wall discharges is lower by 25%-30% compared to that with a graphite (C) wall. In this work, the role of the outer divertor for the reduction of $P_{L\text{-}H}$ was investigated by comparing the electron temperature (T_e) and density (n_e) measured by the divertor Langmuir probes near the outer strike point (OSP) as well as the neutral flux density measured by the ionization pressure gauges in the private flux region. It is found that in the case of a W wall T_e and n_e near the OSP rise substantially before the L-H transition and show a more peaked profile along the target. Since the radial electric field (E_r) in the scrape-off layer is related to the gradient of the target temperature, the pronounced peaking of the T_e profile at the outer target likely leads to a stronger E_r in the SOL. The E×B flows induced by these fields may be important for the access to H-mode.

P 15.24 Di 16:30 HS Foyer

Tools for designing the next generation of Stellarators. — •Jim-Felix Lobsien — Max-Planck Institute for Plasma Physics, Greifswald, Mecklenburg-Vorpommern

Stellarators possess a complex magnetic coil system. At the border between mathematics and its realization, one faces the problem of deviations. It is impossible to build a complex system as one computed it. Furthermore, the exceptional shape makes it difficult to manufacture the coils, the heavy weight complicates the assembly and the usage leads to additional deviations. The question arises, how does the quality of the vacuum magnetic field changes under small deviations of the coil system. Until now, stellarator optimization tries to find the best possible configuration and neglects this information. In this work, we concentrate on the modification of the stellarator optimization routine. In each optimization step, we include the information about the change of the quality of the magnetic field under deviation in the valuation of the coil system. So far stellarator optimization tries to find a peak optimum whereas our newly developed tools seeks for a flat, more realistic optimum. Our goal is to generate a coil system which under small deviation produces an equally good magnetic field. This quality is called robustness.

P 15.25 Di 16:30 HS Foyer

Progression of the tungsten-fibre reinforced tungsten composite production process towards a reproducible dense matrix — •Hanns Gietl[1,2], Johann Riesch[1], Jan W. Coenen[3], Leonard Raumann[3], Philipp Huber[4], Till Höschen[1], and Rudolf Neu[1,2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching — [2]Technische Universität München, 85748 Garching — [3]Forschungszentrum Jülich, IEK4, 52425 Jülich — [4]Lehrstuhl für Textilmaschinenbau und Institut für Textiltechnik, 52062 Aachen

For the use in a fusion device tungsten has unique properties such as low sputter yield, high melting point and low activation. The brittleness below the ductile-to-brittle transition temperature and the embrittlement during operation are the main drawbacks for the use of pure tungsten. Tungsten fibre-reinforced tungsten composites overcome this problem by utilizing extrinsic mechanisms to improve the. The next step is the conceptual proof for the applicability in fusion reactors by the production of larger components and for testing them in cyclic high heat flux. A dense matrix is one of the major issues for the production of such mock ups.

In this study the possibilities of forming a dense tungsten matrix in between the reinforcing wires by geometry optimization are investigated. Weaving processes were implemented in the fibre-preform production and different fabrics were produced. These fabrics were then incorporated into a tungsten matrix via a chemical vapor deposition (CVD) process. The resulting composites were examined by microstructural analysis.

P 15.26 Di 16:30 HS Foyer

Mirror Langmuir Probes for Turbulence Measurements in the Wendelstein 7-X Divertor — •Lukas Rudischhauser — IPP Greifswald, Germany

Transport in Wendelstein 7-X will be dominantly driven by turbulence, especially in the edge region. To measure fast plasma fluctuations with high temporal and spatial resolution, graphite probes embedded into the divertor will be used. We will simultaneously measure plasma density, temperature and potential during turbulent fluctuations which will provide insights into their effect on the divertor power density distribution. The novel Mirror Langmuir probe electronic conceived at MIT is ideally suited for the task of driving these probes and evaluating their characteristics and will be employed in a trial during the next operation phase of W7-X. The concept uses a matched dummy probe in conjunction with a Wheatstone bridge to negate transmission line effects and an analogue computer to predict optimal drive parameters. Here we present the design as well as test results and fluctuation measurements from the first operation phase of W7-X.

P 16: Plasma Diagnostics III

Zeit: Mittwoch 8:30–10:10 Raum: HS 1010

Hauptvortrag P 16.1 Mi 8:30 HS 1010

Influence of released surface electrons on the pre-ionization of helium barrier discharges — •Robert Tschiersch, Sebastian Nemschokmichal, and Jürgen Meichsner — Institute of Physics, University of Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald

The understanding of the interaction between the plasma species and a dielectric surface is still a fundamental issue in the physics of barrier discharges (BDs). The presented contribution highlights the role of residual surface electrons with low binding energy in acting as a seed-electron reservoir that favors the pre-ionization of diffuse BDs. Here, a glow-like BD was operated in helium at a pressure of 500 mbar in between two plane electrodes each covered with float glass at a distance of 3 mm. The change in the discharge development due to photodesorption of surface electrons by a Nd-YAG laser was studied by electrical measurements and optical emission spectroscopy. Moreover, adapting a 1D numerical fluid simulation of the discharge to the laser-photodesorption effect from the experiment allowed the understanding of the impact of released surface electrons on the reaction kinetics in the volume. When the laser beam hits the cathodic dielectric charged with residual electrons during the discharge pre-phase, the breakdown voltage decreases significantly. According to the adapted simulation, the laser releases only a small amount of surface electrons in the order of 10 pC which, nevertheless, supports significantly the pre-ionization. Moreover, both experiment and simulation emphasize that a further enhancement of the yield of released surface electrons triggers the transition from the glow mode to the Townsend mode.

Fachvortrag P 16.2 Mi 9:00 HS 1010

Electron and heavy particle density measurements of a stable axially blown arc in argon — •Jan Carstensen, Patrick Stoller, Bernardo Galletti, Charles Doiron, and Alexey Sokolov — ABB Corporate Research, Segelhofstr. 1K, 5405 Baden-Daettwil, Switzerland

Two color spatial carrier wave interferometry was used to measure the electron density and heavy particle density in the stagnation point of a stable, axially blown arc in argon for currents of 50 A to 200 A and stagnation point pressures of 0.2 to 1.6 MPa. The high spatial resolution achieved allows the hot core of the arc to be readily distinguished from the surrounding boundary layer. The arc radius determined from the heavy particle density decreases with increasing stagnation pressure and increases with the current in good agreement with a simple theoretical model based on the work of [Lowke and Ludwig, J. Appl. Phys., 1975. 46(8)] for arc core temperatures of approximately 16,500 K. The measured electron density at the center of the arc agrees well with a prediction based on local thermodynamic equilibrium.

P 16.3 Mi 9:25 HS 1010

Measurements on a high voltage pulsed substrate (PBII) in a HiPIMS process — •Sven Gauter[1], Maik Fröhlich[2], Wagdi Garkas[2], Martin Polak[2], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics, CAU Kiel, Germany — [2]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany

In a novel experiment a HiPIMS discharge was combined with plasma based ion implantation (PBII). Proper synchronization of the HiPIMS and PBII pulses allows successive and simultaneous coating and doping of the substrate surface in a complex, finely adjustable system. The delay between the HiPIMS and the PBII pulse is a critical parameter for the synchronization of the pulses. To investigate the effect of this parameter on the energy flux towards the PBII substrate, VI-probe and calorimetric measurements were performed.

The energy flux was measured utilizing a specially designed setup for indirect calorimetric measurement of the high voltage pulsed substrate. The results reveal the effect of the delay on the energy flux and ion current to the substrate for different PBII pulse durations and PBII voltages. A maximum of electrical power and energy flux was found for delay values significantly longer than the duration of the HiPIMS pulse. This maximum is explained to be caused by an ion wave/bunch which originates at the target and travels towards the substrate with the energy obtained from the sputter process. The investigation of different PBII and HiPIMS parameters revealed additional information about the transport of the ions from the target to the substrate.

P 16.4 Mi 9:40 HS 1010

Spectroscopic studies of active screen plasma nitrocarburizing processes comparing a steel and a carbon mesh as an active screen — •Constantin Rupp[1], Stephan Hamann[1], Andy Nave[1], Igor Burlacov[2], Heinz-Joachim Spies[2], Horst Biermann[2], and Jürgen Röpcke[1] — [1]INP Greifswald, 17489 Greifswald, Germany — [2]TU Bergakadamie Freiberg, 09599 Freiberg, Germany

The active screen plasma nitriding (ASPN) is an advanced technology for the hardening of steel components. Additionally, carbon-containing gases such as CH4 and CO2 can be admixed to the N2-H2 gas achieving an active screen plasma nitrocarburizing (ASPNC) process. However, the amount of adding carbon-containing gases to the process is limited. As a new appraoch an active screen made of graphite is used as a carbon source.

This contribution presents the results of a spectroscopic study of N2-H2 containing pulsed DC plasmas in an industrial scale ASPN reactor using two different active screens (steel and graphite meshes) with an inner volume of about 1 m^3. Based on optical emission spectroscopy (OES) the emission trends of H, N and N2 were qualitatively monitored. The concentration of CH4, NH3, C2H4, HCN and CO has been determined by the usage of infra-red laser absorption spectroscopy (IR-LAS). The concentrations of the monitored species were found to be in the range of 10^{13} to 10^{15} molecules cm^{-3}, whereby the concentrations of measured hydrocarbon components were found to increase significantly using a graphite mesh.

P 16.5 Mi 9:55 HS 1010

Broadening and shift of optical emission lines in a high power impulse magnetron sputtering discharge — •Julian Held, Ante Hecimovic, and Volker Schulz-von der Gathen — Ruhr-Universität Bochum, Germany

Mass spectrometers and Langmuir probes are often used to measure the energy distribution functions and densities of charged species in high power impulse magnetron sputtering (HiPIMS) discharges. However, it is not possible to use these tools in the region close to the target, where the magnetic field lines are closed, without critically disturbing the plasma. In this work, time resolved optical emission spectroscopy was employed to gain greater insight into the region close to the target, where the most important plasma processes take place. A high resolution plane grating spectrograph combined with a fast, gated, intensified CCD camera was used to analyze the discharge. Chromium or Titanium was used as the target material and the discharge was operated in pure Argon. Broadening and shift of optical emission lines was studied to gain information about the velocity distribution of sputtered species.

Supported by Deutsche Forschungsgemeinschaft (DFG) within the framework of the SFB-TR 87.

P 17: Dusty Plasmas II

Zeit: Mittwoch 8:30–10:25 Raum: HS 2010

Hauptvortrag P 17.1 Mi 8:30 HS 2010

PK-4 - Complex Plasmas under Microgravity — •Markus Thoma — I. Physikalisches Institut, Universität Giessen

Complex plasmas are created in low-temperature and low-pressure discharges by injecting micron size particles into the plasma. By electron collection the micro-particles get highly charged, building a strongly coupled component of the plasma. Complex plasmas can be used as a model for the dynamics (e.g. phase transitions, non-equlibrium physics) of strongly interacting many-body systems.

Experiments with complex plasmas in the laboratory are often strongly disturbed by gravity, restricting the micro-particle clouds to the plasma sheath. Therefore experiments in microgravity conditions are performed in parabolic flights and on board the ISS since almost 20 years. The experiment facility PK-4 (”Plasmakristallexperiment 4”) was launched to the ISS in 2014 and used in ten parabolic flight campaigns since 2003.

After an introduction to complex plasmas the PK-4 experiment and its first results from ISS and latest parabolic flights will be discussed.

Fachvortrag P 17.2 Mi 9:00 HS 2010

Multiple Camera Diagnostics of 3D Particle Motion in Dusty Plasmas — •Michael Himpel and André Melzer — Institute of Physics, University Greifswald

Stereoscopic camera systems are a standard diagnostic tool in dusty plasmas since many years. There, a small volume of a particle-containing plasma is observed with two or more cameras under different angles. The evolving imaging hardware makes it possible to achieve continuously higher framerates and higher spatial resolutions. This leads to the possibility to observe and track dust clouds with higher particle number densities. Such stereoscopic systems have been used in laboratory experiments and on parabolic flights to study waves and vortices. In a future plasma experiment (*EKoPlasma*) onboard the ISS, a four-camera system is planned to be implemented. This would be one of the first three-dimensional dusty plasma diagnostics to be used under space conditions.

This contribution gives an insight into the capabilities of such multi-camera systems and a brief presentation of all neccessary steps ranging from calibration to triangulation. Preliminary measurements of clusters with more than 1000 particles are shown demonstrating that single-particle reconstruction in volume-filling dust-clouds is possible.

P 17.3 Mi 9:25 HS 2010

Plasma Parameter Control for Complex Plasma Experiments — •Christina A. Knapek, Peter Huber, Daniel P. Mohr, Erich Zähringer, and Hubertus M. Thomas — DLR German Aerospace Center, Research Group Complex Plasmas, Wessling, Germany

Complex plasmas are generated by injecting micrometer-sized grains into a low temperature noble gas discharge. The particles acquire high negative charges of up to several thousand elementary charges, interact with each other via a screened Coulomb potential, and can form gaseous, liquid or solid states. Since the particles are individually visible, complex plasmas provide an experimental approach for fundamental studies of strong coupling phenomena with fully resolved dynamics at the individual particle level. Electron temperature and plasma density play an important role for the charging and interaction potential of the particles. The Zyflex plasma chamber, which has been developed within the PlasmaLab/EkoPlasma project as the future laboratory for complex plasma research in microgravity on the International Space Station (ISS), offers several possibilities for manipulation of plasma parameters, either by variable rf operation modes, or by using special grid electrodes for electron temperature control. In the latter case, the region of plasma production is separated from the working volume containing the particles, and the electron temperature can be controlled by the grid parameters. Results of first experiments – performed during parabolic flights and in the laboratory – with complex plasmas in such a “controllable” plasma environment are presented.

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

P 17.4 Mi 9:40 HS 2010

In situ analysis of optically thick nanoparticle clouds — •Florian Kirchschlager[1], Sebastian Groth[2], Sebastian Wolf[1], and Franko Greiner[2] — [1]Institute of Theoretical Physics and Astrophysics, Kiel, Germany — [2]Institute of Experimental and Applied Physics, Kiel, Germany

In an argon-acetylene plasma nano-particles are grown. Kinetic single-wavelength Mie ellipsometry allows one to constrain the size of these particles.

We find deviations between experimental measurements and numerical simulations based on single Mie-scattering. These deviations were previously assumed to result from multiple scattering in the plasma clouds.

We present 3D Monte-Carlo polarized radiative transfer simulations which allow us to calculate normalized Stokes vectors for dusty systems with arbitrary optical depth. With this approach it was possible for the first time to reproduce the experimental data. This technique has the potential to extend the existing diagnostic method for the in-situ analysis of the properties of nano-particles to systems where multiple scattering can not be neglected anymore.

P 17.5 Mi 9:55 HS 2010

Investigations of size dynamics of nanodust clouds by means of imaging Mie diagnostics — •Sebastian Groth, Franko Greiner, Benjamin Tadsen, and Alexander Piel — Institute of Experimental and Applied Physics, Kiel University, Germany

The long term behavior of plasma-grown nanodust clouds in an argon plasma shows various interesting phenomena once the initial growth process is stopped and the particles remain confined within the plasma discharge.

The investigation of such nanodust clouds with kinetic single-wavelength ellipsometry and extinction measurements at a fixed position show the loss of particles caused by an imperfect confinement and a decrease of the particle size via etching. In addition, a strong variation of the line-integrated dust density is observed. These measurements indicate a dynamic size sorting process due to spatially inhomogeneous etching. Here, this cannot be fully understood using diagnostics at a fixed position. To gain more detailed insight into the dynamics of the entire nanodust clouds a new diagnostic setup with a 2D-imaging rotating-compensator ellipsometer (I-RCE) using a CCD camera has been developed. In this way the spatially resolved in situ determination of all dust properties is possible.

This work was funded by the SFB-TR24 Greifswald-Kiel, Project A2.

P 17.6 Mi 10:10 HS 2010

Characterization of Dusty Plasmas in a Magnetic Field — •Benjamin Tadsen, Franko Greiner, and Alexander Piel — Institute of Experimental and Applied Physics, Kiel University, Germany

If a dusty plasma is exposed to a magnetic field, it's topological structure changes. As the electrons get magnetized, the plasma is confined with a cylindrical shape [1] due to the low cross-field mobility of the electrons. In such a situation a variety of instabilities like dust-density waves (DDWs) and plasma filamentation can be observed. In this contribution, an experimental setup is presented that is used to characterize the dust cloud of submicron particles in an rf plasma. The particle size is determined using Mie-scattering of polarized light and the dust particle density is calculated from extinction images of the dust cloud with an Abel inversion algorithm. The DDWs are observed at a frame rate well above the dust plasma frequency. Information about ion density and dust charge can be extracted from the data [2]. Using these diagnostics, the transition from an unmagnetized to a magnetized plasma will be examined.

Supported by DFG via SFB-TR24, project A2.

[1] B. Tadsen et al., Phys. Plasmas **21**, 103704 (2014)
[2] B. Tadsen et al., Phys. Plasmas **22**, 113701 (2015)

P 18: Theory and Modeling II

Zeit: Mittwoch 14:30–15:45 Raum: HS 2010

Hauptvortrag P 18.1 Mi 14:30 HS 2010

The structure and its role in uncovering the physics of warm dense matter — •Jan Vorberger — Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Warm dense matter states in the transition region from high pressure solids to high temperature plasmas are found in terrestrial planets, giant planets, and exoplanets. Such states are created in the laboratory during interaction of lasers or shock waves with matter. The intention is usually to obtain direct experimental access to equilibrium or non-equilibrium warm dense matter states or it might be an intermediate state on the way to fusion plasmas states or laser-plasma acceleration experiments.

Studying warm dense matter, one faces several challenges. The first is the determination of a full set of basic parameter like density, charge state, temperature, or the momentum distribution function that fixes the state of matter in the phase space. Only then is it meaningful to investigate important quantities like the equation of state, phase transitions, structure, collective excitations, relaxation processes, or the stopping power.

Here, we present recent developments and results in warm dense matter physics. The close interplay between theory and experiment via x-ray scattering and first principle simulations is highlighted. The dynamic structure factor containing a wealth of information serves as the connection between measurements and calculations. Results are given for a number of elements like aluminium, carbon, or iron, and materials like plastic.

P 18.2 Mi 15:00 HS 2010

An iterative model to study the coupling between the plasma and a floating surface — •Jan Kaiser, Sebastian Wilczek, and Ralf Peter Brinkmann — Ruhr-Univesität Bochum, Lehrstuhl für Theoretische Elektrotechnik, 44780 Bochum

Measuring plasma parameters (e.g. plasma density, electron temperature) has practical importance to control the plasma process. Common tools to determine these parameters are probes, such as the multipole resonance probe (MRP) or different types of Langmuir probes (LP). All kinds of active probes represent a floating surface which leads to the generation of a plasma sheath and, therefore, to a disturbance of the plasma dynamics in the region around the probe. In this work an iterative model to determine the coupling between the MRP and the plasma is presented. The MRP is modeled as a curved boundary with a fixed potential. The electron and ion physics are treated in two coupled models which are iterated until convergence is achieved. Results for the potential, the electron and ion densities in the region of the MRP are presented.

P 18.3 Mi 15:15 HS 2010

Scaling laws for a High Efficiency Multistage Plasma Thruster — •Tim Brandt[1,3,4], Ralf Schneider[2], Julia Duras[2,6], Daniel Kahnfeld[2], Franz Georg Hey[5], Frank Jansen[1], Thomas Trottenberg[4], Holger Kersten[4], Johann Ulrich[5], and Claus Braxmaier[1,3] — [1]DLR, Institute of Space Systems, Bremen, Germany — [2]Institute of Physics, Ernst-Moritz-Arndt University Greifswald, Germany — [3]Center of Applied Space Technology and Micrograviy, University of Bremen, Germany — [4]Institute of Experimental and Applied Physics, University of Kiel, Germany — [5]Airbus Defence and Space, Claude-Dornierstraße 1, Immenstaad, Germany — [6]Department of Applied Mathematics, Physics and Humanities, Nuremberg Institute of Technology, Germany

Upcoming formation flying space missions have unprecedented requirements in both low thrust and low noise-to-thrust ratio for attitude control. With the recent discovery of gravitational waves, LISA (Laser Interferometer Space Antenna) is an outstanding example for such a mission. Its requirements are thrust no more than 100 μN and root of the noise spectral density $\leq 0.1\ \mu\mathrm{N}/\sqrt{\mathrm{Hz}}$. One attempt to reach this regime is to develop a downscaled version of the High Efficiency Multistage Plasma Thruster (HEMPT). One part of this activity is to support the development by computer modeling. In order to simulate the thruster plasma, the Particle-in-Cell (PiC) method is used. We will present analytical considerations and models using the PiC method for a downscaled and an unscaled HEMPT which has been performed in order to investigate the scaling laws of this kind of plasma thruster.

P 18.4 Mi 15:30 HS 2010

3d Energy-Conserving Implicit Particle-in-Cell (PIC) Code for Simulations of Magnetized Plasmas — •Denis Eremin — Institute for Theoretical Engineering, Ruhr University Bochum, Univeristätsstrasse 150, 44801, Bochum, Germany

One of the most heavily used tools for the thin film deposition applications in plasma processing industry is magnetron discharge, operated in a broad range of different regimes, from the dc to the HiPIMS. Despite low pressure of the neutral gas characteristic of the sputtering regime in such devices, they have enhanced electron confinement and power deposition due to the magnetic field. Owing to the non-uniformities of the latter, the plasma density profile is also strongly non-uniform, exhibting very large gradient close to the cathode and relatively small gradient in the bulk plasma. Whereas the low pressure regime demands a kinetic modeling approach, standard PIC schemes often fail to adequately simulate such magnetized plasmas within reasonable computational time due to the numerical limitations on applicability of such schemes. This work proposes a novel energy-conserving implicit PIC approach with a non-uniform computational grid resolving the cathode sheath region. The new approach has fewer limitations and its ability to simulate early stages of HiPIMS discharges is demonstrated. The corresponding code is in part massively parallelized on GPU.

Financial support the German Research Foundation in the framework of the SFB-TR 87 project is greatly acknowledged.

P 19: Plasma Diagnostics IV

Zeit: Mittwoch 15:00–16:00 Raum: HS 1010

P 19.1 Mi 15:00 HS 1010

Investigation of the self-modulation seeding by a short electron bunch within a long proton bunch — •Mathias Julius Hüther — Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Deutschland — Technische Universität München, Deutschland

The AWAKE (Advanced Wakefield Experiment) at CERN is world's first proton-driven plasma wakefield accelerator aiming for acceleration of externally injected electrons in gradients up to the GeV/m scale.
The 12 cm long proton bunch from CERN's Super Proton Synchotron (SPS) propagates through a 10–m long laser induced plasma channel and is split into a train of micro-bunches on the order of the plasma wavelength by its electromagnetic interaction with the plasma.
This modulation is caused by the self-modulation instability (SMI), a transverse plasma instability. According to simulations, this instability does not significantly grow over a meter scale and in the experimental plan is therefore seeded by having an ionizing laser beam co-propagating at the centre of the proton bunch.
In this talk, we present calculations and simulations for a different concept of seeding the SMI by electron injection. The timing between laser and protons is shifted, so that the whole proton bunch propagates through a preformed plasma. The proton beam current is modulated by the external injection of a short electron bunch in the centre of the proton beam. The resulting sharp rise of the total current drives large wakefields that seed the growth of the SMI.
This seeding technique will also be tested experimentally.

P 19.2 Mi 15:15 HS 1010

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

Dynamics of an electron in strong fields includes the precession of the spin as well as its orbital motion, which is determined by the Lorentz force, a spin-dependent Stern-Gerlach force and a radiation-reaction force. Classical investigations, however, often treat the electron as a spinless particle because of the lack of a definite classical unified description of the electron's orbital motion and its spin dynamics. Although many classical models have been proposed to include the spin, the validity of them was seldom investigated. We investigate the reliability of different classical spin models by numerical comparisons to the Dirac theory for specific strong-field setups and suggest a reliable model [1]. In strong fields where effects of the Stern-Gerlach force become relevant also radiation reactions are expected to set in [2]. Depending on the electron's energy and the field configuration either radiation reactions or spin effects may dominate. Spin contributions may be identified by considering electrons of opposite spin state and radiation reactions are verifiable by spin-averaged electron beams.

[1] M. Wen, H. Bauke, C. H. Keitel, "Identifying the Stern-Gerlach force of classical electron dynamics", *Sci. Rep.* **6**, 31624 (2016)

[2] M. Wen, C. H. Keitel, H. Bauke, "Spin one-half particles in strong electromagnetic fields: spin effects and radiation reaction", arXiv:1610.08951

P 19.3 Mi 15:30 HS 1010

Highly efficient source of Kα radiation driven by relativistic interaction of mid-infrared laser pulses with nanostructured solid targets — •Zhanna Samsonova[1,2], Sebastian Höfer[1], Ingo Uschmann[1,2], Vural Kaymak[3], Skirmantas Ališauskas[4], Audrius Pugžlys[4], Lukas Trefflich[5], Carsten Ronning[5], Alexander Pukhov[3], Andruis Baltuška[4], Eckhart Förster[1,2], Christian Spielmann[1,2], and Daniil Kartashov[2] — [1]Helmholtz Institute Jena, Jena, Germany — [2]Institute of Optics and Quantum Electronics, Abbe Center of Photonics, Friedrich-Schiller-University Jena, Jena Germany — [3]Institute for Theoretical Physics, Heinrich-Heine-University Düsseldorf, Düsseldorf, Germany — [4]Photonics Institute, Vienna University of Technology, Vienna, Austria — [5]Institute of Solid State Physics, Friedrich-Schiller-University Jena, Jena, Germany

We report on recent studies of a novel regime of relativistic laser-plasma interaction between solid nanostructures targets and ultra-intense mid-infrared pulses at 3.9 μm. We experimentally investigate the dependence of X-ray generation on the morphology of the targets and focusing conditions. A record high conversion efficiency of the essentially background free, cold Zn K-shell emission reaches a value of 3E-4 using only 20 mJ laser pulses. Numerical PIC-simulations predict solid density plasma with the electron temperature close to the estimations from the measurements. Our results suggest that relativistic interaction of long wavelength femtosecond laser pulses with nanostructured solids is a very promising way to realize highly efficient, femtosecond X-ray backlighter for high density plasma physics.

P 19.4 Mi 15:45 HS 1010

Development of an active bremsstrahlung detector for ultra-intense laser-plasma experiments — •Maria Molodtsova[1,2], Anna Ferrari[1], Alejandro Laso Garcia[1], Manfred Sobiella[1], Daniel Stach[1], David Weinberger[1,2], and Thomas Cowan[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]Technische Universität Dresden, Germany

Ultra-intense laser-matter interaction physics is of growing interest worldwide, because of its ability to create new extreme states of matter and to explore technologically interesting processes such as new concepts for particle acceleration, material science, and fusion energy. A critical component in laser-solid interaction is the acceleration of relativistic electrons and their transport in the material of the target, generating ultra-intense bremsstrahlung in a sub-ps time scale and with a high intensity ($\sim 10^{10}$ photons). Usual spectrometry techniques using pulse height analysis cannot therefore be used, and new active methods need to be developed. The concept of a novel detector is presented, based on a multi layered scintillator structure, which allows the characterization of the longitudinal development of the radiation. By measuring the deposited energy in each layer the photon spectrum can be reconstructed by using an unfolding technique. Via extensive FLUKA Monte Carlo simulations, the detector was optimized to resolve the photon spectrum in the dynamic range between 50 keV and 20 MeV, and the most promising model was chosen to realize the first prototype. In this talk the optimization process, together with the construction and the first tests, are presented.

P 20: Laser Plasmas

Zeit: Mittwoch 16:30–18:30 Raum: HS Foyer

P 20.1 Mi 16:30 HS Foyer

Laser-plasma interactions in ultra-intense fields of colliding laser pulses — •Christoph Baumann and Alexander Pukhov — Institut für Theoretische Physik I, Heinrich-Heine-Universität, 40225 Düsseldorf, Deutschland

The continuous development of laser technology will open the door of studying laser-plasma interactions in fields with intensities above 10^{23} Wcm^{-2}. In the so-called quantum-dominated regime, the plasma dynamics can change significantly due to the increasing influence of nonlinear Compton scattering and Breit-Wheeler pair production on the interaction process.

In the present work, we use PIC simulations to report about the interaction of a one micron thick plasma foil with two counter-propagating circularly-polarized laser pulses that have intensities up to the order of 10^{24} Wcm^{-2}. We analyze the influence of pair production on the interaction process. In a second simulation setup, we report about the generation of a train of attosecond electron bunches within the interaction of the plasma target with two Laguerre-Gaussian laser pulses of ultra-high intensity.

P 20.2 Mi 16:30 HS Foyer

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 ion acceleration in the laboratory.

P 21: Plasma Technology

Zeit: Mittwoch 16:30–18:30 Raum: HS Foyer

P 21.1 Mi 16:30 HS Foyer

Zündspannung und Penning-Ionisation in Atmosphärendruck-DBE in Argon mit Beimischungen von HMDSO und TMS — •D. Loffhagen[1], M. M. Becker[1], J. Philipp[2], A. Czerny[2] und C.-P. Klages[2] — [1]INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald — [2]TU Braunschweig, Pockelsstr. 14, 38092 Braunschweig

Hexamethyldisiloxan (HMDSO) und Tetramethylsilan (TMS) werden häufig als Präkursoren in dielektrisch behinderten Entladungen (DBE) zur Abscheidung Silizium-organischer Schichten verwendet. Aufgrund von Penning-Ionisationsprozessen führen bereits geringe Mengen von wenigen ppm dieser Präkursoren im Trägergas zu einer wesentlichen Veränderung des Entladungsverhaltens. Im Rahmen dieses Beitrags wird der Einfluss von HMDSO und TMS auf die Zündspannung einer Atmosphärendruck-DBE in Argon sowohl experimentell als auch theoretisch untersucht. Mittels experimenteller Validierung der Ergebnisse eines zeitabhängigen, räumlich eindimensionalen Fluid-Modells werden die Ratenkoeffizienten für Penning-Ionisation und Quenching in Stößen zwischen angeregtem Argon und HMDSO bzw. TMS spezifiziert. Der experimentell beobachtete Abfall der Zündspannung mit steigender Präkursorkonzentration im Bereich von 0 bis 200 ppm um etwa 60 % kann mit dem validierten Modell mit sehr guter Übereinstimmung nachempfunden werden.

Die Arbeiten wurden im Rahmen des SFB-TRR 24 sowie unter den Geschäftszeichen LO 623/3-1 und KL 1096/23-1 durch die DFG gefördert.

P 21.2 Mi 16:30 HS Foyer

Bend for the 28 GHz transmission line on TJ-K — •Enrique Casado Romero, Burkhard Plaum, Walter Kasparek, Gabriel Sichardt, and Günter Tovar — Plasmaforschung, Universität Stuttgart, Stuttgart, Germany

At the stellarator TJ-K, a 28GHz Electron Cyclotron Resonance Heating (ECRH) system will be installed. The oversized transmission line from the gyrotron with TE02 mode output to the stellarator consists of mode converters and a circular polarizer in order to generate a HE11 mode at the end of the 63.5 mm corrugated waveguide. Due to the geometry of the system, it is necessary to integrate a 90° bend. The objective is having an optimal behavior of the bend, with minimum losses and preservation of the HE11 mode. Two options are investigated: the first one is a gradually curved waveguide bend. By optimizing the size and curvature of the bend, one can minimize mode conversion in the bend, i.e. to keep the same mode as in the input. The second option is a low-loss 90° mitre bend at the diameter 123 mm, including a taper from 63.5 mm diameter to 123 mm. By appropriate phase correction of the mitre bend mirror, high transmission efficiency is obtained. Simulations for Gaussian beam and for HE11 mode are performed. We make all the simulations with the programming tool *PROFUSION* created in the IGVP in Stuttgart, which allow us to calculate and simulate fields along waveguides and its different possible components. In the poster, the two designs for the bend are discussed and compared, and first tests of the transmission line components are presented.

P 21.3 Mi 16:30 HS Foyer

Oberflächenanalyse von realen plasmabehandelten Proben — •Janine Mandler und Sandra Moritz — Justus-Liebig-Universität, Gießen, Deutschland

In diesem Versuch wurden plasmabehandelte Proben nach einer langzeit Plasmabehandlung auf Oberflächenveränderungen untersucht.

Der Versuchsaufbau bestand aus einer Plasmakammer, einer Probenkammer, einer Pumpe und einem Luftbefeuchter. Das besondere hierbei war, dass alle Kammern miteinander verbunden waren. Durch die Pumpe wurde hierbei ein Kreislauf erzeugt der dazu führte, dass die Luft befeuchtet wurde, weiter in die Plasmakammer gelangte und dann zur Probenkammer weitergeleitet wurde.

Verwendet wurden handelsübliche Materialien, die 12 Stunden lang mit einem atmosphärischen Plasma behandelt wurden. Das Plasma wurde mittels SMD Elektroden erzeugt.

Die Proben wurden jeweils vor und nach der Plasmabehandlung untersucht. Zum einen wurden die Kontakwinkel gemessen, wodurch folgend die Oberflächenenergie ermittelt werden konnte. Zum anderen wurde eine konfokalmikroskopische Untersuchung in 2D und 3D durchgeführt.

Bei allen Proben konnte eine Veränderung der Oberflächenenergie nach der Plasmabehandlung festgestellt werden. Bei der Konfokalmikroskopie konnten keine Veränderungen beobachtet werden.

P 21.4 Mi 16:30 HS Foyer

Optische Emissionsspektroskopie an lichtbogenbeheizten Plasmabrennern bei Atmosphärendruck — •Stefan Merli[1], Andreas Schulz[1], Matthias Walker[1], Bernd Glocker[2], Jakub Szałatkiewicz[3] und Günther Tovar[1] — [1]IGVP, Universität Stuttgart, 70569 Stuttgart — [2]PlasmaAir AG, 71263 Weil der Stadt-Hausen — [3]Industrial Research Institute for Automation and Robotics (PIAP), 02-486 Warschau, Polen

Lichtbogenbeheizte Plasmabrenner finden eine breite Anwendung in der Industrie und Forschung, wie zum Beispiel beim Plasmaschneiden, Plasmaspritzen oder zur chemischen Gassynthese. Das Funktionsprinzip beruht auf einer Bogenentladung, welche innerhalb der Plasmaquelle zwischen einer Kathode und einer Anode gezündet und mit Hilfe eines Arbeitsgases als Plasmajet ausgeblasen wird. Das resultierende Plasma ist in der Regel nahezu im thermischen Gleichgewicht und hat eine Gastemperatur von einigen 1000 K. Neben der hohen Temperatur ist auch die Erzeugung von reaktiven Atomen, Molekülen und Ionen für die Wirksamkeit der Plasmaquellen von Bedeutung.

In diesem Beitrag werden zwei verschiedene lichtbogenbeheizte Plasmabrennersysteme mittels optischer Emissionsspektroskopie untersucht und verglichen. Das Ziel ist die Bestimmung wichtiger Größen wie die Temperatur, die Plasmadichte sowie die Verteilungsfunktion der erzeugten reaktiven Spezies. Durch die Erstellung von Gastemperatur-, Dichte- und reaktiver Speziesprofilen werden unter anderem die optimalen Arbeitsbereiche für die Umsetzung gasförmiger Medien oder die Behandlung verschiedener Materialien ermittelt.

P 22: Theory and Modelling II

Zeit: Mittwoch 16:30–18:30 Raum: HS Foyer

P 22.1 Mi 16:30 HS Foyer

An Ar/O_2 collisional radiative model for the plasma plume of an assist source in PIAD — •Jochen Wauer, Jens Harhausen, Rüdiger Foest, and Detlef Loffhagen — Leibniz Institut für Plasmaforschung und Technologie, Felix-Hausdorff-Strasse 2, 17489 Greifswald

Plasma ion assisted deposition (PIAD) is a technique commonly used to produce high-precision optical interference coatings. Knowledge regarding plasma properties is most often limited to dedicated scenarios without film deposition [1]. Approaches have been made to gather information on the process plasma in situ [2] to detect drifts which are suspected to cause limits in repeatability of resulting layer properties. Present efforts focus on radiance monitoring of the plasma plume of an Advanced Plasma Source (APSpro, Bühler) by optical emission spectroscopy to provide the basis for an advanced plasma control. In this contribution modelling results of the plume region are presented to interpret these experimental data. In the framework of the collisional radiative model used, 17 argon and 14 oxygen states in the plasma are considered. The electron energy distribution function was gained in measurements. Results of the species densities are compared with the measured optical emission of various argon $2p-1s$ transitions and the oxygen 777nm and 844nm lines.

This work was funded by BMBF under grant 13N13213.

[1] Harhausen et al., *Plasma Sources Sci. Technol.* **21** (2012) 035012
[2] Styrnoll et al., *Plasma Sources Sci. Technol.* **22** (2013) 045008

P 22.2 Mi 16:30 HS Foyer

Nonequilibrium dynamics of correlated fermions: A benchmark analysis of the nonequilibrium Green functions approach — •Niclas Schlünzen[1], Jan-Philip Joost[1], Fabian Heidrich-Meisner[2], and Michael Bonitz[1] — [1]ITAP, CAU Kiel — [2]LMU München

The nonequilibrium dynamics of correlated fermions in lattice systems are of high current interest for condensed matter physics, ultacold atoms and plasma-surface interaction. While there is remarkable progress in experiments (e.g. Ref. [1]), the theoretical description remains challenging, especially in the regime of strong coupling and beyond 1 dimension (1D). Recently, 2D quantum simulations of the expansion of fermions based on nonequilibrium Green functions [2] (NEGF) have been presented [3] that showed excellent agreement with cold atom experiments. We present a benchmark analysis of the NEGF approach compared to results of the numerically accurate density matrix renormalization group (DMRG) method [4], which predominantly has been limited to one dimenional systems. The results indicate that NEGF can compete for weak to intermediate coupling strengths while being easily extendable to higher dimensions, larger system sizes and longer propagation times.

[1] U. Schneider *et al.*, Nat. Phys. **8**, 213 (2012)
[2] K. Balzer and M. Bonitz, Lect. Notes Phys. **867** (2013)
[3] N. Schlünzen, S. Hermanns, M. Bonitz, and C. Verdozzi, Phys. Rev. B **93**, 035107 (2016)
[4] N. Schlünzen *et al.*, submitted for publication

P 22.3 Mi 16:30 HS Foyer

Convergence analysis of an approximated response function of the impedance probe — •Jan Hendrik Röhl and Jens Oberrath — Institute of Product and Process Innovation, Modelling within Local Engineering, Leuphana University Lüneburg, 21339 Lüneburg, Germany

Active plasma resonance spectroscopy (APRS) is a widely used method to measure plasma parameters like electron density and electron temperature. In Plasmas of a few Pa measurements with APRS probes typically show a broadening of the spectrum due to kinetic effects. A general kinetic model in electrostatic approximation based on functional analytic methods has been presented to analyze the broadening in the spectra of these probes [1]. One of the main results is, that the system response function Y is given in terms of the matrix elements of the resolvent of the dynamic operator evaluated for values on the imaginary axis.

The dynamic operator is approximated by a huge matrix, which is given by a banded block structure. This structure allows to apply a block-based LU decomposition to determine the response function of the impedance probe with a minimum of computation time. However, a convergence analysis dependent on the dimension of the approximated matrix is necessary to analyze the final broadening of the spectra, especially in the collisionless case.

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

P 22.4 Mi 16:30 HS Foyer

Numerical investigation of the dynamics of geodesic acoustic modes in tokamak plasmas. — •Ivan Novikau[1], Alessandro Biancalani[1], Alberto Bottino[1], Garrard Conway[1], Peter Manz[1], Pierre Morel[2], Özgür Gürcan[2], and Emanuele Poli[1] — [1]Max Planck Institute of Plasma Physics — [2]Laboratoire de Physique des Plasmas, Ecole Polytechnique

Tokamak micro-turbulence is often accompanied by meso-scale electric fields that take the form of radially sheared poloidal ExB flows, named zonal flows (ZFs). These flows are driven by nonlinear interactions with the turbulence and, in turn, they can regulate the plasma transport via flow shearing. The action of curvature in tokamak on ZFs gives rise to oscillations of radial electric field called the geodesic acoustic modes (GAMs) which are observed mainly in the external region of tokamak plasmas, with characteristic frequencies of the order of the sound frequency, and mainly m=0 n=0 potential perturbation and m=1 n=0 density perturbation (with m and n being respectively the poloidal and toroidal mode numbers). Nonlinear interaction between turbulence and these structures is crucial for turbulence saturation.

Different characteristics like GAM frequency and collisionless damping rate are investigated by means of numerical simulations with the global gyrokinetic particle-in-cell code ORB5 and different numerical diagnostics. The influence of the plasma shape, density and temperature gradients is studied with the aim of making predictions for realistic tokamak geometries. The effect of kinetic electrons is considered for realistic electron masses.

P 22.5 Mi 16:30 HS Foyer

Electron and ion distribution functions in ccrf discharges with secondary electron emission — •Michael Marsand, Hanno Kählert, and Michael Bonitz — ITAP, Christian-Albrechts-Universität zu Kiel, Leibnizstr. 15, 24098 Kiel

Secondary electrons emitted from the electrodes can significantly affect the physical characteristics of ccrf discharges [1]. Here, we use PIC-MCC simulations (Particle-in-Cell with Monte-Carlo collisions) to resolve the electron and ion distribution functions in space and time during the rf cycle in Ar and He plasmas. We determine the influence of secondary electron emission (SEE) on the distribution functions in the bulk and sheath regions and perform a comparison for low and high gas pressures and different SEE coefficients.

[1] A. Derzsi, I. Korolov, E. Schuengel, Z. Donkó, and J. Schulze, Plasma Sources Sci. Technol. 24, 034002 (2015)

P 22.6 Mi 16:30 HS Foyer

Microwave beam broadening due to plasma density fluctuations — •Alf Köhn[1], Michael Brookman[2], Lorenzo Guidi[1], Eberhard Holzhauer[3], Jarrod Leddy[4], Omar Maj[1], Emanuele Poli[1], Antti Snicker[1], Matthew Thomas[4], and Roddy Vann[4] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Institute for Fusion Studies, Austin (TX), US — [3]IGVP, Stuttgart, Germany — [4]York Plasma Institute, York, UK

Electromagnetic waves in the microwave regime are commonly used for heating, current drive, and diagnostic purposes in fusion plasmas. They suffer, however, from the fact that they have to traverse the plasma boundary, a region where substantial density fluctuations can occur resulting in perturbations of the microwave beam. Time-averaging over the effect of the fluctuations basically leads to a broadening of the microwave beam. The strength of this broadening is investigated with full-wave simulations. The comparison with computational less time expensive methods serves to identify their region of validity. The turbulence parameters are varied in a series of parameter scans to find the cases with the strongest perturbations. Possible implications for localized heating and current drive in fusion plasmas are also discussed.

P 22.7 Mi 16:30 HS Foyer

Fluid description of secondary electrons in low pressure ccrf discharges — •M. M. Becker[1], H. Kählert[2], M. Bonitz[2], and D. Loffhagen[1] — [1]INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald — [2]ITAP, Christian-Albrechts-Universität zu Kiel, Leibnizstr. 15, 24098 Kiel

Recently, the classical and an advanced fluid model as well as Particle-in-cell/Monte Carlo collision (PIC/MCC) simulation methods have been applied for the theoretical description of capacitively coupled radio-frequency (ccrf) discharges in helium and argon in the pressure range from 10 to 80 Pa [1]. At this stage, the plasma-wall interaction has been neglected. In the present contribution, the impact of secondary electron emission on the results provided by the different solution methods for ccrf discharges in helium and argon at 20 Pa is investigated. It is shown that the fluid approach applied for the description of the electron component in argon discharges largely influences the results provided by the different fluid models. In contrast, the description of electrons in helium is found to be less crucial. The results of the different fluid models are compared to PIC/MCC simulation results.

This work is supported by the German Research Foundation (DFG) via SFB-TRR24.

[1] M. M. Becker et al., arXiv:1608.04601, submitted to *Plasma Sources Sci. Technol.*

P 22.8 Mi 16:30 HS Foyer

Development of a parallel multi-term Boltzmann solver using the Qubus framework — •Christopher Hinz[1,2], Markus Becker[2], Detlef Loffhagen[2], and Michael Bonitz[1] — [1]ITAP, Christian-Albrechts-Universität zu Kiel, Leibnizstr. 15, 24098 Kiel — [2]INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald

Electron transport and rate coefficients required by hydrodynamic plasma models are frequently obtained by solving the stationary and homogeneous Boltzmann equation of the electrons. The present contribution reports on the status of the implementation of such a Boltzmann solver by means of the parallelization framework Qubus [1]. Qubus particularly assists in the development of parallel codes for multiple platforms without compromising the ability to easily adapt the code to new requirements. The considered solution procedure is based on a multi-term expansion of the electron velocity distribution function in Legendre polynomials [2]. The speedup of the solution procedure provided by Qubus finally enables the direct coupling of the kinetic equation with hydrodynamic plasma models.

[1] http://qubus.qbb-project.org
[2] H. Leyh, *et al., Comput. Phys. Commun.* **113** (1998) 33–48

P 22.9 Mi 16:30 HS Foyer

Ab initio approach to ion stopping at the plasma-solid interface — Karsten Balzer[1], •Niclas Schlünzen[2], Jan-Philip Joost[2], Lasse Wulff[2], and Michael Bonitz[2] — [1]Rechenzentrum, CAU Kiel — [2]ITAP, CAU Kiel

The energy loss of ions in solids is of key relevance for many applications of plasmas, ranging from plasma technology to fusion. Standard approaches are based on density functional theory or SRIM simulations, however, the applicability range and accuracy of these results are difficult to assess, in particular, for low energies. Here, we present an independent approach that is based on *ab initio* nonequilibrium Green functions theory, e.g. [1,2] that allows to incorporate electronic correlation effects of the solid. As a first application of this method to low-temperature plasmas, we concentrate on proton and alpha-particle stopping in a graphene layer and similar finite honeycomb lattice systems. In addition to the stopping power we present time-dependent results for the local electron density, the spectral function and the photoemission spectrum [3] that is accessible in optical, UV or x-ray diagnostics [4].

[1] M. Bonitz, *Quantum Kinetic Theory, 2nd edition* (Springer, 2016)
[2] K. Balzer and M. Bonitz, Lect. Notes Phys. **867** (2013)
[3] M. Eckstein and M. Kollar, Phys. Rev. B **78**, 245113 (2008)
[4] K. Balzer, N. Schlünzen, and M. Bonitz, Phys. Rev. B **94**, 245118 (2016)

P 22.10 Mi 16:30 HS Foyer

Simulation of metal cluster growth on a thin polymer film during sputter deposition — Jan-Willem Abraham[1], Thomas Strunskus[2], •Michael Bonitz[1], and Franz Faupel[2] — [1]ITAP, 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. Under typical conditions in PVD experiments, crucial properties such as composition, size and shape of the nanoparticles evolve in a self-organized way. Computer simulations can help to improve the understanding of the relevant processes, but the required length and time scales pose big challenges. In this work, we present an approach based on Langevin dynamics that allows us to microscopically investigate the growth of gold and bi-metallic Ag-Cu clusters on polymer surfaces *on experimentally relevant time scales of seconds* [1]. The method takes into account the deposition of single metal atoms, diffusion of the particles on the surface, desorption of atoms as well the creation of surface defects caused by the impingement of ions that are emitted from the plasma environment. Our results are in good agreement with recent GISAXS experiments that studied sputtering of gold on a thin polystyrene film in real time [2]. Finally, we calculate the intensity of scattered X-rays as well as the UV-Vis absorption spectrum for our simulated structures.

[1] J. W. Abraham *et al.*, J. Appl. Phys. **119**, 185301 (2016).
[2] M. Schwartzkopf *et al.*, ACS Appl. Mater. Interf. **7**, 13547 (2015).
This work is supported by the DFG via SFB-TR 24.

P 22.11 Mi 16:30 HS Foyer

Spontaneous formation of temperature anisotropies in strongly coupled magnetized plasmas — •Torben Ott[1], Michael Bonitz[1], Peter Hartmann[2], and Zoltan Donkó[2] — [1]Institute for Theoretical Physics and Astrophysics, CAU, Kiel, Germany — [2]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Budapest, Hungary

We consider the effect of an external magnetic field on the thermal conduction properties of a strongly correlated plasma through molecular dynamics simulations [1]. A perturbation of the temperature equilibrium through a local, isotropic heating leads—above a critical magnetic field strength—to the spontaneous formation of a temperature anisotropy between the field-parallel and cross-field temperature components. It is shown that this behaviour is caused by the prolongation of the isotropization time scales due to the magnetic field. An extension of the heat equation with an isotropization term is able to reproduce the observed behaviour [2].

[1] T. Ott, M. Bonitz, and Z. Donkó, "Effect of correlations on heat transport in a magnetized strongly coupled plasma", Phys. Rev. E 92, 063105 (2015).
[2] T. Ott, M. Bonitz, P. Hartmann, and Z. Donkó, "Spontaneous generation of a temperature anisotropy in a strongly coupled magnetized plasma", to appear in Phys. Rev. E (2017)

P 23: Low Temperature Plasmas

Zeit: Mittwoch 16:30–18:30 Raum: HS Foyer

P 23.1 Mi 16:30 HS Foyer

Kinetic Modeling of the Surface Mode Excitation in CCP Discharges with the Electrostatic and Electromagnetic Field Descriptions — •Denis Eremin, Ali Arshadi, Schabnam Naggary, and Ralf Peter Brinkmann — Institute for Theoretical Engineering, Ruhr University Bochum, Univeristätsstrasse 150, 44801, Bochum, Germany

It has been recently demonstrated that uniformity of the plasma density and ion fluxes impinging on the electrodes in large-scale CCP reactors operated at very high frequencies can be linked to excitation of the surface modes supported by such reactors filled with plasma. There are two types of such modes, which can be distinguished by the physical phenomena associated with them, the plasma-series-resonance (PSR) and the self-bias (SB) modes. In this work excitation of these modes and their influence on the plasma uniformity is investigated by means of self-consistent particle-in-cell/Monte-Carlo (PIC/MCC) simulations in the electrostatic and the electromagnetic limits. In the latter case a novel implicit PIC/MCC energy-conserving approach is employed, which helps to get rid of numerical heating. The particle algorithms of the corresponding codes are massively parallelized on GPU.

The authors gratefully acknowledge financial support of the German Research Foundation within the framework of SFB-TR 87 project.

P 23.2 Mi 16:30 HS Foyer

Guide field magnetic reconnection on electron and ion scales — •Adrian von Stechow, Dusan Milojevic, Ilya Shesterikov, Olaf Grulke, and Thomas Klinger — Max-Planck-Institut für Plasmaphysik, Greifswald

Magnetic reconnection is a generic plasma process characterized by the release of accumulated magnetic energy due to rapid changes in magnetic topology. A central feature of reconnection is the formation of a highly localized current sheet on length scales much smaller than those of the externally imposed magnetic field. The detailed properties of this sheet determine the rate at which reconnection proceeds, and the appropriate model description depends crucially on the ordering of plasma length and time scales with respect to those of the current sheet.

VINETA.II is a linear, moderate to high guide field laboratory reconnection experiment that has previously operated in a regime in which ion dynamics play a minor role ($f > f_{ci}$) and for which an electron-MHD model is appropriate. Recent upgrades significantly extend this parameter space into an Alfvénic regime by increasing the time scales at which reconnection is driven and by broadening the current sheet through improved plasma sources. This contribution characterizes the transition between these regimes by interpreting key current sheet parameters such as magnetic flux transfer, current and plasma densities as well as wave propagation velocities.

P 23.3 Mi 16:30 HS Foyer

Force balance and Ohm's law in the reconnecting current sheet in the VINETA-II magnetic reconnection experiment — •Ilya Shesterikov[1], Adrian von Stechow[1], Dusan Milojevic[1], Olaf Grulke[1] und Thomas Klinger[1,2] — [1]Max Planck Institu-

te for Plasma Physics, 17491 Greifswald, Germany — [2]Institut für Physik, Ernst-Moritz-Arndt Universität Greifswald, Felix-Hausdorff-Straße 6, D-17489 Greifswald

VINETA-II is a linear experiment developed for the study of a driven magnetic reconnection. The global description of the current sheet properties is important to relate magnetic reconnection to the response of the plasma. This includes the three-dimensional (3D) estimate of the diamagnetic current, the Lorenz force and $\vec{E} \times \vec{B}$ terms included in the MHD force balance equation. A 3D positioning system equipped with a fast swept Langmuir probe and B-dot probe is used. These two probes together provide a complete set of quantities required in the analysis: n_e, T_e, ϕ_{fl}, ϕ_p - from the Langmuir probe and $\vec{B}$ from the B-dot probe. $\vec{E}$ is evaluated on the base of the spatial distribution of ϕ_p. Within the frame of global description one addresses the key question which terms in the generalized Ohm's law have a major influence on the evolution of magnetic reconnection. The previous 2D estimate of the in-plane MHD force balance showed that the $\vec{E} \times \vec{B}$ term plays a significant role. In the present work we present a full 3D estimation, without the assumption on the axial homogeneity.

P 23.4 Mi 16:30 HS Foyer

Plasma formation in the KATRIN tritium source — •Laura Kuckert — for the KATRIN collaboration, KIT, Karlsruhe, Germany

The Karlsruhe Tritium Neutrino Experiment (KATRIN) aims to measure the neutrino mass with a sensitivity of 200 meV/c^2 (90% C.L.) in a direct approach using the beta decay of molecular tritium. The neutrino mass is extracted from a fit of modelled beta decay spectra to the measured electron spectrum. Hence, it is important to consider all effects that impact the electron energy. The potential energy of the emitted electrons is set by the electrostatic potential at the position of beta-decay in the windowless gaseous tritium source (WGTS). The potential distribution in the WGTS is determined by a cold low-density plasma that forms inside the strong magnetic field of the WGTS through beta decay and secondary ionizations. To understand the formation and structure of the plasma potential, a comprehensive fluid plasma model has been developed that includes the creation, annihilation and motion of electrons and ions as well as neutral gas flow. The results of the plasma modelling are reviewed with regard to different surface conditions and a monitoring option for the potential distribution is presented that uses monoenergetic electrons from ^{83m}Kr. Implications on the systematics budget for the neutrino mass measurement are inferred. Supported by BMBF (05A14VK2), HAP and the Helmholtz Association.

P 23.5 Mi 16:30 HS Foyer

Single self-stabilized filament in plane-parallel barrier discharge configuration: existence regimes, breakdown mechanism, and memory effects — •Robert Tschiersch, Sebastian Nemschokmichal, and Jürgen Meichsner — Institute of Physics, University of Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald

This contribution reports on a single filament which is self-stabilized in the plane-parallel barrier discharge configuration. The discharge is operated inside a gap of 3 mm shielded by glass plates on both electrodes, using helium-nitrogen mixtures and square-wave feeding voltage at a frequency of 2 kHz. The combined application of electrical measurements, ICCD camera imaging, optical emission spectroscopy, and surface charge diagnostics allowed to study the correlation between volume and surface processes during the discharge development. Priority is given to the formation conditions, breakdown mechanism, and underlying memory effects. Therefore, the existence regimes were investigated by systematic variation of the nitrogen admixture to helium, the total pressure, and the feeding voltage amplitude. In each case, the single self-stabilized discharge filament is obtained by significant reduction of the voltage amplitude after the discharge ignition in the multi-filament regime. Here, the outstanding importance of the surface-charge memory effect for the long-term stability is pointed out by the calculation of the spatio-temporally resolved gap voltage. The optical emission from the discharge reveals characteristics that are partially reminiscent of both the glow-like barrier discharge and the microdischarge regime.

P 23.6 Mi 16:30 HS Foyer

Inactivation of *Enterococcus mundtii* by Indirect Plasma Treatment using Surface Micro-Discharge Electrode — •Sandra Moritz[1], Janine Mandler[1], Sylvia Binder[2], Tetsuji Shimizu[2], Meike Müller[3], Markus H. Thoma[1], and Julia Zimmermann[2] — [1]I. Physikalisches Institut, JLU Gießen, Germany — [2]terraplasma GmbH, Garching, Germany — [3]DLR Oberpfaffenhofen, Germany

Inactivation of microorganism by CAP is one major application in the field of plasma medicine. In this contribution, the inactivation of bacteria by an indirect plasma treatment using a Surface Micro-Discharge electrode is discussed. This could be used for e.g. disinfection of dental equipment. The experimental setup consists of a SMD electrode in a box, a chamber for samples, a humidifier (optionally) and a pump. A voltage of 6.4 kVpp at 10 kHz was applied to the electrode and the power consumption was around 3.5 W. By the pump a plasma gas flow is circulated from the electrode to the treatment chamber, through the humidifier and back to the pump. The plasma gas is confined in the system. Bacterial samples were prepared on stainless steel plates using *Enterococcus mundtii*. Each had approximately 10^6 bacteria. They were placed in the chamber and treated for 1-15 min.

Until 5 min in treatment time, there is a relatively fast inactivation effect with D-value (1 log reduction) of 1.5 min. After 5 min, the inactivation effect becomes slower. In 15 min, a larger than 5 log reduction of bacteria could be achieved. In the conference, time evolution of reactive species and mechanism of bactericidal effect will be discussed.

P 23.7 Mi 16:30 HS Foyer

Experimentelle Untersuchung der Streamerpropagation und Entladungsentwicklung auf dielektrischen Oberflächen — •Manfred Kettlitz, Rouven Klink, Hans Höft und Ronny Brandenburg — INP Greifswald, Felix-Hausdorff-Straße 2, 17489 Greifswald

Untersucht wurde das Ausbreitungsverhalten von Mikroentladungen auf einer Keramikoberfläche in Stickstoff-Sauerstoff-Gasgemischen bei Atmosphärendruck. Um die Entladungsentwicklung auf die Oberfläche zu begrenzen, wurde eine Anordnung mit direkt auf dem Dielektrikum anliegenden Nadelelektroden verwendet. Die Entladungen wurden mit einer unipolaren gepulsten Rechteckspannung mit variabler Amplitude und 4,3 kHz Wiederholfrequenz betrieben. Der Zündvorgang sowie die Entladungsausbildung auf der Oberfläche wurden durch schnelle ICCD-Kameras und eine Streakkamera beobachtet. Während in Einzelaufnahmen eine ungleichäßige und verzweigte Struktur der Entladungskanäle sichtbar wird, zeigt die Akkumulation über mehrere Entladungen eine konzentrische Propagationsfront, die von der Spitze der Nadelelektrode ausgeht. Je nach Polarität der metallischen Elektrode im Vergleich zum umgebenden Dielektrikum zeigen sich sowohl Unterschiede in der Ausbreitung der Entladung als auch in deren Propagationsgeschwindigkeit. So entwickelt sich bei positiver Polarität der metallischen Elektrode (steigende Flanke des HV-Pulses) ein positiver Streamer mit wesentlich größerer Ausbreitungsgeschwindigkeit ($5 \cdot 10^5$ $\frac{\mathrm{m}}{\mathrm{s}}$) als bei negativer Polarität (fallende Flanke des HV-Pulses).

P 23.8 Mi 16:30 HS Foyer

Direct determination of electron phase trajectories in striated inert gas discharges — •Yuri B. Golubovskii[1], Sergey Valin[1], and Florian Sigeneger[2] — [1]St. Petersburg State University, Universitetskaya St. 7/9, 199034 St. Petersburg, Russia — [2]INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald

A new dynamic method to analyse resonance effects in striated glow discharge plasmas is proposed as a supplement to kinetic approaches. The method is applicable to striations which are caused by the nonlocal electron behaviour at lower pressure and current. It is based on the direct analysis of the electron phase trajectories in spatially periodic fields and avoids the solution of the spatially inhomogeneous Boltzmann equation.

Main aspects of the resonance effects are obtained by studying the electron phase trajectories in strongly modulated electric fields. The relaxation into the established periodic state is demonstrated by varying the initial electron energy. For S, P and R striations, the obtained trajectories very good agree with corresponding results obtained from a kinetic approach. Furthermore, the resonance behaviour in the case of S striations is studied by detuning the period length of the electric field.

P 23.9 Mi 16:30 HS Foyer

Investigations on the dynamics of non-reactive and reactive high-power impulse magnetron sputtering plasmas — •Katharina Grosse, Wolfgang Breilmann, Christian Maszl, Jan Benedikt, and Achim von Keudell — Ruhr-Universität Bochum

High power impulse magnetron sputtering (HiPIMS) is a technique for thin film deposition and can be operated in reactive and non-reactive mode. The growth rate of HiPIMS in the non-reactive mode reduces to 30% compared to direct current magnetron sputtering (dcMS) at same average power. However, the quality of the coatings produced with HiPIMS is excellent which makes these plasmas highly appealing. Target poisoning is occurring in the reactive mode which among other things influences the plasma dynamics and changes the secondary electron emission coefficient. An advantage of reactive HiPIMS is that the sputtering process can be operated hysteresis-free which can result in a higher growth rate compared to dcMS. In this work, thin films are deposited by a HiPIMS plasma which is generated by short pulses of 100 μs with high peak power densities in the range of >1 kW/cm^2. Both Ar and Ar/N_2 admixtures are used to sputter a 2" titanium target. The particle transport from the target to the substrate is analysed with time-resolved ion energy distribution measurements and phase-resolved optical emission spectroscopy. Furthermore, the time-resolved growth rate of the deposited film is investigated. The time- and energy-resolved particle fluxes in non-reactive and reactive HiPIMS plasmas are compared and implications on the sputter process are discussed.

P 23.10 Mi 16:30 HS Foyer

Spatiotemporal evolution of the reconnection current sheet — •Dusan Milojevic[1], Adrian von Stechow[1], Ilya Shesterikov[1], Olaf Grulke[1], and Thomas Klinger[1,2] — [1]Max Planck Insitute for Plasma Physics,17491 Greifswald,Germany — [2]Instituet fr Physik, Ernst-Moritz-Arndt Universitaet Greifswald, Felix-Hausdorff-Str. 6, D-17489 Greifswald

Magnetic reconnection is a process, in which magnetic field lines break up at the magnetic X-point and rearrange, often accompanied by a transfer of magnetic field energy into thermal energy. The plasma response to magnetic reconnection is characterized by the formation of a current sheet in an area around the magnetic X-point, where the magnetic field lines diffuse. The shape of the current sheet has a strong influence on the evolution of reconnection. In the linear VINETA-II experiment the plasma current is provided by an array of plasma guns, which act as an electron source and influence the spatial distribution and amplitude of the reconnection current. The plasma guns can be operated individually which gives the possibility for a variety of initial conditions for the current sheet. In this contribution the spatiotemporal evolution of the reconnection current sheet is studied in dependence of the current source and reconnection drive scheme. Special attention is paid to the response of the current sheet to a spatially inhomogeneous reconnection drive scheme.

P 23.11 Mi 16:30 HS Foyer

Electronegativity and oxygen kinetics during E-H transition in inductively coupled radio frequency plasmas . — •Thomas Wegner[1] and Jürgen Meichsner[2] — [1]Max-Planck-Institute for Plasma Physics, Greifswald, Germany — [2]Institute of Physics, University of Greifswald, Greifswald Germany

The electronegativity and oxygen kinetics in inductively coupled plasma at 13.56 MHz was evaluated during the E-H transition by comprehensive plasma diagnostics to determine experimentally the particle density for electrons, negative atomic oxygen ions, metastable and ground state molecular oxygen as well as the effective electron temperature and gas temperature. Furthermore, the negative atomic oxygen ion density was calculated by their balance equation taking into account the experimentally determined densities and temperatures as well as the rate coefficients from literature. The calculated negative ion density is compared with the measured negative ion density by laser photodetachment experiment and by the electron density peak in the early afterglow due to collisional detachment. The three different methods provide adequate agreement in the negative ion density and describe the continuous decrease of the electronegativity over two orders of magnitude from the E-mode to the H-mode. Additionally, the dominant elementary processes are identified for negative ion formation and recombination in the E-mode and H-mode, respectively.

Funded by the DFG Collaborative Research Center Transregio 24, project B5.

P 23.12 Mi 16:30 HS Foyer

Characterisation of Sub-microsecond Pulsed Discharges in Water — •Raphael Rataj, Jana Kredl, Camelia Miron, Tilo Schulz, Jürgen F. Kolb, and Ronny Brandenburg — Leibniz-Institut für Plasmaforschung und Technologie e.V., Felix-Hausdorff-Str. 2, 17489 Greifswald

Corona-like plasma discharges in water that are instigated with nanosecond high voltage pulses are of great interest for water treatment and novel approaches in green chemistry. Accordingly, much effort has been spent to characterize this type of discharge depending on operating parameters. Physical processes of electrical breakdown and discharge development will be studied in a point-to-plane geometry for the application of defined 100 ns high voltage pulses. Systematic investigations of a single pulse event will include electrical diagnostics, fast imaging by iCCD-cameras and spectroscopy. First results, such as in particular on electrical characteristics and the branching ratios of streamers, will be presented and discussed.

P 23.13 Mi 16:30 HS Foyer

Characterization of the high density helicon plasma cell PROMETHEUS-A for the Advanced Wakefield Experiment — •Birger Buttenschön, Nils Fahrenkamp, and Olaf Grulke — Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany

The Advanced Wakefield Experiment (AWAKE), the world's first proton-beam driven plasma wakefield accelerator test facility, is currently being set up and commissioned at CERN in its first stage. In order to reach significant output beam energies, an accelerating plasma section that is scalable in length to tens or hundreds of meters is required. We present a prototype plasma cell based on a high power helicon discharge ($P_{\rm rf} \leq 100$ MW/m^3) with an axially distributed antenna system. In this prototype, accelerator-relevant plasma densities of $n_{\rm e} \leq 6 \cdot 10^{20}$ m^{-3} are now routinely produced for short periods of time. The plasma is characterized by means of laser interferometry with respect to temporal density evolution, its radial distribution and the scaling with external control parameters such as ambient magnetic field, neutral gas inventory and specifics of the helicon wave coupling.

P 23.14 Mi 16:30 HS Foyer

A Computationally Assisted Spectroscopic Technique to measure secondary electron emission coefficients in technological RF plasmas — •Birk Berger[1,2], Manaswi Daksha[1], Edmund Schüngel[1], Mark Koepke[1], Julian Schulze[1,2], Ihor Korolov[3], Aranka Derzsi[3], and Zoltán Donkó[3] — [1]Department of Physics, West Virginia University, Morgantown, USA — [2]Institute for Electrical Engineering, Ruhr-University Bochum, Germany — [3]Wigner Research Centre for Physics, Hungarian Academy of Sciences, Hungary

A Computationally Assisted Spectroscopic Technique to measure secondary electron emission coefficients (y-CAST) in capacitively coupled radio-frequency plasmas is proposed. This non-intrusive, sensitive diagnostic is based on a combination of Phase Resolved Optical Emission Spectroscopy and particle-based kinetic simulations. In such plasmas the spatio-temporally resolved electron-impact excitation rate features two distinct maxima adjacent to each electrode at different times within each RF period. While one maximum is the consequence of the energy gain of the electrons due to sheath expansion, the second maximum is produced by y-electrons accelerated towards the plasma bulk by the sheath electric field at the time of maximum voltage drop across the adjacent sheath. Due to the different excitation mechanisms the ratio of the intensities of these maxima is very sensitive to y, which allows for its determination via comparing the experimentally measured excitation profiles with corresponding simulation data obtained with various y-coefficients. This diagnostic is tested here in a geometrically symmetric reactor, for stainless steel electrodes and argon gas.

P 23.15 Mi 16:30 HS Foyer

Phase resolved laser absorption spectroscopy on a low pressure dielectric barrier discharge jet — •Roman Bergert and Slobodan Mitic — I. Physikalisches Institut, Justust-Liebig Universität Gießen

Dielectric barrier discharge (DBD) jets at low pressures ($\approx$ 100 Pa) were investigated by laser absorption targeting the 1_{s4} argon resonant state at 842.46 nm and fluorescence spectroscopy. The accuracy of the measurements was improved by synchronization of the laser scan with the voltage dynamics providing the possibility for phase resolved reconstruction of the measured absorption profiles.

Preliminary fits with a Gaussian profile resulted in pure description of measured profiles; wings indicating additional broadening components. The latter is considered to be caused by charge particles (Stark broadening) while pressure broadening at the applied pressures should not be detectable.

The laser absorption was measured across the jet, between electrodes, providing the phase resolved local information on the state density, gas temperature and electron density. Laser absorption in axial direction was also performed confirming strong phase dependent gas thermodynamics based on detection of Doppler shift induced florescence imaging of the plasma jet. The observed DBD jets had very strong phase dependent development with high densities and relatively low gas temperature making it a quite efficient and robust plasma source.

P 23.16 Mi 16:30 HS Foyer

Planar Multipole Resonance Probe: Comparison of a Functional Analytic Approach and Full 3D Electromagnetic Field Simulations — •Michael Friedrichs[1], Christian Schulz[2], Ilona Rolfes[2], Ralf Peter Brinkmann[3], and Jens Oberrath[1] — [1]PPI, Leuphana University Lüneburg, Germany — [2]HFS, Ruhr-University Bochum, Germany — [3]TET, Ruhr-University Bochum, Germany

Measuring plasma parameters, e.g. electron density and electron temperature, is an important procedure to verify the stability and behavior of a plasma process. For this purpose, the multipole resonance probe (MRP) represents a promising design. However, the influence of the probe on the plasma through its physical presence makes it unattractive for most processes in industrial applications.

A solution, suitable for industrial applications, is the planar version of the MRP (pMRP). It combines the design and benefits of the spherical MRP and can be mounted into the chamber wall.

To analyze the resonance behavior of the pMRP the cold plasma model is coupled to the Poisson equation and an analytical expression for the admittance of the probe-plasma system can be derived by means of functional analytic methods. It is adjusted to the design of the pMRP in cylindrical geometry and the corresponding spectra are compared to full 3D electromagnetic field simulations. Based on the Finite Integration Technique, the commercial software CST Microwave Studio is utilized for these simulations. The resulting complex reflection coefficient is evaluated, obtained by the frequency domain solver in conjunction with a tetrahedral mesh and the Drude model.

P 24: Plasma Wall Interaction

Zeit: Donnerstag 8:30–10:15 Raum: HS 1010

Hauptvortrag P 24.1 Do 8:30 HS 1010

Quasi-steady state plasma operation in the Be/W material mix: from the JET tokamak to ITER — •Sebastijan Brezinsek — Forschungszentrum Jülich GmbH

ITER will operate with metallic wall an employ PFCs made of Beryllium at the first wall and Tungsten in the divertor. The positive aspects of the envisaged material mix for ITER have been confirmed (low fuel retention, low erosion and material migration, dust production), but plasma-surface interaction at these metallic components has shown vital impact on the operational space as we all as on the plasma performance. A two weeks period of identical plasma discharges in H-mode conditions accumulating more than 900s of plasma time and more than 30 000 ELMs has been executed to mimic ITER-like plasma discharge conditions which can be expected at half magnetic field operation as foreseen in the start sequence of ITER. Detailed analysis of the discharges as well as associated edge modelling will be presented to allow extrapolation to ITER.

P 24.2 Do 9:00 HS 1010

PWI in n=1 RMP scrape-off layer on EAST — •Marion Dostal[1], Yongliang Li[2], and Yungfeng Liang[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]Institut of plasma physics, Chinese academy of science, China

Steady state operation of ITER and future power plants will require a detailed understanding of plasma-wall interaction. These plasma-wall interactions, in special particle and heat transport, depends on the magnetic topology. Lots of experiments have demonstrated the essential role of this interplay.

Therefeore experiments with n=1 RMP scrape-off layer on EAST were made by using a combined multi-channel retarding field analyzer. The results of fast particle confinement, heat transport and heat flux distribution for n=1 RMP plasmas w/ and w/o good phase for ELM controll will be shown.

P 24.3 Do 9:15 HS 1010

Spectral Emission of Fast Non-Maxwellian Atoms at Metallic Surfaces in Low Density Plasmas — •Sven Dickheuer[1], Oleksandr Marchuk[1], Christian Brandt[2], and Albrecht Pospieszczyk[1] — [1]Forschungszentrum Jülich GmbH - Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]Max- Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

We have observed Doppler-shifted emission of Balmer lines in hydrogen-argon mixed plasmas in a linear plasma ($n_e \approx 10^{11}$ cm^{-3}, $T_i \approx 2$ eV). In pure hydrogen plasmas no Doppler-shifted emission above the signal-to-noise ratio could be measured [C.Brandt et al. O3.J107, EPS conference (2015)]. But in H-Ar mixed plasmas with a composition of 1:1 the intensity of Doppler-shifted emission reaches its maximum and the blue- and red-shifted components of the Balmer lines could be clearly detected. Different target materials (e.g. Ag, Pd, C) have been used to measure the dependence of the Doppler-shifted emission on the target material. The dependence of the emission on the target potential has been investigated by varying the target potential between −30 V and −220 V. Two possible processes could explain the observations of Doppler-shifted emission. The first one is the excitation by argon ground state Ar + H → (ArH)* → Ar + H*, the other one is the excitation transfer from the argon metastable state Ar* + H → (ArH)* → Ar + H*. Both possibilities are discussed in the talk and compared to the theoretical cross sections and measurements with other hydrogen-noble gas mixed plasmas.

P 24.4 Do 9:30 HS 1010

Oxidation resistance of plasma-facing tungsten alloys — •Felix Klein[1], Andrey Litnovsky[1], Tobias Wegener[1], Marcin Rasinski[1], Christian Linsmeier[1], Jesus Gonzalez[2], Martin Bram[2], Uwe Breuer[3], Hongchu Du[4], and Joachim Mayer[4] — [1]Forschungszentrum Jülich, Institut für Energie- und Klimaforschung (IEK) - Plasmaphysik — [2]Forschungszentrum Jülich, IEK - Werkstoffsynthese und Herstellungsverfahren — [3]Forschungszentrum Jülich, Zentralinstitut für Engineering, Elektronik und Analytik, Analytik — [4]Ernst Ruska-Centrum, 52425 Jülich

Tungsten (W) is the prime candidate as plasma-facing material for the first wall of future fusion power plants like DEMO. Advantages of W include the high melting temperature and the low sputtering rate. A problem is oxidation and sublimation of radioactive oxide in case of an accident featuring a loss of active cooling and air ingress. Therefore, new alloys are developed. On the one hand the alloys exhibit the advantages of W and on the other hand they passively develop corrosion resistance in case of an accident. Using W-Cr-Y thin films, prepared by magnetron sputtering, the suppression of tungsten oxide formation was shown for up to 9 h at 1273 K. Cr continuously formed a protective oxide layer. In contrast, the problem of WO_3 formation/sublimation occurred during studies of first powder-metallurgically prepared bulk samples. A key difference was the distribution of Y: Homogeneous within the thin films versus nano-particles at the grain boundaries of the bulk samples. Microstructure and oxidation behaviour are analysed and approaches for further development are presented.

P 24.5 Do 9:45 HS 1010

Plasma exposure of W-based smart alloys for the fusion power plant — •Janina Schmitz[1,2], Felix Klein[1], Tobias Wegener[1], Xiaoyue Tan[1], Andrey Litnovsky[1], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich — [2]Department of Applied Physics, Ghent University, Ghent

Although the final design of the fusion power plant DEMO has not been specified yet, there is no doubt that the plasma-facing wall will be subject to extreme conditions. Tungsten (W), featuring among others low tritium retention and sputter yield, is preferred as first wall material. In case of a LOCA (Loss-of-Coolant-Accident) the wall temperature rises above 1200 K for up to 3 months due to nuclear decay heat. With additional air ingress, radioactive volatile WO will be formed and its mobilisation into the environment poses a severe threat.

Smart alloys aim at suppressing the WO_3-sublimation while, thanks to preferential sputtering, behaving like pure W during plasma operation. Experiments in the linear plasma device PSI-2 help understanding the plasma influence onto the developed alloys. First experiments with W-Cr-Ti alloys and pure W showed comparable sputter yields (W: 1 mg, smart alloy: 1.1 mg mass loss) and confirmed the expected depletion of the alloying elements at the plasma-facing surface. In addition, the results of studies of new W-Cr-Y-systems under plasma impact, including changes in microstructure and oxidation behaviour, will be presented and discussed.

P 24.6 Do 10:00 HS 1010

Emulation of fusion neutron damage studies by 30 MeV protons — •Rahul Rayaprolu, Sören Möller, and Christian Linsmeier — Institut für Energie- und Klimaforschung - Plasmaphysik, Forschungszentrum Jülich GmbH, 52425 Jülich

Fusion reactor first wall materials are anticipated to undergo detrimental changes in mechanical properties upon exposure to characteristic neutron flux. The increase in yield stress in conjugation with drop in strain with increasing dose, initiates brittle behaviour which leads to imminent failure of parts under thermal cycling. Thus mapping of thermo-mechanical properties under fusion irradiation conditions is a major concern needing to be addressed.

While the straightforward path is to subjugate test materials to fission reactor studies, they often are time consuming (1+ years) and low energy tail biased. We propose the use of high energy (15 - 30 MeV) protons, under depth/ thickness constraints (300 - 500 μm) to obtain fusion irradiation emulated macroscopic mechanical properties. This is seen to reduce the cycle time from years to months and has shown better conformity to simulated fusion reactor estimates (1 dpa irradiation). Additionally, established codes FISPACT-II and SPECTRA-PKA are applied to completely describe proton irradiation behavior on materials.

P 25: Theory and Modeling III

Zeit: Donnerstag 8:30–10:30 Raum: HS 2010

Hauptvortrag P 25.1 Do 8:30 HS 2010

Modeling streamer discharges in strong magnetic fields — •Jannis Teunissen[1], Anbang Sun[2], and Ute Ebert[3] — [1]Centre for Mathematical Plasma-Astrophysics, KU Leuven, Belgium — [2]Xi'an Jiaotong University, China — [3]Centrum Wiskunde & Informatica, Amsterdam, The Netherlands

There exist many electric discharges in which magnetic effects play a major role, but streamers are typically not one of them. However, it appears that in Jupiter's atmosphere streamers could actually be magnetized. Here we employ numerical simulations to investigate this phenomenon, using a combination of 3D particle-in-cell simulations, electron transport calculations, and plasma fluid modeling. We observe that streamer inception, propagation and branching are all affected by a strong external magnetic field, and we discuss how this can be related to the modified electron transport properties.

P 25.2 Do 9:00 HS 2010

Electron dynamics in magnetized technological plasmas: A kinetic description — •Ralf Peter Brinkmann and Dennis Krüger — Ruhr-Universität Bochum

Many advanced thin-film deposition processes like HIPIMS (High Power Impulse Magnetron Sputtering) or PIAD (Plasma-Ion Aided Deposition) employ magnetized plasmas at a pressure range of 0.1 to 1 Pa and a magnetic field of 10 to 100 mT. In such plasmas, the electron gyration radius rL is of the order of a millimeter, whereas the mean free path λ is much larger, typically comparable with the plasma source dimension L itself (some tens to hundreds of millimeters). It is generally acknowledged that in this regime fluid dynamics fails and a kinetic approach is required. This work employs the smallness of the parameter epsilon rL/λ*rL/L to reduce the complexity of that approach to a tractable level. As an application, the phenomenon of spoke formation in HIPIMS discharges is addressed.

P 25.3 Do 9:15 HS 2010

Electric double layers at plasma-wall interfaces — •Franz Xaver Bronold and Holger Fehske — Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, 17489 Greifswald, Deutschland

The basic response of a plasma to a macroscopic body is the formation of the plasma sheath. It is the positive part of an electric double layer whose negative part is inside the solid. A stationary sheath develops if the generation of electrons and ions in the plasma is balanced by electron and ion losses at or inside the wall. A complete modeling of the plasma sheath has to take the losses into account. It should thus cover not only the plasma physics of the positive part of the double layer but also the solid state physics affecting the negative part. For a dielectric wall we developed such a model. It is based on two sets of Boltzmann equations operating in disjunct half-spaces: One set is for the electrons and ions in the plasma half-space while the other is for conduction band electrons and valence band holes in the wall half-space. The two sets are connected by a quantum-mechanically derived matching condition for the electron distribution functions and a semi-empirical model for hole injection due to neutralization of ions at the plasma-wall interface. Essential for the model is also the merging of the space charge region with, respectively, the neutral bulk plasma and the intrinsic or extrinsic bulk of the wall. To demonstrate the feasibility of our approach we present results for a collisionless double layer developing, respectively, at an intrinsic silicon dioxide and p-type silicon surface both facing a low-temperature hydrogen plasma. — Supported by DFG through CRC/Transregio TRR24.

P 25.4 Do 9:30 HS 2010

Kinetische Berechnung der Transportkoeffizienten der Elektronen in CO_2 — •Detlef Loffhagen — INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald

Untersuchungen zum Verhalten von Elektronenschwärmen ermöglichen es, wesentliche Transportkoeffizienten der Elektronen in Gasen zu bestimmen. Hierbei werden häufig Time-of-Flight-Experimente durchgeführt, bei denen der hydrodynamische Zustand zur Ermittlung der Driftgeschindigkeit des Massenschwerpunkts, des zugehörigen longitudinalen Diffusionskoeffizienten und der effektiven Ionisationsfrequenz verwendet wird. Im Rahmen dieses Beitrages wird eine neues numerisches Verfahren zur Bestimmung dieser Transportkoeffizienten der Elektronen vorgestellt. Die Methode basiert auf der Lösung der orts- und zeitabhängigen Boltzmanngleichung der Elektronen in einer räumlich eindimensionalen Anordnung. Die Lösung dieser kinetischen Gleichung erfolgt auf der Grundlage der konventionellen Zweitermnäherung der Entwicklung der Geschwindigkeitsverteilung der Elektronen nach Legendre-Polynomen. Sie ermöglicht die Charakterisierung des raum-zeitlichen Verhaltens der Elektronenschwärme sowie die Bestimmung der Transportkoeffizienten des Massenschwerpunkts und der geschwindigkeitsgemittelten makroskopischen Größen der Elektronen. Erste Ergebnisse für CO_2 werden vorgestellt und mit experimentellen Daten und Resultaten von Monte-Carlo-Simulationen verglichen.

P 25.5 Do 9:45 HS 2010

Thermodynamics of the ions in the sheath — Uwe Czarnetzki and •Tsanko Tsankov — Institute for Plasma and Atomic Physics, Ruhr-University Bochum, 44780 Germany

Space charge sheaths form where the plasma is in contact with a surface. The high electric field in the sheath strongly accelerates the ions and largely determines the properties of their population reaching the wall. These properties are important for the plasma-wall interaction. One of the prominent parameters that describe the energy spread of the ions is their effective temperature.

Here, through a kinetic approach it will be shown, that in a fully collisionless sheath the effective ion temperature cools down due to an adiabatic expansion. The presence of collisions leads to ion energy flow and heating of the ions. This effect can reverse the trend of a decrease of the effective ion temperature as the ions approach the wall. Experiments and simulations show that even weak collisionality is sufficient for that. The results apply for both stationary and oscillating sheaths, provided the ion transport can be treated as quasi-stationary.

P 25.6 Do 10:00 HS 2010

Effective interaction potentials and dynamic properties of

weakly coupled partially degenerate nonisothermal dense plasmas — •Zhandos Moldabekov[1,2], Tlekkabul Ramazanov[2], Sandugash Kodanova[2], Maratbek Gabdullin[2], and Moldir Issanova[2] — [1]ITAP, CAU, Kiel, Germany — [2]Al-Farabi Kazakh National University, Almaty, Kazakhstan

Hot dense plasma generated in NIF, Z-pinch, and GSI is usually nonisothermal and evolves from nonideal dense quantum plasma to ideal classical plasma. The effective pair interaction approach can be used for the fast and accurate study of the various physical properties of the weakly coupled semiclassical dense plasma. Therefore, the effective interaction potentials for the description of such plasma have been developed. Thermodynamic, microscopic, and transport properties of the weakly coupled dense nonisothermal plasma have been studied [1,2,3]. First of all, it is shown that developed effective interaction potentials correctly describes thermodynamic properties [1]. Secondly, the calculations of the transport properties in the simple pair collision approximation on the basis of the effective interaction potentials give good agreement with the orbital free DFT results [2]. Thirdly, the impact of the dynamical screening and electrons degeneracy on the stopping power has been analyzed. Finally, the impact of the nonideality effect on the characteristics of the DT tablet explosion has been considered.

[1] T.S. Ramazanov et al., Phys. Rev. E 92, 023104 (2015) [2] M.K. Issanova et al., Laser and Particle Beams 34, 457 (2016) [3] M.K. Issanova et al., Contrib. Plasma. Phys. 56, 425 (2016)

P 25.7 Do 10:15 HS 2010

Macroparticles in ion beam processing — •Elena Romashchenko, Igor Girka, and Alexander Bizyukov — V.N.Karazin Kharkiv National University, Svobody sq.,4, Kharkiv 61077, Ukraine

Ion beam processing of materials such as vacuum arc deposition and ion implantation is utilized to produce coatings with advantageous properties. The macroparticle (MP) contamination is the most important technological problem. The results of theoretical study of MP charging and dynamics in front of the negatively biased substrate for two energy regimes of ions are presented. The charge and dynamics of MP are governed by local parameters of ion and secondary electron emission fluxes in the sheath. The effect of electron emission from the substrate due to bombardment of multiply charged ions on MP dynamics is studied. It has been found that the MP number decreases with increasing substrate bias for both cases. It is shown that the maximum possible velocity of repelled MP increases with increasing substrate bias voltage.

P 26: Plenarvortrag Annemie Bogaerts

Zeit: Donnerstag 11:00–11:45 Raum: HS 2010

Plenarvortrag P 26.1 Do 11:00 HS 2010

Plasma-based CO2 conversion: Better insights by modeling — •Annemie Bogaerts — Research group PLASMANT, University of Antwerp, Department of Chemistry, Antwerp, Belgium

Plasma-based CO2 conversion is gaining increasing interest. To improve this application in terms of conversion, energy efficiency and product formation, a good insight in the underlying mechanisms is desirable. We try to obtain this by computer modeling. We use 0D chemical kinetics modelling to describe the plasma chemistry in three types of plasma reactors most commonly used for CO2 conversion, i.e., dielectric barrier discharges, microwave plasmas and gliding arc discharges.

We focus especially on the role of vibrationally excited CO2 levels, which are crucial for energy efficient CO2 conversion.

We have also studied the plasma chemistry in CO2/CH4 and CO2/H2O mixtures, for producing value-added chemicals, such as syngas and oxygenated compounds. A detailed chemical kinetics analysis allows to elucidate the different pathways leading to the observed results, and to propose solutions on how to further improve the formation of value-added products.

Finally, we also studied the plasma chemistry in CO2/N2, to investigate the effect of this important impurity in effluent gases. Several harmful NOx compounds are produced, and the reaction pathways for the formation of these compounds are again explained based on a kinetic analysis, which allows proposing solutions on how to prevent the formation of these harmful compounds.

P 27: Low Temperature Plasmas

Zeit: Donnerstag 14:00–16:00 Raum: HS 2010

Hauptvortrag P 27.1 Do 14:00 HS 2010

Plasma discharges for the ambient processing of materials — •James Bradley — University of Liverpool, United Kingdom

Atmospheric-pressure plasmas are finding many applications in industry and technology, ranging from thin film deposition to wound healing. At the University of Liverpool, dielectric barrier discharges (DBD's) are being developed and studied for the processing of polymeric materials. Two configurations are being considered: parallel plate discharges for the treatment of polypropylene in packaging applications and plasma jets for the polymerisation of soft organic films in cell/tissue engineering applications and for the production of antimicrobial surfaces. To understand these plasmas better, a suite of diagnostic techniques are being used, including molecular beam mass spectrometry, non-invasive current probes and nano-second 2-D imaging. Thin films and treated surfaces produced by the different discharge configurations are analysed using XPS, FTIR and TOF SIMS.

P 27.2 Do 14:30 HS 2010

ERO modelling of surface morphology effect on metal erosion — •Alina Eksaeva[1,2], Dmitry Borodin[1], Arkadi Kreter[1], Daisuke Nishijima[3], Albrecht Pospieszczyk[1], Tobias Schlummer[1], Bernhard Unterberg[1], Stephan Ertmer[1], Andreas Kirschner[1], Juri Romazanov[1], Sebastijan Brezinsek[1], and Evgeny Marenkov[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung, 52425 Jülich, Germany — [2]National Research Nuclear University MEPhI, 31, Kashirskoe sh., 115409, Moscow, Russia — [3]Center for Energy Research, University of California at San Diego, 9500 Gilman Dr., La Jolla, CA 92093-0417, USA

Linear plasma device PSI-2 with its continuous plasma operation is an excellent test bed for the investigation of plasma-facing material erosion including delicate effects like e.g. nano- and micro-scale surface structures and roughness. However, numerical modelling is indispensable for the correct interpretation of experiments. The 3D Monte-Carlo code ERO is a tool for describing the erosion and local transport of impurities taking into account the particular geometry. Several experiments have been carried out at PSI-2 facility to investigate the evolving surface morphology of tungsten (W) and chromium (Cr) and provide a consistent set of data for the interpretation with the ERO code. The aim of this work is to incorporate the effect of surface morphology into the ERO modelling based on free parameters (angular, energy distributions of sputtered particles, sputtering yields influenced by morphology evolution, metastable states lifetime) matched with the experiments.

Fachvortrag P 27.3 Do 14:45 HS 2010

Coupling mechanisms in inductive discharges with RF substrate bias driven at consecutive harmonics with adjustable relative phase — •Birk Berger[1,2], Thomas Steinberger[1], Mark Koepke[1], Thomas Mussenbrock[2], and Julian Schulze[1,3] — [1]Department of Physics, West Virginia University, Morgantown, USA — [2]Electrodynamics and Physical Electronics Group, Brandenburg University of Technology, Cottbus, Germany — [3]Institute for Electrical Engineering, Ruhr-University Bochum, Germany

In plasma etching applications a combination of inductively and capacitively coupled RF plasmas are commonly used. The reason is that the inductive coupling ensures a high plasma density, while the capacitive coupling allows for a control of the ion bombardment energy at a substrate. In our study we experimentally investigate the coupling mechanisms between a phase-locked inductive and capacitive source driven at 13.56 MHz and 27.12 MHz, respectively. In the E-Mode the DC self-bias at the electrode can be controlled via the Electrical Asymmetry Effect by adjusting the phase between both sources. In the transition region from E- to H-Mode the ion flux to the electrode was measured using a Retarding Field Energy Analyzer. The ion flux was found to be affected by the value of relative phase, which can be explained by the electron power dissipation dynamics during one RF cycle using Phase Resolved Optical Emission Spectroscopy.

Fachvortrag P 27.4 Do 15:10 HS 2010

Striations in electronegative capacitively coupled radio frequency plasmas — •Julian Schulze[1,2], Yong-Xin Liu[3], Edmund Schüngel[4], Ihor Korolov[5], You-Nian Wang[3], and Zoltan Donko[5] — [1]Department of Physics, West Virginia University, USA — [2]Institute for Electrical Engineering, Ruhr-University Bochum, Germany — [3]School of Physics, Dalian University, China — [4]Evatec, Switzerland — [5]Hungarian Academy of Sciences, Hungary

Self-organized spatial structures in the light emission from the radio frequency plasma of an electronegative gas (CF4) are observed experimentally by Phase Resolved Optical Emission Spectroscopy for the first time. Their formation is analyzed and understood with the aid of particle-based kinetic simulations. These "striations" are found to be generated by a resonance between the external driving radio-frequency and the eigenfrequency of the ion-ion plasma that leads to a modulation of the electric field, the ion densities, as well as the energy gain and loss processes of electrons in the plasma. The growth of the instability is followed by the numerical simulations [1]. The presentation introduces this effect conceptually and explains its physical origin. [1] Y.-X. Liu et al. 2016 Phys. Rev. Lett. 116 255002

Fachvortrag P 27.5 Do 15:35 HS 2010

Radiale Entwicklung des Streamerdurchbruchs in gepulsten, dielektrisch behinderten Entladungen — •Hans Höft und Manfred Kettlitz — INP Greifswald, Felix-Hausdorff-Straße 2, 17489 Greifswald

Die zeitliche Entwicklung des Durchmessers von gepulsten, dielektrisch behinderten Entladungen (DBE) wurde mit Hilfe von iCCD- und Streakkameraaufnahmen mit Sub-ns-Zeitauflösung untersucht. Dazu wurde eine Einzelfilamentanordnung mit 1 mm Entladungsspalt in einem N_2-O_2-Gasgemisch bei Atmosphärendruck (0,1 Vol.-% O_2 in N_2) genutzt. Es wurde ein Zusammenhang zwischen der axialen Propagationsgeschwindigkeit des positiven (kathodengerichteten) Streamers und der Vergrößerung des Durchmessers gefunden, d. h. der Durchmesser erhöht sich mit steigender axialer Propagationsgeschwindigkeit. Dieses Resultat wird durch die gleichzeitige Betrachtung von axialer und radialer Propagationsgeschwindigkeit ergänzt, die sich um ca. zwei Größenordnungen unterscheiden ($v_{\text{Prop}}^{\text{axial}} \sim 10^6\ \frac{\text{m}}{\text{s}}$ bzw. $v_{\text{Prop}}^{\text{radial}} \sim 10^4\ \frac{\text{m}}{\text{s}}$). Außerdem konnte die radiale Ausbreitung des kathodengerichteten Streamerdurchbruchs sowie der anschließenden transienten Glimmentladung separiert werden. Dazu wurden spektral aufgelöste Aufnahmen des zweiten positiven und ersten negativen Systems von N_2 bzw. N_2^+ (337 nm und 391 nm) genutzt. Diese Ergebnisse liefern einen Einblick in die radiale Dynamik des Streamers mit hoher Orts- und Zeitauflösung. Zusammen mit synchronisierten elektrischen Messungen können zudem Aussagen über die zeitliche und räumliche Entwicklung der Stromdichte im Entladungskanal getroffen werden.

P 28: Helmholtz Graduate School III

Zeit: Donnerstag 14:00–16:30 Raum: HS 1010

P 28.1 Do 14:00 HS 1010

Modelling of Caesium redistribution in the RF negative hydrogen ion source ELISE — •Alessandro Mimo, Christian Wimmer, Dirk Wünderlich, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

The Neutral Beam Injection systems for ITER rely on large and powerful RF sources of negative hydrogen ions, which are mostly produced by conversion of neutral hydrogen atoms on a converter surface. The conversion efficiency is increased by evaporating Cs in the source, which provides a reduction of the converter surface work function. Experiments have shown that a sufficient flux of Cs onto the converter surface during the beam pulse needs to be provided in order to avoid a reduction of the performance. The dynamics of Cs redistribution in negative ion sources was modeled by means of the Monte Carlo transport code CsFlow3D, which calculates the time evolution of Cs fluxes and coverage onto the source surfaces. Preliminary simulations have shown that the Cs dynamics is influenced by the location of the Cs evaporation nozzle and the amount of Cs present inside the source. This work focuses on the application of the code to the large ion source ELISE, half of the ITER NBI source size. Results of Cs redistribution simulations for different operational parameters, such as the Cs evaporation rate, the duty cycle and the duration of the beam pulse (from ten seconds up to one hour) will be presented and compared with experimental measurements. The results will help to improve the Cs management and to reduce the Cs consumption which is, in particular, of high relevance for a NBI system for DEMO.

P 28.2 Do 14:25 HS 1010

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

Tokamak fusion devices rely on a high plasma current (several MA) for magnetic confinement. When the plasma suddenly loses most of its thermal energy due to instabilities, the plasma current disrupts. This leads to high heat loads onto the plasma facing components, large forces on the vacuum vessel due to induced eddy and halo currents in the strong toroidal magnetic field and electrons at relativistic energies. Massive gas injection (MGI) has proven to be an effective tool for mitigating heat loads, induced currents and runaway electrons. For this purpose, the tokamak ASDEX Upgrade has been equipped with a new system of in-vessel fast gas valves which are able to release a strong pulse of noble gas into the vessel within milliseconds (typical flow rate 10^5 Pam^3/s). The system consists of two pairs of valves located on opposite toroidal positions. The first pair is composed of two identical spring-driven valves (max. gas inventory 640 Pam^3), one on the mag. low field side (LFS) and one the high field side (HFS). The second pair includes a piezoelectric valve (210 Pam^3) on the HFS and a spring-driven valve (400 Pam^3) on the LFS. Details on the valve development and the in-vessel setup will be presented.

P 28.3 Do 14:50 HS 1010

Line ratio spectroscopy on thermal helium provides electron temperature and density information at the plasma edge of ASDEX Upgrade — •Michael Griener[1,2], Elisabeth Wolfrum[1], Jorge Muños Burgos[3], Oliver Schmitz[4], Ulrich Stroth[1,2], and the ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]Physik Department E28, TUM, Garching — [3]Department of Physics & Astronomy, Johns Hopkins University, Baltimore, USA — [4]Engineering Physics Department, University of Wisconsin-Madison

In magnetically confined fusion devices large power fluxes cross the last closed flux surface. The local power deposited on the first wall depends strongly on the transport perpendicular to the magnetic field lines. It can be dominated e.g. by filamentary structures or turbulence. To investigate steady-state as well as fast transport processes, a thermal helium beam has been implemented as plasma edge diagnostic at the ASDEX Upgrade experiment. Helium emission intensity ratios of two singlet lines combined with a collisional radiative model (CRM) enable the reconstruction of electron density values, whereas singlet-triplet ratios provide the electron temperature.
In this talk, the physical principle as well as the hardware components of the He-diagnostic will be presented. The measured absolute emission intensity profiles of several He I transitions are compared to the

calculated values of two CRMs. One is based on equilibrium assumptions, the other models the time evolution of the two spin systems. This influence on the resulting n_e and T_e profiles is discussed.

P 28.4 Do 15:15 HS 1010

Argon LIF Measurements in a high-power helicon discharge — •Nils Fahrenkamp, Birger Buttenschön, and Olaf Grulke — Max Planck Institute for Plasma Physics, 17491 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 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 shows a transient behavior over the discharge 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 radial neutral gas and ion density profile with high temporal resolution. Detailed measurements of the neutral pumping effect for various operation parameters and neutral gas inlet options are presented with special emphasis on its effect on the peak metastable density and the plasma density dynamics. The results are compared with a zero dimensional reaction rate model developed for low temperature argon plasmas and plasma density measurements of a CO_2-interferometer setup. Calculations of temporally resolved radial electron temperature profiles are shown using atomic line intensity ratio measurements.

P 28.5 Do 15:40 HS 1010

Interpretation of the Electron Cyclotron Emission of hot thermal and non-thermal ASDEX Upgrade plasmas — •Severin S. Denk[1,2], Rainer Fischer[1], Joan Decker[3], Omar Maj[1], Stefan K. Nielsen[4], Morten Stejner[4], Emanuele Poli[1], Jörg Stober[1], Ulrich Stroth[1,2], Wolfgang Suttrop[1], Branka Vanovac[5], Egbert Westerhof[5], Matthias Willensdorfer[1], and The ASDEX Upgrade Team[1] — [1]MPI für Plasmaphysik, Garching, Germany — [2]Physik-Department E28, TUM Garching, Germany — [3]EPFL, Centre de Recherches en Physique des Plasmas Lausanne, Switzerland — [4]Department of Physics, DTU, Lyngby, Denmark — [5]FOM-Institute DIFFER, Eindhoven, The Netherlands

The electron cyclotron emission (ECE) diagnostic is a well established and robust instrument for the measurement of the electron temperature T_e. However, the conventional interpretation of ECE measurements is inaccurate near the plasma edge, for $T_\mathrm{e} > 7\,\mathrm{keV}$, and for plasmas with fast electron populations. It will be shown that these limitations can be overcome if the electron cyclotron radiation transport is integrated in the analysis of the ECE measurements. For hot plasmas the accuracy of the radiation transport model could be greatly improved, by extending the model with a fully relativistic absorption coefficient, where the dispersion of the plasma is considered in the cold plasma limit. Furthermore, the model allows the ECE by fast electrons to be estimated. Moreover, models predicting the formation of fast electron populations will be compared with experimental observations.

P 28.6 Do 16:05 HS 1010

Acceleration of Bayesian Model Based Data Analysis for W7-X Density and Temperature Profiles — •Humberto Trimino Mora[1], Jakob Svensson[1], Andreas Werner[1], Oliver Ford[1], Sergey Bozhenkov[1], Dirk Timmermann[2], Robert Wolf[1], and W7-X Team[1] — [1]MPI für Plasmaphysik — [2]Rostock University

Density estimation for plasma analysis and control is a crucial element in magnetic confinement devices. Most of these have redundant density diagnostics to compare or calibrate; meaning that data from two different diagnostics measuring the same plasma parameter are available. Although the data is typically analyzed separately, a good solution for data fusion of two or more diagnostics is Bayesian data analysis. This allows estimation of specific parameters and their uncertainties for non-linear inverse problems in a strictly mathematical way.
The computation time and power required for the aforementioned problem is usually long, making it a post-processing technique that cannot be used in real time with rare exceptions.
This contribution proposes a design to accelerate data fusion of the W7-X Dispersion Interferometer's line integrated electron density with the Thomson Scattering's electron density and temperature along congruent lines of sight. This in order to provide in real time, a temperature profile and a more reliable density profile. The proposed design is implemented with reconfigurable hardware taking advantage of application specific circuits and parallelism to improve its processing time. An acceleration of Bayesian analysis for inverse problems is often necessary and would prove generally valuable for scientific inference.