Plasma Physics Division
Fachverband Plasmaphysik (P)

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Overview of Invited Talks and Sessions

(Lecture rooms A 0.112 and Kl 1.174; Poster Redoutensaal and Zelt Ost/West)

Invited Talks

P 2.1	Mon	10:30–11:00	KI 1.174	**Key Features of Reactive High Power Impulse Magnetron Sputtering** — •Daniel Lundin
P 4.1	Mon	14:00–14:30	KI 1.174	**High-resolution spectroscopic and electrical diagnostics of barrier discharges** — •Tomas Hoder
P 6.1	Mon	16:15–16:45	KI 1.174	**Collisionless damping in the spectra of active plasma resonance spectroscopic probes** — •Jens Oberrath
P 7.1	Tue	10:30–11:00	A 0.112	**Plasma Edge Physics with 3D Magnetic Boundaries - an Overview** — •Oliver Schmitz
P 8.1	Tue	10:30–11:00	KI 1.174	**Life in the void: nanoparticle formation in reactive plasmas** — •Ferdi van de Wetering
P 9.1	Tue	14:00–14:30	A 0.112	**Next generation gases in gas discharge applications.** — •Christian Franck
P 10.1	Tue	14:00–14:30	KI 1.174	**Self-consistent theory of radiation friction losses in ultraintense laser-plasma interaction** — •Tatyana Liseykina, Sergey Popruzhenko, Andrea Macchi
P 16.1	Wed	14:00–14:30	KI 1.174	**Diagnostics and application of reactivity of atmospheric plasmas in studies relevant for plasma medicine** — •Jan Benedikt, Mohamed Mokhtar Hefny, Gert Willems, Pascal Vogel, Clara Karczewski, Julia Bandow, Petr Lukes
P 23.1	Thu	10:30–11:00	A 0.112	**Advanced Materials for a Damage Resilient Divertor for DEMO** — •Jan Willem Coenen, Johann Riesch, Hanns Gietl, Yiran Mao, Leonard Raumann, Rudolf Neu, Christian Linsmeier
P 24.1	Thu	10:30–11:00	KI 1.174	**Transient plasma photonic crystals as novel optical devices for high-intensity lasers** — •Götz Lehmann, Karl-Heinz Spatschek

Invited talks of the joint symposium SYPS

See SYPS for the full program of the symposium.

SYPS 1.1	Mon	14:00–14:30	RW HS	**Floquet engineering of interacting quantum gases in optical lattices** — •André Eckardt
SYPS 1.2	Mon	14:30–15:00	RW HS	**Experiments on driven quantum gas and surprises** — •Cheng Chin
SYPS 1.3	Mon	15:00–15:30	RW HS	**Exploring 4D Quantum Hall Physics with a 2D Topological Pumps** — •Oded Zilberberg, Michael Lohse, Christian Schweizer, Immanuel Bloch, Hannah Price, Yaacov Kraus, Sheng Huang, Mohan Wang, Kevin Chen, Jonathan Guglielmon, Mikael Rechtsman
SYPS 1.4	Mon	15:30–16:00	RW HS	**Floquet Discrete Time Crystals in a Trapped-Ion Quantum Simulator** — •Guido Pagano, Jiehang Zhang, Paul Hess, Antonis Kyprianidis, Patrick Becker, Jacob Smith, Aaron Lee, Norman Yao, Tobias Grass, Alessio Celi, Maciej Lewenstein, Christopher Monroe

Invited talks of the joint symposium SYAD

See SYAD for the full program of the symposium.

SYAD 1.1	Tue	10:30–11:00	RW HS	**Integrated photonic quantum walks in complex lattice structures** — •Markus Graefe
SYAD 1.2	Tue	11:00–11:30	RW HS	**Testing the Quantumness of Atom Trajectories** — •Carsten Robens
SYAD 1.3	Tue	11:30–12:00	RW HS	**Engineering and probing topological bands with ultracold atoms** — •Nick Fläschner
SYAD 1.4	Tue	12:00–12:30	RW HS	**Statistical signatures of many-particle interference** — •Mattia Walschaers

Invited talks of the joint symposium SYPT

See SYPT for the full program of the symposium.

SYPT 1.1	Thu	10:30–11:00	M 00.910	**Pseudospark Research in Southern California** — •Martin Gundersen
SYPT 1.2	Thu	11:00–11:30	M 00.910	**Features of a hollow-cathode discharge in pseudospark switches** — •Yuri Korolev
SYPT 1.3	Thu	11:30–12:00	M 00.910	**Overview of R&D Activities on Vacuum and Gas Discharges and Their Applications in South Korea** — •Sang Hoon Nam
SYPT 1.4	Thu	12:00–12:30	M 00.910	**Plasma Stripper, Plasma Window, Plasma Gun as Applications of Discharge Plasmas** — •Joachim Jacoby
SYPT 2.1	Thu	14:00–14:30	M 00.910	**Plasmaphysical Basics of Vacuum Switching Devices for High Currents and Voltages** — •Norbert Wenzel
SYPT 2.2	Thu	14:30–15:00	M 00.910	**Discharge inception and breakdown in weakly and strongly electronegative gas in HV switchgear applications** — •Martin Seeger
SYPT 2.3	Thu	15:00–15:30	M 00.910	**Plasma Technological Research for Electrical Engineering and Medicine** — •Dirk Uhrlandt
SYPT 2.4	Thu	15:30–16:00	M 00.910	**Progress in Understanding Arc-Electrode Interaction** — •Jürgen Mentel

Sessions

P 1.1–1.6	Mon	10:30–13:00	A 0.112	**Helmholtz Graduate School I - Theory**
P 2.1–2.7	Mon	10:30–12:30	KI 1.174	**Low Pressure Plasmas I**
P 3.1–3.8	Mon	14:00–16:00	A 0.112	**Plasma Wall Interactions I / Astrophysical Plasmas**
P 4.1–4.7	Mon	14:00–16:00	KI 1.174	**Atmospheric Pressure Plasmas I**
P 5.1–5.4	Mon	16:15–17:55	A 0.112	**Helmholtz Graduate School II**
P 6.1–6.5	Mon	16:15–17:45	KI 1.174	**Codes and Modelling**
P 7.1–7.5	Tue	10:30–12:40	A 0.112	**Magnetic Confinement I - Helmholtz Graduate School III**
P 8.1–8.6	Tue	10:30–12:25	KI 1.174	**Complex Plasmas and Dusty Plasmas I**
P 9.1–9.7	Tue	14:00–16:00	A 0.112	**Atmospheric Pressure Plasmas II**
P 10.1–10.7	Tue	14:00–16:00	KI 1.174	**Laser Plasmas I**
P 11.1–11.33	Tue	16:15–18:15	Redoutensaal	**Helmholtz Graduate School - Poster**
P 12.1–12.14	Tue	16:15–18:15	Redoutensaal	**Magnetic Confinement - Poster**
P 13.1–13.17	Tue	16:15–18:15	Redoutensaal	**Low Pressure Plasmas - Poster**
P 14.1–14.4	Tue	16:15–18:15	Redoutensaal	**Astrophysical Plasmas - Poster**
P 15.1–15.5	Wed	14:00–16:05	A 0.112	**Helmholtz Graduate School IV - Plasma Wall Interaction**
P 16.1–16.7	Wed	14:00–16:00	KI 1.174	**Low Pressure Plasmas II**
P 17.1–17.12	Wed	16:15–18:15	Zelt Ost	**Atmospheric Pressure Plasmas - Poster**
P 18.1–18.3	Wed	16:15–18:15	Zelt Ost	**Plasma Wall Interaction I - Poster**
P 19.1–19.9	Wed	16:15–18:15	Zelt Ost	**Codes and Modelling - Poster**
P 20.1–20.8	Wed	16:15–18:15	Zelt West	**Plasma Wall Interaction II - Poster**
P 21.1–21.10	Wed	16:15–18:15	Zelt West	**Laser Plasmas - Poster**
P 22.1–22.6	Wed	16:15–18:15	Zelt West	**Complex Plasmas and Dusty Plasmas - Poster**
P 23.1–23.5	Thu	10:30–12:00	A 0.112	**Plasma Wall Interaction II**
P 24.1–24.5	Thu	10:30–12:00	KI 1.174	**Laser Plasmas II**
P 25	Thu	12:00–13:00	A 0.112	**Annual General Meeting of the Plasma Physics Division**
P 26.1–26.6	Thu	14:00–16:30	A 0.112	**Magnetic Confinement II - Helmholtz Graduate School V**
P 27.1–27.7	Thu	14:00–15:55	KI 1.174	**Complex Plasmas and Dusty Plasmas II**

Annual General Meeting of the Plasma Physics Division

Thursday 12:00–13:00 A 0.112

- Report
- Elections
- Locations of the DPG 2019 and 2020
- Presentation of the Poster Prizes

Conference Language

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

P 1: Helmholtz Graduate School I - Theory

Time: Monday 10:30–13:00 Location: A 0.112

P 1.1 Mon 10:30 A 0.112

Fully kinetic simulations of kinetic-scale collisionless plasma turbulence — •Daniel Groselj[1], Silvio Cerri[2], Alejandro Banon Navarro[1], Alfred Mallet[3], Christopher Willmott[4], Daniel Told[1], Nuno Loureiro[4], Francesco Califano[5], and Frank Jenko[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Department of Astrophysical Sciences, Princeton University, Princeton, NJ, USA — [3]Space Science Center, University of New Hampshire, Durham, NH, USA — [4]Plasma Science and Fusion Center, MIT, Cambridge, MA, USA — [5]Physics Department "E. Fermi", University of Pisa, Pisa, Italy

We present an overview of recent results obtained from a set of two- and three-dimensional, first-principles kinetic simulations of collisionless plasma turbulence with applications to the solar wind. The properties of the turbulence are compared against theoretical predictions as well as with results obtained from reduced-kinetic (gyrokinetic and hybrid-kinetic) simulations. The findings compare favorably against experimental measurements and demonstrate—from first physics principles—that the sub-ion-scale plasma turbulence under solar wind conditions is predominantly of kinetic Alfvén type. Furthermore, results from three-dimensional simulations show that the kinetic-scale turbulence naturally develops a scale-dependent anisotropy with respect to the local mean magnetic field, consistent with theoretical expectations for a so-called critically balanced kinetic Alfvén cascade.

P 1.2 Mon 10:55 A 0.112

Gyro-kinetic simulations of tokamaks and stellarators including collisions — •Christoph Slaby, Axel Könies, and Ralf Kleiber — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald

Gyro-kinetic particle-in-cell simulations are a versatile numerical tool that we use to compute the non-linear dynamics of energetic-ion-driven Alfvénic perturbations. Collisions, though often neglected in numerical simulations, play an important role, since they can significantly modify the non-linear saturation levels and thus influence particle transport out of the plasma. Especially with regard to a future fusion reactor, gaining an understanding of the underlying physics is crucial.

The non-linear dynamics and saturation of toroidicity-induced Alfvén eigenmodes is studied in tokamak and Wendelstein 7-X (W7-X) geometry. In the tokamak case, the numerical findings agree with the analytically predicted $\nu^{2/3}$-scaling from the Berk-Breizman model. On the other hand, the stellarator W7-X which is not covered by analytical theory shows a different scaling.

Lastly, hybrid simulations are performed for a realistic W7-X scenario looking for unstable modes that could be experimentally relevant. This W7-X case includes neutral beam injection, as foreseen for the up-coming operation phase 1.2b, and a realistic slowing-down distribution function for the fast ions coupled with a slowing-down collision operator.

P 1.3 Mon 11:20 A 0.112

Studying Alfvén eigenmodes driven by energetic particles in fusion plasmas using hybrid-gyrokinetic modelling — •Thomas Hayward-Schneider and Philipp Lauber — Max-Planck-Institut für Plasmaphysik (IPP), 85748 Garching, Germany

Although current fusion experiments see energetic particles (eps) from their heating systems, the suprathermal alpha particle population born from the fusion reactions of future burning plasmas will have a much greater ability to interact with Magnetohydrodynamic (mhd)-like modes. We introduce Alfvén eigenmodes (aes), and describe how the toroidicity of tokamak plasmas introduces the toroidicity-induced Alfvén eigenmode (tae) gap. Perturbative modelling of these taes is presented, using the nonlinear perturbative drift-kinetic initial value code hagis and the linear gyrokinetic eigenvalue code ligka. We show that reduced models can be used for the eigenvalue problem, allowing fast semi-analytical results applicable for wide parameter scans. For the projected iter 15 mega ampere scenario, we present both linear tae physics results comparing these models, and also nonlinear mode saturation results, making predictions about the saturated perturbation amplitudes and the transition between different ep transport regimes for iter.

P 1.4 Mon 11:45 A 0.112

Splitting Schemes and Compatible Spaces for Linearized MHD — •Mustafa Gaja[1,2], Emmanuel Franck[3], Eric Sonnendruecker[1,2], Ahmed Ratnani[1,2], Jalal Lakhlili[1], and Mariarosa Mazza[1] — [1]Max Planck Institute fuer Plasma Physik, Garching, Germany — [2]Technische Universitaet Muenchen, Muenchen, Germany — [3]Inria Nancy Grand Est and IRMA, Strasbourg, France

We investigate the linearized Magnetohydrodynamics (MHD) model for the evolution of the perpendicular components of the velocity and the magnetic fields in the context of tokamaks via the novel technique of Isogeometric Analysis (IgA) with high degree B-Splines. The discretization is based on compatible finite element spaces that preserve the natural properties (i.e, divergence-free condition) of the resulting operators to avoid spurious modes and related numerical instabilities. The geometry is planar and is written to be easily generalized to a torus case. We present results on the compatible discretization and couple this investigation with a hamiltonian splitting in time which allows to deconstruct the system into 'building-blocks' operators that could be inverted individually. Such operators, Laplacian like and Mass operators (H1 and L2 projectors, respectively) for example, are inverted using a robust and optimal ad-hoc multigrid (MG) designed using the Generalized Locally Toeplitz (GLT) theory. This MG is used as a preconditioner for Krylov-Type solvers where the GLT theory is used to construct an efficient smoother for the MG that eliminates the pathology ensuing from using high order B-Splines discretization.

P 1.5 Mon 12:10 A 0.112

An aligned discontinuous Galerkin method for anisotropic diffusion and variants — •Benedict Dingfelder[1,3], Florian Hindenlang[1], Ralf Kleiber[2], Axel Könies[2], and Eric Sonnendrücker[1,3] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]May-Planck-Institut für Plasmaphysik, Greifswald, Gearmany — [3]Technische Universität München, Garching, Germany

In magnetized plasmas of fusion devices the strong magnetic field leads to highly anisotropic physics. If only diffusion processes are considered, the diffusion along the magnetic field is dominating. In the limit of vanishing perpendicular diffusion, we obtain the anisotropic diffusion equation with a semidefinite diffusion tensor whose associated eigenvalue problem reads

$$-\nabla \cdot (bb \cdot \nabla\phi) = \omega^2\phi \qquad \text{in } \Omega \subset \mathbb{R}^2$$

for the two-dimensional fully periodic domain Ω and direction of the magnetic field b. This eigenvalue problem is difficult to solve due to the non-coercivity of the differential operator. We propose a discontinuous Galerkin (DG) method on a non-conforming mesh with locally aligned cells which allows us to coarsen the resolution parallel to the magnetic field. The resulting distribution of resolution is particularly suited for calculating small eigenvalues.

P 1.6 Mon 12:35 A 0.112

Analysing the performance of neural networks on reconstructing edge plasma properties in Wendelstein 7-X — •Marko Blatzheim[1,2], Daniel Böckenhoff[1], Hauke Hölbe[1], Thomas Sunn Pedersen[1], and Roger Labahn[2] — [1]MPG IPP, Greifswald, Germany — [2]University Rostock, Rostock, Germany

Artificial neural networks are a key technology to benefit from large amounts of data. The nuclear fusion experiment Wendelstein-7X is a fully optimized stellarator with the main goal to demonstrate steady state capability of fusion reactors. It is tried to analyse the edge plasma properties by artificial neural networks. Most data is based on simulations because experiment time is very limited. The same neural network should be able to deal with simulated results or experimental camera data as input. In a pre-processing step, characteristics of the simulation results and the camera images are extracted. These are expected to be sufficiently similar. The neural network performance for different such parametrizations is compared. Depending on the parametrization dimensionality, more complex neural network structures can be investigated. The most promising parametrizations will be used for more complicated plasma property reconstructions and predictions.

P 2: Low Pressure Plasmas I

Time: Monday 10:30–12:30 Location: KI 1.174

Invited Talk P 2.1 Mon 10:30 KI 1.174

Key Features of Reactive High Power Impulse Magnetron Sputtering — •Daniel Lundin — Laboratoire de Physique des Gaz et Plasmas - LPGP, UMR 8578 CNRS, Université Paris Sud, Université Paris Saclay, 91405 Orsay Cedex, France

For many thin film applications, such as optical coatings, energy-related coatings, hard coatings, etc., the coated layers are not single metal thin films, but rather compound coatings obtained from at least one metal (e.g. Al, Ti) or a non-metal (e.g. C, B) and a reactive gas (e.g. O2, N2). This talk will address a promising thin film deposition technology called high power impulse magnetron sputtering (HiPIMS), and how this method differs from conventional processes. Key features in reactive HiPIMS, such as eliminated/reduced hysteresis and stable high-rate deposition in the transition mode, will be discussed. It will be shown that the discharge current evolution plays an important role, which we will analyze by investigating the combined processes of self-sputter recycling and process gas recycling using results from recent plasma process modelling in combination with experimental plasma characterization. Above a critical current density, a combination of self-sputter recycling and gas-recycling is generally required. The relative contributions of these recycling mechanisms, in turn, influence both the electron energy distribution and the stability of the discharges. A new framework including a generalized recycling map will be introduced to quantify these effects.

P 2.2 Mon 11:00 KI 1.174

Probing the Electron Density of Spokes in a HiPIMS Plasma Using Target Inserts — Ante Hecimovic, •Julian Held, Volker Schulz-von der Gathen, Wolfgang Breilmann, Christian Maszl, and Achim von Keudell — Experimental Physics II, Ruhr-University Bochum, Germany

In High power impulse magnetron sputtering (HiPIMS) a magnetron discharge is operated with short, high-voltage pulses, creating a highly dense plasma. Those pulses have a length in the order of 100 μs and power densities of several kW cm^{-2}. At high discharge currents, the plasma emission is not homogeneous but is instead organized into distinct zones of high plasma emission, which rotate in ExB direction a few mm above the target surface. These so called "spokes" are thought to improve ion transport to the substrate and might therefore be the key to improve the deposition rate. The strong emission indicates an elevated electron density. However, it would disturb the plasma considerably to position a probe in the vicinity of the target. Therefor, no direct measurement of the electron density inside the spokes has been performed. In this contribution, small electrically isolated inserts in the target surface were used to probe the local current density. Simple sheath theory was then applied to derive the electron density at the sheath edge. The electron density was in the order of 10^{19} m^{-3} and scaled linearly with discharge current. The electron density was elevated by about 50% when a spoke was present above the insert.

P 2.3 Mon 11:15 KI 1.174

Correlation of current shape and surface poisoning in reactive high power impulse magnetron sputtering by means of X-ray photoelectron spectroscopy — •Sascha Monjé[1], Vincent Layes[1], Carles Corbella[1], Achim von Keudell[1], Teresa de los Arcos[2] und Volker Schulz-von der Gathen[1] — [1]Experimental Physics II, Ruhr-University Bochum, Germany — [2]Technical and Macromolecular Chemistry, Paderborn University, Germany

High power impulse magnetron sputtering (HiPIMS) has established itself as one of the premier methods for depositing high quality hard coatings. Reactive gases can be added to the discharge to produce hard ceramic coatings. These gases can react with the target surface which is called "target poisoning". It has often been claimed that target poisoning is accompanied by a strong change of the current waveform but direct experimental verification is still needed. This was addressed by connecting spatially resolved X-ray photoelectron spectroscopy (XPS) measurements with measurements of the current waveform. The XPS characterization was performed after an in-vacuum transfer of the target to avoid any oxidation or contamination. A chromium target was used for the discharge. The Ar/O2 mixture, the input power and the frequency were varied to evaluate the racetrack oxidation state in different discharge regimes. The transition from poisoned to metal mode by increasing the power can be achieved using a frequency of 20 Hz. This transition can as well be seen in the current shape of the discharge which converges to its non-reactive form. This is a first approach to investigate the assumed correlation.

P 2.4 Mon 11:30 KI 1.174

Reactive magnetron sputtering of Ta-doped SnO_2 polycrystalline films at low temperatures: carrier transport and role of negative ion bombardment — •Stefan Seeger, Klaus Ellmer, Rainald Mientus, and Michael Weise — Optotransmitter-Umweltschutz-Technologie e.V., Köpenicker Str. 325, 12555 Berlin

Tin oxide (SnO_2) is significantly cheaper and chemically more resistive compared to the often used tin-doped indium oxide (ITO). In principle, low resistivities of doped SnO_2 are possible, caused by its isotropic 5s orbitals which are advantageous for good TCO transport properties. In this work conductive and transparent $SnO_2 : Ta$ films were deposited at low substrate temperatures by reactive DC and RF magnetron sputtering from a ceramic target ($Sn98at\%Ta2at\%O_2$) in Ar/O_2 , Ar/N_2O, and H_2O gas mixtures. The films were X-ray amorphous for substrate temperatures below about 200 °C. While the amorphous films are remarkably conductive ($5x10^{-3}\Omega cm$), the crystallized films exhibit higher resistivities due to grain boundary limited electrical transport. Also, for larger film thicknesses, caused by the heating of the films by the energy influx from the film species and the plasma, crystallization occurs. The width of the process window with respect to the reactive gas partial pressure depends on the type of the reactive gas and is wider for N_2O and H_2O. A prospective application of such X-ray amorpous $SnO_2 : Ta$ films are low temperature transparent and conductive protection layers, for instance to protect semiconducting photoelectrodes for water splitting.

P 2.5 Mon 11:45 KI 1.174

Modelling of chemical vapor deposition to improve tungsten fiber reinforced tungsten composites (Wf/W) — •L. Raumann[1], J.W. Coenen[1], J. Riesch[2], Y. Mao[1], H. Gietl[2,3], T. Höschen[2], C. Linsmeier[1], and O. Guillon[1] — [1]Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Max-Planck-Institut für Plasmaphysik, 85748 Garching b. München — [3]TU München, 85748 Garching

Due to the unique combination of excellent thermal properties, low sputter yield, hydrogen retention and activation, tungsten is the main candidate for the first wall material in future fusion devices. However, its intrinsic brittleness and its susceptibility to operational embrittlement is a major concern. To overcome this drawback, tungsten fiber reinforced tungsten composites featuring pseudo ductility have been developed. Bulk material can be successfully produced utilizing chemical vapor deposition of tungsten fabrics. However, a fully dense composite with a high fiber volume fraction is still a huge challenge. Therefore, a model is currently developed in Comsol including the complex coupling of transport phenomena and chemical reaction kinetics. To validate the model with experimental data, fibers were deposited in heated tubes under controlled parameter variation. The temperature and tungsten growth rate were measured along the fibers and inner tube surfaces for different heater temperatures, partial pressures and gas flows. With the experimental results the prediction of the model has been improved. As next step the model will be applied to design infiltration experiments to fabricate fully dense Wf/W composites with a high fiber volume fraction.

P 2.6 Mon 12:00 KI 1.174

Spectroscopic investigations of plasma nitrocarburizing processes with a mid-infrared frequency comb — Norbert Lang[1], Alexander D. F. Puth[1], Grzegorz Kowan[2], Stephan Hamann[1], Jürgen Röpcke[1], Piotr Masłowski[2], and •Jean-Pierre H. van Helden[1] — [1]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany — [2]Institute of Physics, Nicolaus Copernicus University, Torun, Poland

We report on the use of mid-infrared broadband direct frequency comb spectroscopy (DFCS) as a novel plasma diagnostic applied to spectroscopic investigations of plasma nitrocarburizing processes. With DFCS many molecular species can be detected simultaneously with high sensitivity and time-resolution yielding comprehensive data on their kinetics in the plasma and their interactions with a surface. Active screen plasma nitrocarburizing (ASPNC) is an advanced technology for the hardening of steel components using pulsed N_2-H_2 plasmas with an active screen made of solid carbon to produce carbon-containing species, which support the generation of anti-corrosive layers of high quality. However, many plasma chemical phenomena are far from completely understood. Therefore, spectroscopic investigations are being carried out in a downscaled plasma reactor based on an industrial scale ASPNC reactor. Our frequency comb operates around 3.2 μm (2900-3500 cm^{-1}), the fingerprint region for key process species such as NH_3, C_2H_2, C_2H_6, HCN, and CH_4 molecules. We will discuss the workings of DFCS and the influence of pressure, screen plasma power, and gas mixture on the concentrations of these species.

P 2.7 Mon 12:15 KI 1.174

***In-situ* measurement of optical properties of metallic surfaces using the Doppler-shifted emission of fast neutral atoms in a low density plasma** — •Sven Dickheuer[1], Oleksandr Marchuk[1], Christian Brandt[2], Andrei Goriaev[1], Mykola Ialovega[1], and PSI-2 Team[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

The knowledge about the optical properties of metallic surfaces during plasma exposition is crucial for many plasma diagnostics. In fusion plasmas, for instance, reflection properties of the plasma facing mirror and plasma wall components have a strong impact on the signal in the visible range. Until now no technique exists, which is able to monitor the modification of the optical properties without any additional calibration sources. We present an *in-situ* technique to measure the reflectance, its dynamic evolution and the polarization of different metallic surfaces (e.g. C, Al, Ti, Fe, Mo, Rh, Pd, Ag, Sn and W) in a H/Ar mixed plasma. The measurements are performed in the linear plasma device PSI-2, operating in the electron density range of $10^{11} - 10^{12}$ cm^{-3} and electron temperature range of $4 - 10$ eV. The optical properties are measured by analyzing the Doppler-shifted emission of fast hydrogen atoms, backscattered from the metallic surface, at different lines-of-sight at 656.279 nm (Balmer-α line). The comparison between measured reflectance and theoretical data shows a very good agreement (within 10 %).

P 3: Plasma Wall Interactions I / Astrophysical Plasmas

Time: Monday 14:00–16:00 Location: A 0.112

P 3.1 Mon 14:00 A 0.112

Impact of steady state deuterium plasmas on WCrY Smart Alloys — •Janina Schmitz[1,2], Andrey Litnovsky[1], Felix Klein[1], Tobias Wegener[1], Xiao Yue Tan[1], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung, 52425 Jülich, Germany — [2]Department of Applied Physics, Ghent University, 9000 Ghent, Belgium

Tungsten (W) is envisaged as first wall material for future fusion devices such as DEMO. W-based smart alloys aim at improving one of the drawbacks of W, its fast oxidation in case of accidental reactor scenarios such as a Loss-of-Coolant-Accident (LOCA) with air ingress. By adding chromium (Cr) and yttrium (Y) as alloying elements a protective oxide scale is formed on the smart alloy's surface when coming into contact with oxygen. During normal plasma operation alloying elements should be depleted, leaving the plasma facing a pure W surface. For assessing the plasma compatibility of smart alloys, WCrY and pure W samples were exposed to steady state pure D plasmas in the linear plasma-device PSI-2. By means of target biasing the ion impact energy was varied. For the two experiments conducted a fluence of $1 * 10^{26}$ ions/m^2 was reached, further plasma conditions are based on calculated DEMO first wall loads. As a consequence of preferential sputtering, ion energies of 220 eV resulted in a nearly doubled volumetric loss of WCrY in comparison to W. In contrast to this, at lower ion energies of 120 eV, Cr and Y were significantly depleted towards the surface while W was enriched. Analysis by Focussed Ion Beam (FIB) Technique revealed similar erosion yields for W and WCrY.

P 3.2 Mon 14:15 A 0.112

Characterization of a SnO2:Ta magnetron discharge by a multifunctional plasma and deposition sensor — Michael Weise[1], Stefan Seeger[1], Rainald Mientus[1], Karsten Harbauer[2], and •Klaus Ellmer[1] — [1]Optotransmitter-Umweltschutz-Technologie e.V., 12555 Berlin (Germany) — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, 14109 Berlin (Germany)

A multifunctional sensor (Welzel et al., Appl. Phys. Lett. 102 (2013) 211605), based on a conventional quartz crystal monitor (microbalance) for mass increase/decrease measurements, was used to measure quasi-simultaneously the deposition/etching flux, the energy flux and the charged particle flux in a magnetron discharge with a SnO2:Ta target. By moving the magnetron radially relative to the sensor, the lateral (radial) flux profiles of the 75 mm * magnetron were measured with a lateral resolution of about 8 mm, the diameter of the aperture in front of the quartz crystal. By combining the different measured quantities the ion-to-neutral ratio jion/jneutral and the mean energy per deposited atom were calculated, parameters that are essential for the characterization of plasma deposition and etch processes. These radial distributions were related to the optical and electrical properties of the transparent and conductive SnO2:Ta films, indicating a strong influence of the jion/jneutral ratio on the film resistivity.

P 3.3 Mon 14:30 A 0.112

Separated effects of particle species on plasma deposited coatings — •Beatrix Biskup, Christian Maszl, Wolfgang Breilmann, Julian Held, Marc Böke, Jan Benedikt, and Achim von Keudell — Experimental Physics II - Reactive Plasmas, Ruhr-University Bochum, 44780 Bochum, Germany

This work investigates the influence of different plasma particle species, namely neutrals, ions, metastables and (V)UV-photons, on the properties of plasma deposited coatings. To separate the different species and their influence on plasma treatment and film growth, we build an ion-repelling grid system (IReGS), which repels ions from the substrate.

In a first approach the deposition rate in a high power impulse magnetron sputtering (HiPIMS) process of chromium was measured with the composition of the IReGS and a quartz crystal microbalance (QCM). With this setup it is possible to measure the ionized metal flux fraction (IMFF). In comparison with measured ion fluxes by mass spectrometry and spoke image data we see the direct influence of the anomalous transport through spokes on the IMFF.

P 3.4 Mon 14:45 A 0.112

The impact of carbon and oxygen impurities on the effective charge state distribution in Wendelstein 7-X — •Jörg Cosfeld[1], Michael Rack[1], Detlev Reiter[1], Yühe Feng[2], and Wendelstein 7-X Team[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie und Klimaforschung Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald / 85748 Garching, Germany

Carbon and Oxygen have been identified as the two major impurities in the first divertor operation phase of the stellarator Wendelstein 7-X (W7-X). We present a computational approach to evaluate basic differences between these impurities regarding the effective charge state profile in the boundary region. The three dimensional interpretation tool EMC3-EIRENE [1][2] is applied, to isolate computationally the plasma responses caused by the strong inflows of Carbon and Oxygen, respectively, from other unknown plasma properties.

Here, differences for a plasma containing Carbon impurities, a plasma containing Oxygen impurities and a combination of both are evaluated. Free parameters considered for this study are the spatial location of impurity sources, plasma material interaction coefficients (mainly sputtering coefficients) and further free simulation parameters. An overview of the influence on plasma parameters like 3D density and temperature distributions is given.

[1] Y. Feng *et al. J. Nucl. Mater.* **266-269**, 812, (1999)
[2] D. Reiter *et al. Fusion Sci. Technol.* **47**, 172-186, (2005)

P 3.5 Mon 15:00 A 0.112

Experimental studies on tungsten produced by powder

injection moulding as plasma-facing materials — •Robert Krug[1], Bernhard Unterberg[1], Steffen Antusch[2], Jan-Peter Bähner[1], Jan Willem Coenen[1], Christoph Kaufmann[1], Arkadi Kreter[1], Yulia Martinova[1], Sören Möller[1], Gerald Pintsuk[1], Marcin Rasinski[1], Michael Rieth[2], Marius Wirtz[1], and Christian Linsmeier[1] — [1]Institut für Energie-und Klimaforschung, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Karlsruhe Institute of Technology, Institute for Applied Materials, P.O. Box 3640, 76021 Karlsruhe

Tungsten is the plasma facing material for future fusion reactors. In this contribution, we report on plasma exposure of pure tungsten produced via Powder Injection Moulding in the linear plasma device PSI-2 using deuterium plasmas with a moderate plasma flux density.The sample temperature has been kept to 420-450° C. In addition, some samples have been exposed to transient heat loads ($0.38GWm^{-2}$). Reference W samples(Plansee) were exposed under the same conditions for comparison. Net erosion, surface roughness and the resulting fuel inventory have been measured. The surface morphology has been analyzed prior and after the exposure. We observe in all cases an enhanced erosion of the PIM material. The response of the material to the transient heat loads is similar for both samples. Fuel retention in PIM-W shows strong variation with the resiudal carbon content. For PIM-W samples with lowest carbon content fuel retention is comparable to that in reference samples.

P 3.6 Mon 15:15 A 0.112

Optical spectroscopy of coronal iron in an electron beam ion trap — •Hendrik Bekker, Christian Hensel, Arnesh Daniel, Alexander Windberger, and José R. Crespo López-Urrutia — Max-Planck-Insitüt für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Solar eclipses, such as the recent (August 21st 2017) all-American total eclipse, are prime opportunities to study the weak optical coronal emission. This is because normally, emission from the photosphere overpowers it. Known since the 1870s, and first explained in the 1930s, the forbidden lines of highly charged iron ions are still a visible reminder of the not-yet well understood coronal heating mechanisms. This is in part due to a lack of reference data of the studied transitions. Therefore, we have investigated the optical spectra of highly charged Fe X-XIV ions using the Heidelberg electron beam ion trap (HD-EBIT). Using grating spectrometers, 12 lines were studied. Wavelengths of the often observed red and green coronal lines were determined with better-than-ppm precision, allowing in principle for absolute velocity determinations in coronal plasmas with uncertainties below 0.2 km s^{-1}. Furthermore, the Zeeman splitting of several of the lines in the strong magnetic field of the HD-EBIT was measured, yielding data of interest for studying the influence of magnetic fields in the coronal heating problem.

P 3.7 Mon 15:30 A 0.112

Nuclear reactions in laser-generated plasmas and their applications in astrophysics — •Yuanbin Wu — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany

Plasma screening is a general feature of nuclear reactions in astrophysical environments. We have recently theoretically demonstrated that it is possible to determine the plasma screening enhancement factor in the weak-screening regime for fusion reactions with an experimental setup envisaged at the upcoming ELI-NP facility where two laser beams generate two colliding plasmas [1].

In order to have a more similar condition to the astrophysical environments, we analyse here thermonuclear reactions in a single laser-generated plasma. Studies have shown that it is possible to isochorically heat targets at solid-state density to temperatures of a few hundred eV or even a few keV [2,3]. With this solid-state density plasma, we show that direct measurements of reaction rates in plasmas of astrophysical interest are possible under the conditions of strong-screening regime. Furthermore, neutrons produced from thermonuclear reactions in such plasmas have a very narrow energy spectrum which would have both astrophysical and industrial applications.

[1] Y. Wu and A. Pálffy, Astrophys.J. 838, 55 (2017).
[2] Y. Sentoku *et al.*, Phys. Plasmas 14, 122701 (2007).
[3] Y. Wu, J. Gunst, C.H. Keitel, and A. Pálffy, arXiv: 1708.04826.

P 3.8 Mon 15:45 A 0.112

Acceleration of Cosmic Rays in Supernova Shocks: mass to charge selectivity — •Adrian Hanusch[1], Tatyana Liseykina[1], and Mikhail Malkov[2] — [1]Universität Rostock - Institut für Physik — [2]University of California San Diego

The recent precise measurements of galactic cosmic rays (CR) by PAMELA [1] and AMS-02 [2] may shed light on the long standing problem of CR origin. While the CR particles are believed to be accelerated in supernova remnant (SNR) shocks via diffusive shock acceleration (DSA), it is still not understood how different CR elements are extracted from the supernova environments and injected into the DSA. The similarity of He/p, C/p, and O/p rigidity spectra demonstrated by AMS-02 has provided new evidence that injection is a mass-to-charge dependent process.

We perform hybrid simulations of collisionless shocks and study the joint injection of different ion species with A/Z up to 16. We analyze the A/Z-dependence of the injection efficiency, and by convolving it with the time evolution of the SNR reproduce the measured p/He ratio as a function of particle rigidity.

[1] O. Adriani *et al.*, *Science*, 332, 69, 2011.
[2] M. Aguilar *et al.*, *Phys. Rev. Lett.*, 115(21):211101, 2015.

P 4: Atmospheric Pressure Plasmas I

Time: Monday 14:00–16:00 Location: KI 1.174

Invited Talk P 4.1 Mon 14:00 KI 1.174

High-resolution spectroscopic and electrical diagnostics of barrier discharges — •Tomas Hoder — Masaryk University, Brno, Czech Republic

Streamer mechanism is one of the main ionisation mechanisms in high-pressure plasma jets, pulsing coronas or barrier discharges. In atmospheric air, it is an ultra-fast process which produces a light emission or current pulses with duration of only several units of nanoseconds. In such challenging case, an enhanced diagnostic method has to be applied. In this contribution, high-resolution sensitive spectroscopic and electrical methods will be presented which enable the determination of basic plasma parameters in mentioned fast ionising events. The presented methods will be applied to barrier discharges in contact with condensed matter - solid and liquid - and their use for further applied research will be critically discussed.

P 4.2 Mon 14:30 KI 1.174

Influence of feed gas humidity and reactor geometry on surface dielectric barrier discharges — •Michael Schmidt, Manfred Kettlitz, and Markus Becker — INP Greifswald, Felix-Hausdorff-Straße 2, 17489 Greifswald

Surface dielectric barrier discharges (SDBDs) are widely used for coating, gas cleaning and treatment of liquids or as plasma actuators. To achieve high energy efficiency and for safety reasons, smooth electrical operation parameters like low amplitudes and frequencies are desirable. The applicability of frequencies < 1 kHz and high voltage amplitudes < 7 kV for SDBDs in air is investigated in the presented study. It is found that the feed gas humidity has a substantial influence on the chemical activity of the plasma as well as on the electrical behavior of the discharge. Additionally, it is found that the reactor geometry and hence the flow properties of the feed gas also influences the performance of the SDBD significantly. The study shows that under dry conditions a large reactor volume, where only a small part of the feed gas is replaced continuously, has a higher chemical activity, measured by production of ozone, compared to a smaller reactor volume. However, the influence of the feed gas humidity is much stronger for the large reactor volume than for the smaller one. This is shown by power input into the plasma, plasma distribution throughout the SDBD and ozone production.

P 4.3 Mon 14:45 KI 1.174

Optical analysis of nanosecond-pulsed plasmas generated in liquids — •Katharina Grosse, Julian Held, Marc Böke, and Achim von Keudell — Exprimental Physics 2, Ruhr-University Bochum, Germany

Plasmas generated inside liquids have aroused interest over the last years particularly in the field of plasma medicine. The reactive species created in such an environment can modify surfaces which are in direct contact with the treated liquid. The physics of these plasmas and the interaction of the particles created inside the liquid with biological and metallic surfaces is not fully investigated. The analysed plasma is generated by a high-voltage nanosecond pulser creating 10 ns pulses with varying amplitudes of 14-26 kV and a pulsing frequency of 1 Hz. The dynamics of the discharges are monitored with shadowgraphy imaging and the created species with optical emission spectroscopy. Four distinct phases of the plasma development can be identified: ignition and plasma phase (1), generation of a shock wave (2), formation of a gas bubble (3) and separation of the bubble from the high-voltage electrode (4). The shock wave velocity in phase (2) was estimated to approximately 3.3 km/s for the different applied voltages.

P 4.4 Mon 15:00 KI 1.174

Parameters of Streamer Development for Nanosecond High Voltage Discharges in Water — •Jana Kredl, Tilo Schulz, and Juergen F. Kolb — Leibniz Institute for Plasma Science and Technology e.V. (INP Greifswald), Felix-Hausdorff-Str. 2, 17489 Greifswald

More and more drinking water is contaminated by an increasing concentration of pharmaceuticals. Although, concentrations are well below medical significant doses, environmental impacts, e.g. on fish populations, have already been observed. High voltage nanosecond discharges can be used to decontaminate waste water and degrade pharmaceutical residues in drinking water. Streamer that are generated provide in particular a strong reactive chemistry for degradation and decontamination. It is not clear yet how these streamers are created and determine the reactive chemistry. Thus, it is examined how streamer lengths and densities depend on the experimental parameters, i.e. applied voltage, pulse length, water conductance and discharge geometry. Therefore, a coaxial electrode arrangement is used. The inner electrode is a tungsten wire with 0.05 mm in diameter and the outer electrode is an iron mesh. The reactor itself is made of glass for optical access. The applied voltage is supplied by a self-made Blumlein-line pulse generator, which delivers square pulses in the nanosecond-range.

P 4.5 Mon 15:15 KI 1.174

Acoustical analysis of surface dielectric barrier and micro hollow cathode discharges — •Daniel Kotschate[1], Mate Gaal[1], and Holger Kersten[2] — [1]Department of Non-destructive testing, Bundesanstalt für Materialforschung und -prüfung, Germany — [2]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Germany

Due to the multi-physical appearance of gas discharges the possibilities of interaction with their surrounding environment are very wide. Some of the most common applications are the surface or material modification and acting as an ion source for mass spectroscopy applications. Since atmosphere plasma generates a massive amount of thermal energy caused by collisions in the sheath, this temperature alternation is also able to produce acoustic waves in the ambient gas volume (as lightning and thunder), which is called thermoacoustic effect.

This talk presents an overview of the experimental acoustic analysis of surface dielectric barrier and micro hollow cathode discharges. Regarding other methods of acoustic excitation, the thermoacoustic approach benefits of its massless working principle and the proper impedance matching. In addition to the characterisation, possible applications (e.g. plasma acoustic loudspeaker or transducer for air-coupled ultrasonic testing) concerning these discharge types are presented.

P 4.6 Mon 15:30 KI 1.174

Inception and Propagation of Pulsed Corona-like Discharges in Water — •Raphael Rataj, Tilo Schulz, and Juergen F. Kolb — Leibniz Institute for Plasma Science and Technology e.V., Felix-Hausdorff-Strasse 2, 17489 Greifswald, Germany

The potential of corona-like discharges in the liquid-phase for the treatment of sewage water was shown recently in chemical investigations on the degradation of pharmaceutical residues. However, the energy efficiency of this plasma treatment seems to be higher for the generation with short high voltage pulses. In particular discharges instigated with sub-microsecond high-voltage pulses were suggested.

A high-voltage Blumlein-line pulse generator for the application of defined 100-ns pulses was developed and connected to a plasma chamber with a point-to-half-sphere geometry. Single rectangular pulses were applied to the plasma reactor, which was operated with a continuous water flow. Plasma inception voltage and streamer propagation was investigated for different water conductivities, gap distances and pulse amplitudes.

First results show that neither electrode distance nor liquid conductivity have an impact on the streamer propagation lengths. For such short pulses in particular no stop-length could be identified. Detailed inception characteristics and plasma propagation behaviour are topic of the current research and will be presented.

P 4.7 Mon 15:45 KI 1.174

CO_2 dissociation in non-equilibrium atmospheric pressure plasmas — •Theresa Urbanietz, Sarah-Johanna Klose, and Achim von Keudell — Institut für Experimentalphysik II, Ruhr-Universiät Bochum, 44780 Bochum

The reduction of greenhouse gases such as CO_2 and CH_4 has gained a lot of interest in the last years. The conversion of CO_2 in a plasma can be used to produce useful chemicals and fuels such as syngas. The dissociation of CO_2 in a He/CO_2 atmospheric pressure plasma has been studied by in-situ Fourier Transform Infrared (FTIR) spectroscopy. For optimal investigation a plasma source is designed that allows to perform FTIR spectroscopy directly inside the plasma volume. The plasma volume is confined by potassium bromide (KBr) windows for measurements perpendicular and along the gas flow. For a detailed analysis of the FTIR spectra a reference spectrum is modelled using the HiTRAN database and compared to the measured spectra. This gives information about the vibrational and rotational temperature of the species as well as the concentration of the species. A variation of CO_2 admixture and power shows conversation rates up to 20% and energy efficiencies up to 30%. The vibrational temperature of CO is around 1300K whereas the rotational temperature stays nearly at room temperature. Inside the plasma volume a catalyst can be placed to investigate its performance and influence on the plasma. First results with nickel oxide catalysts on silica show a clear increase in the conversation rate.

P 5: Helmholtz Graduate School II

Time: Monday 16:15–17:55 Location: A 0.112

P 5.1 Mon 16:15 A 0.112

Bayesian inference of the electron cyclotron emission diagnostic at Wendelstein 7-X — •Udo Hoefel[1], Neha Chaudhary[1], Oliver Ford[1], Matthias Hirsch[1], Sehyun Kwak[1], Nikolai B. Marushchenko[1], Hans Oosterbeek[1], Andrea Pavone[1], Jonathan Schilling[1], Torsten Stange[1], Jakob Svensson[1], Yuriy Turkin[1], Gavin Weir[1], Robert C. Wolf[1,2], and the W7-X team[1] — [1]Institute for Plasma Physics, Greifswald branch — [2]Technical University Berlin

Wendelstein 7-X (W7-X) is an optimized stellarator that uses a 32 channel heterodyne electron cyclotron emission radiometer (ECE) as a standard diagnostic to measure the electron temperature profile with high temporal resolution.

In order to obtain a systematic calibration procedure with rigorous uncertainty estimates, modelling within the Bayesian Minerva framework has been used to infer the absolute effective sensitivities and beam widths from a periodic switching between a (hot) source at room temperature and a (cold) source at liquid nitrogen temperature.

As the ECE measures the radiation temperature and not directly the local electron temperature, a Gaussian process based profile inversion has been done to extract the electron temperature profile. For this purpose, the radiation transport code TRAVIS has been implemented in Minerva, allowing complex models of multiple diagnostics to include ECE data.

P 5.2 Mon 16:40 A 0.112

Bayesian modelling of multiple diagnostics at Wendelstein 7-

X using the Minerva framework — •Sehyun Kwak[1,2], Jakob Svensson[2], Sergey Bozhenkov[2], Humberto Trimino Mora[2], Udo Höfel[2], Andrea Pavone[2], Maciej Krychowiak[2], Andreas Langenberg[2], and Young-chul Ghim[1] — [1]Department of Nuclear and Quantum Engineering, KAIST, Daejeon 34141, Korea — [2]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

Consistent inference of physics parameters and their uncertainties for large scale experiments requires the capability of handling the physics models of multiple sophisticated diagnostic systems. The Minerva framework has been developed for scientific inference and Bayesian modelling for complex systems, and is the standard analysis infrastructure for the W7-X experiment. It will be shown how Bayesian models implemented in the Minerva framework are capable of inferring electron temperature and density profiles from multiple diagnostic (Thomson scattering, interferometer, He-beam) data in a consistent way. The physics models for each diagnostic have been implemented and analysed individually as well as combined. The profiles are modelled by Gaussian processes with hyperparameters for varying length scales determined by a Bayes Occam*s razor criteria. The full posterior of profiles, hyperparameters, and calibration are explored by Markov chain Monte Carlo sampling. The results show all possible combinations of profiles, hyperparameters, and calibration with their associated uncertainties. Calibration of the Thomson scattering system is automatically handled by the combined model.

P 5.3 Mon 17:05 A 0.112

Bayesian Evaluation of Infrared Thermography determining Surface Heat Flux Densitie — •Dirk Nille, Udo von Toussaint, Micheal Faitsch, Bernhard Sieglin, and the ASDEX Upgrade Team — Max-Planck-Institute for Plasma Physics, Boltzmannstr. 2, D-85748 Garching, Germany

In fusion research the determination of the heat flux distribution onto the material surrounding the plasma is crucial, as power exhaust is a major challenge in the development of a future fusion power plant. Infrared thermography provides spatially and temporally resolved data for this purpose. This is an inverse problem, where the result of the quantity of interest is observed and the cause has to be reconstructed.

Basis is to solve the heat diffusion equation in the target material with the surface temperature as boundary condition, given by measurements. A direct evaluation is in use for decades by deterministic codes, developed for fast evaluation of data. Standard deviation during quasi-static conditions is used as error bars.

Bayesian evaluation is based on a forward model – describing the response of the physical object, the target material – and a model describing the quantity of interest in order to find the most probable cause leading to the measurement. For this purpose adaptive kernel – a multi-resolution model – are used to describe the heat flux density distribution. Taking into account the known experimental uncertainty yields reconstructions of better quality and reliable credibility ranges.

This allows more detailed analysis about the plasma transporting heat from the confined area to the observed target material.

P 5.4 Mon 17:30 A 0.112

Power loads in the scrape-off layer of Wendelstein 7-X — •Holger Niemann[1], Adnan Ali[1], Peter Drewelow[1], Florian Effenberg[2], Marcin Jakubowski[1], Ralf König[1], Fabio Pisano[3], Aleix Puig Sitjes[1], Thomas Sunn Pedersen[1], Glen Wurden[4], and W7-X Team[1] — [1]Max-Planck-Institut für Plasma Physik, Wendelsteinstraße 1, 17491 Greifswald — [2]University of Wisconsin, Madison, USA — [3]University of Cagliari, Cagliari, Italy — [4]Los Alamos National Laboratory, Los Alamos, USA

The advanced stellarator Wendelstein 7-X has a five-fold symmetry and started its first campaign (OP1.1) with a limiter configuration in 2015. Five uncooled graphite limiter were placed periodically on the inboard side of the plasma vessel. This campaign was followed by a divertor campaign (OP1.2a) in 2017. The limiters were replaced by ten symmetrically positioned upper and lower uncooled divertors. Infrared camera systems were used in both campaigns to observe the surface temperature of the plasma facing components. From the measured evolution of the surface temperature the heat flux is evaluated with the THEODOR code. We measured heat fluxes up to 7-8 MW/m^2 on the limiter and up to 10 MW/m^2 on the divertor. The Double fall-off length was measured at the limiter with the narrow scrape-off layer(SOL) being of order of 8 mm and far SOL of order of 2 cm. The width of the SOL shows a clear scaling with connection length. In the divertor campaign the heat flux pattern varies strongly with the magnetic configuration. Depending on the configuration the local measured strike line width is in the range from around 1 cm to around 3 cm.

P 6: Codes and Modelling

Time: Monday 16:15–17:45 Location: KI 1.174

Invited Talk P 6.1 Mon 16:15 KI 1.174

Collisionless damping in the spectra of active plasma resonance spectroscopic probes — •Jens Oberrath — Institute of Product and Process Innovation, Leuphana University Lüneburg, Germany

Different designs of probes, which are based on the concept of active plasma resonance spectroscopy, were invented since the early sixties of last century. Within the last decade improved designs gained new interest as possible devices for industrial plasma diagnostics. Therefore, a mathematical model to determine simple relations between plasma and resonance parameters is needed. A suitable choice to derive a simple model is based on a fluid description of the plasma. However, in low pressure plasmas a fluid model can only predict the resonance frequency, which is related to the electron density. To measure also the electron temperature simultaneously in one measurement, a relation to a second resonance parameter is needed. Such a parameter is given by the half width of the peak, which is related to the damping of the system. In low pressure plasmas not only collisional damping takes place, but also collisionless, which has to be determined kinetically. Within this work, spectra of different probe designs are compared, some are determined by a fluid and others by a kinetic model. It will be shown, that a broadening of the resonance is caused by kinetic effects. Furthermore, good agreement of the spectra can be reached, if the collisionless damping is added to the collisional damping in the fluid calculations. The author acknowledges the financial support by internal funding of Leuphana University and the German Research Foundation (DFG) via the project OB 469/1-1.

P 6.2 Mon 16:45 KI 1.174

Impedance modeling for DF-plasmas where one of the frequencies is well below the ion plasma frequency — •Jan Kuhfeld[1], Yukinori Sakiyama[2], and Uwe Czarnetzki[1] — [1]Institute for Plasma and Atomic Physics, Ruhr-University Bochum, Germany — [2]Lam Research Corporation, 11361 SW Leveton Dr, Bldg. C, Tualatin OR 97062, USA

For industrial applications, e.g. plasma enhanced chemical vapor deposition (PECVD), dual frequency (DF) plasmas are used to gain a better control over important plasma parameters. In contrast to traditional DF discharges where both frequencies are in the MHz range, here the lower frequency is 400 kHz and well below the ion plasma frequency. This means that the ion sheath dynamics play an important role and cannot be neglected. Additionally PECVD reactors are operated at pressures of a few hundred Pa, so that secondary electrons have to be considered as well. Measurements for this case show a typical capacitively dominated impedance for the high frequency voltage (13.56 MHz) while the behavior of the low frequency current is of a resistive nature. Here, this phenomenon is investigated with a fluid simulation and a simple analytical model is developed for a better understanding of the underlying physics.

P 6.3 Mon 17:00 KI 1.174

Towards a tight coupling of fluid model calculations with a multiterm electron Boltzmann solver — •C. M. Hinz[1,2], M. M. Becker[2], D. Loffhagen[2], and M. Bonitz[1] — [1]ITAP, Christian-Albrechts-Universität zu Kiel, Leibnizstr. 15, 24098 Kiel — [2]INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald

Nonthermal plasmas are frequently described by fluid models using tabulated electron transport and rate coefficients as input. These tables are generated prior to the fluid calculations by solving the steady-state electron Boltzmann equation for given electric field strength, species densities, and atomic data. The present contribution reports on the attempt to enable a tight coupling of a time-dependent, spatially one-dimensional fluid model with an electron Boltzmann solver, which is based on a multiterm expansion of the velocity distribution function in Legendre polynomials. This coupling is realized by concurrently solving the electron kinetic equation for each occurring set of electrical field strength and particle densities determined by the fluid model. To enable this hybrid modelling approach and overcome the significant increase in computational costs, the parallelization framework Qubus (https://qubusproject.org) is used to solve the electron kinetic equation on highly parallel hardware without sacrificing the opportunity to easily adapt the hybrid code to new requirements. The presented results demonstrate the abilities of the hybrid method by the example of an abnormal glow discharge in argon at 1 Torr. Using these first results as a baseline, the advantages and shortcomings of the new approach are discussed.

P 6.4 Mon 17:15 KI 1.174

Yacora on the Web: providing collisional radiative models for plasma spectroscopists — •Dirk Wünderlich[1], Maurizio Giacomin[1], Raphael Ritz[2], and Ursel Fantz[1] — [1]Max- Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Max Planck Computing and Data Facility, 85748 Garching, Germany

Collisional radiative (CR) models are essential tools for interpreting population densities measured in low temperature plasmas, for example by optical emission spectroscopy.

The flexible solver Yacora was used in the last years for developing and extensively benchmarking a multitude of CR models for different atomic and molecular species. These models then have been applied for plasma diagnostics at plasma experiments worldwide. The steadily increasing interest triggered the development of Yacora on the Web (`www.yacora.de`), a web application making available some of the Yacora CR models to the broad public, namely the models for atomic and molecular hydrogen and for helium. The model for H includes excitation channels involving other particle species like electron-ion recombination of H^+ and H_2^+ and mutual recombination of positive with negative hydrogen ions. The model for H_2 includes all electronically excited states up to the principal quantum number p=3.

The presentation introduces Yacora on the Web and the features and properties of the available models. Examples for the application for plasma diagnostics are given and future extensions of Yacora on the Web are discussed.

P 6.5 Mon 17:30 KI 1.174

Protection of the First Wall of Wendelstein 7-X with Artificial Neural Networks — •Daniel Böckenhoff[1], Marko Blatzheim[1,2], Hauke Hölbe[1], Roger Labahn[2], and Thomas Sunn Pedersen[1] — [1]Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald — [2]Institut fur Mathematik, Universitat Rostock, Ulmenstraße 69, 18057 Rostock

One of the main objectives of the nuclear fusion experiment Wendelstein 7-X is to demonstrate steady state capability of the stellarator confinement concept. To ensure the safety of the first wall and protect the plasma from impurities, heat load pattern control is essential for long term operation.

It is demonstrated that artificial neural networks can be used to accurately and efficiently predict details of the magnetic topology at the plasma edge of Wendelstein 7-X, based on simulated as well as measured heat load patterns onto plasma-facing components observed with infrared cameras. The use of a neural network makes it feasible to analyze and control the plasma exhaust in real-time, an important goal for Wendelstein 7-X, and for magnetic confinement fusion research in general.

P 7: Magnetic Confinement I - Helmholtz Graduate School III

Time: Tuesday 10:30–12:40 Location: A 0.112

Invited Talk P 7.1 Tue 10:30 A 0.112

Plasma Edge Physics with 3D Magnetic Boundaries - an Overview — •Oliver Schmitz — U of Wisconsin - Madison, USA

High temperature plasmas are confined in doughnut-shaped magnetic field cages to reach conditions which can ultimately allow production of energy by nuclear fusion. The plasma transport in the plasma boundary is governed by the parallel transport along open field lines onto material surfaces. These parallel particle and energy fluxes are sourced by particle and energy transport perpendicular to the magnetic field from the plasma core domain. This basic picture is complicated when three-dimensional (3D) magnetic structures are at play. Then, the topology of these parallel transport flux tubes is complex, sometimes chaotic, and the plasma transport is accompanied by magnetic diffusion and cross-talk between the magnetic flux channels.

In this talk, key aspects of the plasma edge transport and of the plasma material interaction in such 3D plasma boundaries are presented and discussed, based on recent selected experimental findings and accompanying modeling results from a 3D plasma fluid and kinetic neutral transport code - the EMC3-EIRENE model. The 3D aspects discussed are important in tokamak devices, where magnetic perturbation fields are applied to fine tune plasma transport and stability in the plasma edge. Also, they are inherent to stellarator devices, which feature an intrinsically highly 3D plasma boundary defining much of the system state as a possible future energy source.

Acknowledgement: Work funded by the U.S. Department of Energy under grants DE-SC0013911, DE-SC0014210 and DE-SC0012315.

P 7.2 Tue 11:00 A 0.112

Core boron transport studies at ASDEX Upgrade — •Cecilia Bruhn[1,2], Rachael McDermott[1], Clemente Angioni[1], Pierre Manas[1], Alexander Lebschy[1,2], Volodymyr Bobkov[1], Roman Ochoukov[1], Jakob Ameres[2,1], Athina Kappatou[1], Marco Cavedon[1], Ralph Dux[1], and the ASDEX Upgrade Team[1] — [1]Max Planck-Institut für Plasmaphysik, Garching, Germany — [2]Technische Universität München, Garching, Germany

To achieve optimum fusion performance, future fusion reactors need to control the build up of both high- and low-Z impurities in the plasma core. At ASDEX Upgrade, a novel method of studying the boron transport has been developed and is being used to validate the theoretical understanding as well as the mechanisms behind low-Z impurity transport. This method utilizes the fact that a modulation of the power from the ion cyclotron resonance frequency antennae induces a modulation of the boron density, which can be measured with the charge exchange recombination spectroscopy diagnostics. This method allows D and v to be separately determined and it has been applied to a wide variety of plasma discharges. From this, a database of transport coefficients has been assembled. This database and how the transport coefficients depend on the local plasma parameters will be presented in this contribution as well as an in-depth comparison to theory. For the bulk of the database, there is quantitative agreement between the measured and the predicted theoretical diffusion coefficients. However, in all cases the convection is predicted to be more inward than is measured. These results and possible explanations will be discussed.

P 7.3 Tue 11:25 A 0.112

Quantitative study of kinetic ballooning mode theory in magnetically confined toroidal plasmas — •Ksenia Aleynikova[1,2], Alessandro Zocco[1], Pavlos Xanthopoulos[1], and Per Helander[1] — [1]Max-Planck-Institut für Plasmaphysik, EURATOM Association, Greifswald, Germany — [2]MIPT, Dolgoprudny, Russian Federation

In this work, we report a systematic quantitative comparison of analytical theory and numerical gyro kinetic (GK) simulations of kinetic ballooning modes (KBMs) in a magnetically confined toroidal plasma. A physics-based ordering for plasma beta with small asymptotic parameters is found. This allows us to derive several simplified limits of previously known theories and to identify regimes where quantitative agreement between theory and numerical simulations can be achieved. For the axisymmetric case, in simple s-α geometry, it is found that, for large pressure gradients, the growth rate and frequencies computed by the gyrokinetic codes show excellent agreement with those evaluated by using, in the quadratic forms, a diamagnetic modification of ideal MHD. For moderate pressure gradients, a new finite-beta formulation of KBM theory is proposed.

The theory is also extended to treat the stellarator device W7-X. We show results of finite-beta electromagnetic GK simulations of KBMs for various W7-X configurations with different ideal MHD stability properties. This is important since, at present, it is not clear how the KBM and the ideal MHD ballooning mode thresholds relate to each other in stellarator geometry.

P 7.4 Tue 11:50 A 0.112

First results of turbulence investigations at the Wendelstein 7-X stellarator with the phase contrast imaging diagnostic — •Lukas-Georg Böttger[1,2], Olaf Grulke[1,2], Eric Matthias Edlund[3], Adrian von Stechow[1], Jorge Alberto Alcusón[1], and the W7-X Team[1] — [1]Max-Planck Institute for Plasma Physics — [2]Technical University of Denmark — [3]MIT Plasma Science and Fusion Center

Wendelstein 7-X (W7-X) is currently the world's largest optimized stellarator with a plasma volume of $30\,\mathrm{m}^3$. As the reduction of neoclassical transport is one of the optimization criteria, turbulent transport mechanisms are believed to play a much more important role now. Numerical gyrokinetic simulations suggest a significantly different appearance of turbulence in stellarators than in tokamaks. However, a systematic experimental investigation of turbulence in optimized stellarators has not been done yet. To address this topic the phase contrast imaging (PCI) diagnostic was installed at W7-X and successfully put into operation in the recent experimental campaign OP 1.2a. The PCI diagnostic allows for non-invasive spatiotemporal measurements of electron density fluctuations. Ion temperature gradient turbulence and trapped electron modes can be resolved – in the hot core up to the colder edge. This talk presents an analysis of the obtained experimental data and a comparison to GENE simulation results. One key focus is the characterization of turbulence in different magnetic field configurations, which are expected to have a major influence on the growth of the instabilities and the resulting spatial localization.

P 7.5 Tue 12:15 A 0.112

Influence of plasma backgrounds including neutrals on SOL filaments using 3D simulations — •David Schwörer[1,2], Nick Walkden[2], Huw Leggate[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 were seeded on the backgrounds, and the resulting filament motion was studied. Our previous studies found a strong target temperature dependence of the filament velocity. This has been observed for filaments of critical size and larger, whereas smaller filaments showed a stronger density dependence. While investigating the role of viscosity, it was found that sheath currents and the plasma viscosity at the target strongly influence the filament velocity. Here we extend the neutrals model, to allow access to higher density scrape-off layer regimes. This analysis has been carried out using a new python interface for BOUT++, which will also be discussed.

P 8: Complex Plasmas and Dusty Plasmas I

Time: Tuesday 10:30–12:25 Location: KI 1.174

Invited Talk P 8.1 Tue 10:30 KI 1.174

Life in the void: nanoparticle formation in reactive plasmas — •Ferdi van de Wetering — Eindhoven University of Technology, Department of Applied Physics, P.O. Box 513, 5600 MB Eindhoven, the Netherlands

Reactive plasmas are plasmas where nanoparticles spontaneously form in the volume from the feed gas molecules. This can be advantageous since the produced particles generally have a monodisperse size distribution and therefore have a multitude of applications. It can also be detrimental, especially in the semiconductor industry, where plasmas are widely used in the production of integrated circuits.

Nanoparticle formation in these plasmas is generally accepted to follow a step-wise process: polymerization of the feed gas molecules, nucleation, coagulation and accretion of plasma ions and radicals. The resulting particles charge negatively by attachment of plasma electrons and are therefore confined in the positive plasma glow. Under certain conditions this results in a dense cloud of solid nanoparticles levitated in the plasma.

Sometimes, a macroscopic dust-free zone (void) develops as a result of forces pushing particles outward (such as the ion drag force). A new cycle of nanoparticle formation is impeded in the nanoparticle cloud, but it can start in the void region. By employing several diagnostics, such as microwave cavity resonance spectroscopy, electron microscopy, Mie scattering and emission spectroscopy, as well as modeling, we are able to explain the peculiar and interesting dynamics of the void and link this directly to the step-wise and cyclic formation of nanoparticles.

Fachvortrag P 8.2 Tue 11:00 KI 1.174

Investigation of spatial-dependent particle growth using a new imaging RCE technique — •Sebastian Groth, Franko Greiner, and Alexander Piel — Institute of Experimental and Applied Physics, Kiel University, Germany

Under certain circumstances nanometer-sized particles grown in a reactive argon-acetylene plasma form quite homogeneous monodisperse particle clouds. The size evolution of these clouds can be investigated via random point measurements using a commercial RCE or by simple spatially resolved imaging diagnostics [1]. Nevertheless there are various scenarios like sheath growth, void growth or localized growth, where an inhomogeneous size evolution of nanodust clouds is observed. To describe these phenomena in situ quantitatively as a function of space and time a new imaging diagnostic has been developed that measures all four Stokes vector components to determine spatially resolved the particles' size and optical properties. Corresponding to the optical setup the diagnostics are named Imaging Rotating-Compensator-Ellipsometer (I-RCE). We present this newly developed diagnostics and demonstrate its advanced capabilities on different growth scenarios.

Supported by the Deutsche Forschungsgemeinschaft within the SFB-TR24, project A2.

[1] F. Greiner et al., Plasma Sources Sci. Technol. **21**, 065005 (2012)

P 8.3 Tue 11:25 KI 1.174

Coupled modes in the absence of the mode-coupling instability — John K. Meyer, •Ingo Laut, Sergey K. Zhdanov, Volodymyr Nosenko, and Hubertus M. Thomas — Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt, Wessling

The mode-coupling instability (MCI) is a much examined instability in two-dimensional complex plasma crystals which is based on the nonreciprocal, wake-mediated interactions [1]. When the transverse vertical and the longitudinal wave modes intersect, an instable hybrid mode is formed that leads to the melting of the crystal. It was believed that such a coupling of modes is possible only when the modes do intersect.

Here we report an experimental observation of coupling of the transverse vertical and longitudinal wave modes in the absence of MCI [2]. A new large diameter rf plasma chamber was used to suspend the plasma crystal. The observations are confirmed with molecular-dynamics simulations.

[1] L. Couëdel, S. Zhdanov, A. V. Ivlev, V. Nosenko, H. M. Thomas, and G. E. Morfill, Phys. Plasmas **18**,, 083707 (2011)
[2] J. K. Meyer, I. Laut, S. Zhdanov, V. Nosenko, and H. M. Thomas, accepted for publication in Phys. Rev. Lett.

P 8.4 Tue 11:40 KI 1.174

Laser heating of finite binary mixtures in complex plasmas — •Frank Wieben, Tobias Kramprich, and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Complex plasmas, plasmas containing microparticles, are excellent model systems to study the thermodynamic properties of Yukawa systems. In recent experiments laser heating methods proved to be perfect tools to investigate phase transitions in monodisperse 2D and 3D particle ensembles. The melting temperature of finite clusters strongly depends on the total number of particles and the exact configuration of the system. As simulations on the melting of 2D binary Coulomb clusters suggest, the melting temperature in systems containing two species of different sizes and charges also depends on the mixing- and charge-ratio. However, up until recently there has been no experimental access to 2D binary mixtures since particles of different sizes leviate in separated layers. By combining particles of different materials 2D binary mixtures can be generated [1]. In this contribution experimental and simulation results on the heating of finite binary particle systems ($N \approx 100$) are presented. The melting and relaxation behavior of these two-component systems show a strong dependance on the mixing ratio. This work was supported by the Deutsche Forschungsgemeinschaft DFG in the framework of SFB TR 24 Greifswald Kiel, Project A3b and of Research Grant BL555/3-1.

[1] Wieben et al, Phys. Plasmas **24**, 033707 (2017)

P 8.5 Tue 11:55 KI 1.174

effect of discharge polarity reversal on the wave propagation in flowing complex plasma under microgravity condition — •Surabhi Jaiswal, Mikhail Pustylnik, and Sergey Zhdanov — DLR, oberpfaffenhofen, Germany

We presented an experimental investigation of effect of discharge polarity reversal on the wave structure generated in a flowing complex plasma at lower pressure. Experiment has been performed under microgravity conditions on board the International Space Station by using PK-4 facility, which ensured particle levitation inside the chamber up to desired volume. On changing the polarity, direction of dust cloud as a whole has been reverse however direction of associated wave structure remain unchanged with a small shift in the trajectory during polarity reversal. Generation of new crest in between the existing crest and merging of wave crest have been observed. Hilbert transform technique is used to understand the local variation of frequency, wave number and velocity of the crest. A model has been developed to understand the appearance of additional crest and variation in phase speed.

P 8.6 Tue 12:10 KI 1.174

String fluid instability in a complex plasma in a direct current discharge under microgravity — •Mierk Schwabe, Sergey Zhdanov, Mikhail Pustylnik, and Hubertus Thomas — Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Münchener Str. 20, 82234 Weßling

The PK-4 Laboratory is a Russian-European laboratory for studies on complex plasmas on board the International Space Station ISS. Its heart consists of a direct current plasma tube with 3 cm diameter and a total length of 85 cm. Microparticles of various sizes can be injected into the plasma. Here, we report on an instability formed in the microparticle cloud in which waves form. The plasma was driven in polarity switching mode * the DC electric field was quickly switched, and the microparticles were trapped in the center of the discharge. The polarity switching causes the ions and electrons of the plasma to stream around the microparticles, and the ions form wakes in downstream direction of the microparticles, which in turn attract other microparticles and lead to the formation of microparticle strings. Here, we report on the formation of waves in such a string fluid. We study the dispersion relation of the waves, demonstrate that they are not ordinary dust acoustic waves, and hypothesize on the excitation mechanism of the instability.

P 9: Atmospheric Pressure Plasmas II

Time: Tuesday 14:00–16:00 Location: A 0.112

Invited Talk P 9.1 Tue 14:00 A 0.112

Next generation gases in gas discharge applications. — •Christian Franck — Swiss Federal Institute of Technology (ETH Zürich), Zürich, Switzerland

Insulation gases and dielectric discharges are used in a number of industrial and research applications. In many of these, fluorinated gases are used today that have a significant global warming potential and are now regulated by international policies or even phased-out. A strong international research and development for next generation gases and gas mixtures is thus ongoing. Besides the identification and synthesis of new molecules itself, also their behaviour in gaseous discharges needs to be investigated and understood to achieve a comparable performance in the final application.

In this presentation, the search, the requirements, and latest trends in using next generation gases in gas discharge applications are given in the context of two examples: high-voltage gas-insulated switchgear (GIS) and resistive plate chamber (RPC) detectors. Both are operated under very different condition, but the same properties need to be investigated. GIS is operated below the critical electric field strength and at high pressures and down to low ambient temperatures. RPCs are operated above the critical electric field strength, but at ambient pressure and temperature. Basic parameters of interest are ionization, attachment, detachment and ion conversion rates, synergistic behaviour with mixing gases, and basic thermodynamic properties.

P 9.2 Tue 14:30 A 0.112

Decomposition of Gaseous Dielectrics in Gas Insulated Switchgears (GIS) and Lines (GIL) — •Thomas Hammer, Martin Ise, Robert Fleck, Florian Kessler, Thomas Rettenmaier, and Wiebke Sarfert-Gast — Siemens AG, Corporate Technology, Erlangen

Currently substantial efforts are taken to develop climate friendly gaseous dielectrics having the potential for substituting SF_6 in gas insulated medium voltage and high voltage equipment. Recently 3M^{TM} Novec^{TM} 5110 Insulating Gas (heptafluoro-3-(trifluoromethyl)-2-butanone: C5-FK) and 3M^{TM} Novec^{TM} 4710 Insulating Gas (tetrafluoro-2-(trifluoromethyl)propane-nitrile: C4-FN) buffered with air like compounds such as N_2 and CO_2 were suggested for GIS application. Both partial discharges (PD) and switching arcs may irreversibly decompose these compounds. Thus laboratory experiments simulating the lifetime exposure of C5-FK and C4-FN mixtures with N_2 and CO_2 to PD and arcs were performed. Major decomposition products analyzed by means of GC/MS were CF_4, C_2F_6, C_3F_8, C_3F_6, and C_3HF_7. Less than 1% of the initial amounts of the dielectric fluids were decomposed. Specific energies of arc decomposition were around 250 kJ/mol for C4-FN/N_2, 193 kJ/mol for C4-FN/CO_2, and around 100 kJ/mol for C5-FK/N_2. Specific energies of PD decomposition were six times larger.

The authors gratefully acknowledge support of this work by the German Federal Ministry for Economic Affairs and Energy (Funding Code 03ET7551).

P 9.3 Tue 14:45 A 0.112

Experimental investigation of microdischarges in a needle-to-hemisphere dielectric barrier discharge in air at atmospheric pressure — •Sina Jahanbakhsh[1], Volker Brüser[1], and Ronny Brandenburg[1,2] — [1]INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald — [2]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23-24, 18051 Rostock

Metal pin-to-dielectric coated electrode arrangement, known as barrier corona (BC), offers synergies between corona discharge (low breakdown voltage) and Dielectric barrier discharge (DBD) (charge limitation). In this study a sharp metal pin (0.2 mm tip radius) and a hemispherical (2 mm radius) alumina covered electrode are employed. A sinusoidal voltage at the frequency of 7.5 KHz is applied at 11.5 kVp-p. Using an ICCD camera and a Rogowski coil current probe, pictures and current pulses of individual MDs are recorded simultaneously. Time correlated single photon counting (TC-SPC) is used to record the spatio-temporal development of the MDs. The discharge inception and the MD properties in the two polarities of the sinusoidal voltage differ significantly. This contribution will focus on the results of the negative polarity (dielectric cathode). In this polarity two groups of MDs are observed in the same half-period. The first MD leaves a positive surface charge on the dielectric. This residual charge has considerable effects on the propagation and properties of the second MD, such as longer fall and rise time of the current pulse, and longer propagation on the surface of the dielectric.

P 9.4 Tue 15:00 A 0.112

Numerical and experimental analysis of breakdown initiation in single-filament dielectric barrier discharges — •Markus M. Becker, Hans Höft, Manfred Kettlitz, and Detlef Loffhagen — INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald

During the last decade the analysis of single discharge filaments in dielectric barrier discharges (DBD) has proven to be a useful tool for the design and optimization of DBD. In the present contribution, a combined experimental and numerical modelling study of a single-filament DBD at atmospheric pressure (0.1 vol% O_2 in N_2) is presented with special focus on the streamer propagation phase. The DBD has a gap width of 1 mm and is driven by a 10 kV voltage pulse with a rise time of about 45 ns. The experimental diagnostics consists of an iCCD and a streak camera system (50 ps temporal and 2 μm spatial resolution) combined with fast electrical probes. The numerical investigations are based on a spatially two-dimensional axisymmetric fluid model using the local mean energy approximation for the determination of the electron transport coefficients as well as the excitation/ionization rate coefficients. Besides Poisson's equation, balance equations for electrons, the most relevant heavy particle species and the surface charges accumulated on the dielectric surfaces are included. First numerical results are in fair agreement with electrical measurements and the experimental determination of the streamer propagation velocity by means of optical measurements. It is shown that the streamer properties, e.g. propagation velocity and electric field strength, of the DBD differ markedly from those of streamers in unbounded domains.

P 9.5 Tue 15:15 A 0.112

Differences in heating mechanisms for helium and argon discharges in the COST-Jet — •Judith Golda[1,2] and Volker Schulz-von der Gathen[2] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Experimental Physics II, Ruhr-Universität Bochum, Germany

Non-thermal atmospheric pressure plasma jet devices - such as the well-investigated micro-scaled atmospheric pressure plasma jet (μ-APPJ) - efficiently generate reactive species at low gas temperature. Hence, they are commonly used for surface modification and considered for use in bio-medicine. However, the μ-APPJ relies on helium as feed gas and attempts to operate the source in argon without any geometric modifications proved to be difficult due to yet unknown reasons.

Here, we present investigations of the COST-Jet, the successor of the μ-APPJ, that allows operation in helium and argon. The two plasma discharges will be compared by means of electrical, optical and phase-resolved optical measurements.

Electrical and optical measurements are correlated to explain the differences between the behavior of argon and helium discharge. Our results show that the main discharge processes in the argon discharge are similar to the helium discharge, but slight differences due to the intrinsic properties of the gases notably change the discharge behavior.

Funded by the DFG within PlaCiD SCHU-2353/3-1.

P 9.6 Tue 15:30 A 0.112

Particles densities and temperatures in atmospheric pressure microwave plasma torch — •Ante Hecimovic, Federico Antonio D'Isa, Emile Carbone, and Ursel Fantz — Max Planck Institue für Plasmaphysik

Microwave plasmas at atmospheric pressure are commonly used in the field of species detection, for surface treatment and decomposition of harmful gases. Lately, the microwave plasmas at atmospheric pressure have been investigated for use in that field of energy storage, by storing the energy in the form of chemical energy achieving high energy and conversion efficiencies. A plasma torch is used to generate the plasma, which is a custom made resonator consisting of a coaxial and cylindrical resonator, allowing the plasma to be ignited directly at atmospheric pressure (2.45 GHz, 300W-3kW) inside a tube with inner diameter of 25 mm. In this contribution we report on investigation of the microwave plasma in air and air/Ar/N2 mixtures using optical emission spectroscopy, and mass spectrometry. After initial test in air/Ar/N2 mixtures, the transition from an air/Ar/N2 plasma to CO2 plasma is planned. The focus on using the spatially resolved OES investigation is the vibrational and rotational bands of N2, with the energy load of vibrational levels being comparable to the energy levels of CO2. Mass spectrometry measurements of the plasma effluent are performed where the influence of the gas flow, air/Ar gas mixture, and the power level is investigated. The mass spectrometry measurements are done using a custom made spectrometer which configuration should overcome gas-demixing effects.

P 9.7 Tue 15:45 A 0.112

Plasma window as a pressure Valve for FAIR — •Bernhard Bohlender, Andre Michel, Marius Dehmer, Marcus Iberler und Joachim Jacoby — Institut für Angewandte Physik, Goethe Universität Frankfurt

This contribution shows the progress in the development of a plasma window at the institute for applied physics at Goethe University Frankfurt. A plasma window* is a membrane free transition between two regions of different pressure, enabling beam transmission from a rough vacuum area (~1mbar) to a higher pressure (up to 1bar) region on short length scales. In comparison to differential pumping stages a length reduction by a factor of up to 100 is achievable, while the absence of a solid membrane yields prolonged operation time. The sealing effect is based on the high temperature arc discharge sustained in a cooled copper channel between the pressure regimes. Due to a bulk temperature around 10,000K** the viscosity of the gas is dramatically increased, leading to a slower gas flow, enabling a higher pressure gradient. This contribution will present first results regarding the pressure gradient in dependence of the discharge current and the aperture. Until now, a pressure factor around 100 has been established for well over 50min. This contribution goes along with the one from Mr. A. Michel, he focuses on the spectroscopic analysis of the arc plasma. * Hershcovitch, A. J. Appl. Phys., AIP Publishing, 1995, 78, 5283 ** Krasik, Y. E.; Gleizer, S.; Gurovich, V.; Kronhaus, I.; Hershcovitch, A.; Nozar, P. & Taliani, C. J. Appl. Phys., AIP Publishing, 2007, 101, 053305

P 10: Laser Plasmas I

Time: Tuesday 14:00–16:00 Location: KI 1.174

Invited Talk P 10.1 Tue 14:00 KI 1.174

Self-consistent theory of radiation friction losses in ultraintense laser-plasma interaction — •Tatyana Liseykina[1,2], Sergey Popruzhenko[3,4], and Andrea Macchi[5,6] — [1]Institut für Physik, Universität Rostock, Germany — [2]Institute of Computational Technologies, SD RAS, Novosibirsk, Russia — [3]Max-Planck-Institut für Physik komplexer Systeme, Dresden — [4]National Research Nuclear University, Moscow Engineering Physics Institute, Russia — [5]CNR, National Institute of Optics, Pisa, Italy — [6]Department of Physics, University of Pisa, Italy

In the interaction of laser pulses of extreme intensity with high-density, thick plasma targets, collective effects lead to very strong radiation friction losses. We present a classical model for this regime, based on the Zel'dovich solution [1] for the electron motion in the presence of a steady electric field. This improves our previous modeling [2] by making the radiation losses self-consistent with the electron dynamics. The model predicts that in the present context the classical regime of radiation friction is applicable up to intensities still beyond the capabilities of next generation facilities.

[1] Zel'dovich Ya B., Sov. Phys. Usp. 18 79-98 (1975)
[2] Liseykina T., Popruzhenko S., Macchi A., NJP 18, 072001 (2016)

P 10.2 Tue 14:30 KI 1.174

Calorimetry techniques for ultra-intense laser-plasma experiments — •Maria Molodtsova[1,2], Anna Ferrari[1], Alejandro Laso Garcia[1], Arie Irman[1], Benjamin Lutz[1,2], Josefine Metzkes-Ng[1], Irene Prencipe[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

With ultra-high intensity short-pulse lasers generating plasma, new extreme states of matter can be created, and new concepts for particle

acceleration, material science, and fusion energy can be explored. A critical component is the characterization of relativistic electrons that are accelerated and transported in the material of the target, generating ultra-intense bremsstrahlung.
Measuring the bremsstrahlung spectrum is a crucial aspect of plasma diagnostics. In this work it is showed how calorimetric techniques, based on longitudinally resolved measurements of energy deposition, are especially suitable for the reconstruction of the photon spectra.
Multi-layered scintillator calorimeters with different readouts are under development at Helmholtz-Zentrum Dresden-Rossendorf for this purpose. Prototypes have been tested at the ELBE facility both at the γELBE beamline with a well-known bremsstrahlung spectrum and in a laser-plasma environment at DRACO.

P 10.3 Tue 14:45 KI 1.174

Electron acceleration mechanisms in ultrashort pulse-plasma-interactions — •Florian Kleeschulte, Bastian Hagmeister, Dirk Hemmers, and Georg Pretzler — Heinrich-Heine-Universität Düsseldorf

When ultrashort, intense laser pulses interact with solid surfaces, intense electron pulses are ejected into the vacuum and obtain substantial kinetic energies. In this contribution, we present a thorough analysis of the different mechanisms acting together to accelerate electrons to energies almost two orders of magnitude higher than the ponderomotive potential (U_P). In the presented experiments, we have managed to reach kinetic energies above 400 keV with an U_P of only 7.4 keV when using aluminum as a solid density target. These results were reproduced by numerical simulations, which allowed a detailed investigation of the underlying effects. We show that ponderomotive heating, elastic scattering inside the target, and post-acceleration in the space-charge fields act together for generating the unexpectedly high electron energies.

P 10.4 Tue 15:00 KI 1.174

Super-intense single attosecond pulse generation from plasma self-generated gate — •Suo Tang, Naveen Kumar, and Christoph h. Keitel — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69126, Heidelberg, Germany

We present the generation of an isolated super-intense pulse with extremely short duration ($<$ 20 as) in the interaction of solid with ultra-relativistic laser. The generated pulse is characterized with stable phase $\psi = \pm\pi/2$ at the pulse center and slowly decaying exponential spectrum transiting from ROW scaling to CSE scaling. Hole boring effect, as a robust plasma self-generated gate [1], isolates the most efficient pulse emission at the beginning of ion motion by producing an ultra-broadband coherent spectrum. Collision effects also contribute to the attosecond pulse isolation by affecting the intensity of the generated harmonics. Radiation reaction force reduces the phase fluctuation in high frequency components and thus can also affect the intensity of the emitted attosecond pulse.

[1] S. Tang, N. Kumar, and C. H. Keitel, Phys. Rev. E **95**, 051201 (2017)

P 10.5 Tue 15:15 KI 1.174

Plasma Diagnostics with sub-15-fs time resolution via pump-probe experiments — •Michael Stumpf, Christian Greb, Julian Wegner, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

We present a novel experimental setup using a pump-probe technique for observing the expansion of a laser-produced plasma in its early stage. Therefore, the probe beam is reflected at the evolving plasma and then imaged onto the detector by an achromatic lens. The generated phase shift is measured with a Mach-Zehnder interferometer and evaluated using Fourier Transformation. The whole apparatus has exceptional resolution in time (sub-15-fs), space (2 μm) and phase (0.3 rad). As an example, we present an experiment in which the plasma was generated by a laser pulse (pulse-duration 9 fs, maximum intensity $2.4{\cdot}10^{17}$ W/cm^2) focused onto an aluminum mirror. The probe beam was then reflected off the expanding plasma with various delays. To calculate the phase shift, the data from reflection on the plasma is compared with a clean reflection on the metallic mirror. The results illustrate the early-stage plasma expansion with unprecedented temporal resolution.

P 10.6 Tue 15:30 KI 1.174

Seeded Self-Modulationalong the Proton Bunch at AWAKE — •Fabian Batsch[1,2,3], Karl Rieger[2,3], Joshua Moody[2], Edda Gschwendtner[1], and Patric Muggli[1,2] — [1]CERN, Genva, Switzerland — [2]Max-Planck-Institut für Physik, München, Deutschland — [3]Technische Universität München

The AWAKE experiment uses the seeded self-modulation (SSM) to drive large amplitude wakefields in a plasma. The seed for the wakefields is a sharp ionizing front located near the middle of the proton bunch. It is created by an intense laser pulse ionizing Rubidium (Rb). For electron acceleration, the electron bunch must be injected into the accelerating and focusing phase of the wakefields, approximately 100 plasma periods behind the seed laser position. Here, we show that by using a replica of the intense laser pulse we can determine precisely the position (timing) of the proton micro-bunches with respect to the ionizing laser pulse. Since the relative phase of the wakefields is tied to the proton micro-bunches, this method can be used to determine experimentally the delay between the ionizing laser pulse and the proton bunch so that the electrons can be injected into the accelerating and focusing phase of the wakefields. The results presented also show that the timing of the micro-bunches is stable against variations of the proton input parameters. They show as well the difference between seeded and unseeded self- modulation.

P 10.7 Tue 15:45 KI 1.174

Laser-based Diagnostics of Plasma Wakefields in AWAKE — •Anna-Maria Bachmann[1], Patric Muggli[2], and Valentin Fedosseev[1] — [1]CERN, Geneva, Switzerland — [2]Max-Planck Institute for Physics, Munich, Germany

The Advanced Wakefield Experiment AWAKE aims on developing a new plasma wakefield accelerator using a high energy proton beam as a driver. The 400 GeV proton bunch from CERN SPS propagates through a 10 m long rubidium plasma, created by an ionizing 4 TW laser pulse. The relativistic ionization front seeds the self-modulation process. The seeded self-modulation (SSM) transforms the bunch in a train of bunchlets driving wakefields in the plasma. Electrons will be injected and accelerated in the wakefields. AWAKE relies on the micro bunching of the long proton bunch. The modulation of the proton bunch also corresponds to a modulation of the electron plasma density. So far, there are no plasma diagnostics installed in AWAKE. We therefore investigate the possibility of measuring spectral modulation of a CW laser beam propagating perpendicularly to the wakefields to determine some of the wakefields characteristics. Wakefields period information will appear in the position of satellites in the spectrum of transmitted laser light, whereas wakefields amplitude information will be in the satellites intensity.

P 11: Helmholtz Graduate School - Poster

Time: Tuesday 16:15–18:15 Location: Redoutensaal

P 11.1 Tue 16:15 Redoutensaal

Investigation of the pump-out effect by resonant magnetic perturbations in ASDEX Upgrade — •Nils Leuthold[1], Wolfgang Suttrop[1], Matthias Willensdorfer[1], Marco Cavedon[1], Mike Dunne[1], Luis Gil[2], Luis Guimarais[2], the ASDEX Upgrade Team[1], and the MST1 Team[3] — [1]Max-Planck-Institut fuer Plasmaphysik, Boltzmannstr. 2, 85748, Garching, Germany — [2]Instituto de Plasmas e Fusao Nuclear, Instituto Superior Tecnico, Universidade de Lisboa, Portugal — [3]see H. Meyer et al 2017 Nucl. Fusion 57 102014

Future fusion reactors are foreseen to run in the high confinement mode at low collisionality due to the confinement requirements for self-sustained fusion power generation. However, this regime is accompanied by edge localized modes, which expell particles and energy in a pulsed manner. Since this instability has the potential to damage the first wall material, it has to be mitigated or suppressed. While resonant magnetic perturbations (RMPs) can achieve this, they have the drawback of causing a strong reduction of density. Theories trying to explain the transport mechanism underlying this "pump-out" effect are tested experimentally in ASDEX Upgrade. The results indicate that the resonance between the location of penetrating RMP fields and resonant surfaces is not crucial for the pump-out. Reflectometry measurements reveal the presence of toroidally asymmetric turbulence in the steepest gradient region. Those fluctuations correlate well with D-alpha light measurements in the scrape-off layer. Experiments with a modulation of the RMP field strength show, that the change in density happens first also in this region of asymmetric turbulence.

P 11.2 Tue 16:15 Redoutensaal

Towards nonlinear simulations of full ELM cycles — •Andres Cathey, Matthias Hoelzl, and Francois Orain — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

Edge localized modes (ELMs) in tokamak fusion plasmas have been studied extensively both experimentally and theoretically in particular due to the strong associated heat fluxes which potentially exceed material constraints in ITER. Presently, ELM crash simulations are typically started from a peeling-ballooning unstable equilibrium reconstructed from experiments just before an ELM crash occurs. This way many aspects of single ELM crashes have been reproduced successfully in numerical simulations, but their characteristic periodicity still needs to be simulated consistently. In order to produce a more complete description of ELMs including inter-ELM phase and ELM onset, the full cyclic behaviour has to be consistently modelled. An overview of ELM physics will be given along with plans and first steps towards investigating full ELM cycles using the non-linear MHD code JOREK.

P 11.3 Tue 16:15 Redoutensaal

Energy-conserving Implicit Time Discretisation for the GEMPIC Framework — •Benedikt Perse[1,2], Katharina Kormann[1,2], and Eric Sonnendrücker[1,2] — [1]Max-Planck-Institute for Plasma Physics, Garching, Germany — [2]TU München, Zentrum Mathematik, Garching, Germany

For this poster, we consider an energy-conserving implicit time discretisation for the GEMPIC framework by reviewing the "Exactly energy conserving semi-implicit method" of Lapenta.

We adapt the method for the finite element discretisation of the GEMPIC framework, modify the splitting to gain higher order of accuracy for the electromagnetic fields and examine the performance of an 1d2v code in some test cases in regard of the conservation of energy and Gauss' law and the dependence of the accuracy on the time step. Furthermore, we compare the method to the explicit time stepping based on a Hamiltonian splitting proposed for the GEMPIC framework and another semi-implicit method using an average vector field scheme.

P 11.4 Tue 16:15 Redoutensaal

T_{rot} and T_{vib} determination in a CO_2 plasma — •Federico Antonio D'Isa[1], E. Carbone[1], A. Hecimovic[1], S. Gaiser[2], A. Schulz[2], M. Walker[2], S. Soldatov[3], G. Link[3], J. Jelonnek[3], N. Britun[4], and Ursel Fantz[1] — [1]IPP, 85748 Garching, Germany — [2]IVGP, 70569 Stuttgart, Germany — [3]KIT, 76344 Eggenstein-Leopoldshafen, Germany — [4]University of Mons, B7000 Mons, Belgium

Energy storage on demand is of critical importance for an energy grid with proper integration of renewable energies. The power to gas concept aims to store energy in excess into gas by conversion of CO_2 into chemical fuels such as syngas or methanol. To achieve a conversion effiency high enough to make the process advantageous, the CO_2 molecule must be preferentially dissociated by means of vibrational excitation which requires less energy than direct electron impact dissociation. The determination of the vibrational and rotational temperatures of the molecule in CO_2 plasma is crucial for understanding the conversion mechanism. In this work several CO_2 plasmas excited by microwaves have been studied by optical emission spectroscopy. The emission of the excited states of the C_2 ($d^3\Pi_g$ state) molecule and of the CN ($B^2\Sigma^+$ state) molecules is used to determine the rotational and vibrational temperature at pressures between 0.3 to 1 bar by fitting the measured spectra with a simulation done using on PGOPHER and MassiveOES. From the emission of the CO ($B^1\Sigma^+$ state) the rotational temperature has been determined at a pressure of 2 mbar. The results with the fitting routine will be presented and discussed.

P 11.5 Tue 16:15 Redoutensaal

Beam asymmetry and homogeneity characterization at the large negative ion source ELISE — •Isabella Mario, Dirk Wünderlich, Ursel Fantz, and Federica Bonomo — Max-Planck-Institut für Plasmaphysik, Garching, Germany

The ITER neutral beam injection (NBI) system is based on RF sources for production of negative ions (H^-/D^-). The ELISE test facility (source size is half the size of the source for ITER NBI) is an intermediate step in the European R&D roadmap towards the full size ITER source. The aim of ELISE is to fulfill the basic ITER requirements regarding extracted ion current, electron ion ratio at low filling pressure ($\leq$ 0.3 Pa) up to one hour pulse. On the beam side, at the exit of the acceleration stage, local maximum deviation from the averaged beam power density must be less than 10% in order to ensure good beam line transmission. For ELISE, with a beam of about 1 m^2, the lowest achievable beam divergence is about 17 mrad and vertical asymmetry and inhomogeneity are mainly caused by the interplay of plasma drift, non-uniform negative ion production as well as beam deflection by magnetic field. Aim of this work is to improve the understanding of the correlation between locally resolved beam properties with global electrical measurements from beamline components and source parameters. For this purpose we make use of two beam diagnostics: beam emission spectroscopy placed at 2.7 m downstream the extraction system, with a vertical resolution of 5 cm, and the infrared calorimetry on a diagnostic calorimeter at 3.5 m, with a resolution of 4 cm. Both diagnostics provide beam divergence and accelerated current.

P 11.6 Tue 16:15 Redoutensaal

Magnetic field configurations for reducing co-extracted electrons from an ITER NBI relevant ion source. — •Ivar Mauricio Montellano, S. Mochalskyy, D. Wünderlich, and U. Fantz — Max- Planck-Institut für Plasmaphysik, 85748 Garching, Germany

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 presence of two different magnetic fields, the filter field and the electron deflection field, which are perpendicular to each other, breaks the symmetry of the system making the application of a 3D model necessary. The 3D Particle in cell (PIC) code ONIX is capable to simulate the plasma 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 ions and of co-extracted electrons. Of particular importance is the ratio of co-extracted electron current to extracted ion current which has to be kept below one for ITER. In the experiment several parameters can be modified to reduce and stabilize the co-extracted electrons, for example the strength topology of the magnetic fields. In order to improve the physical insight and as first step towards predictive calculations, different magnetic field configurations are simulated with ONIX to determine their effect in the co-extracted electron current. Presented are the results of these simulations and the discussion about the influence of different magnetic field configurations.

P 11.7 Tue 16:15 Redoutensaal

Spectral discretization for the Vlasov Equation — •Anna Yurova and Katharina Kormann — Max-Planck-Institut für Plasmaphysik, Garching b. München, Deutschland

Solving the full kinetic equations can help in understanding possible shortcomings of gyrokinetics. We consider a Galerkin method with Fourier discretization in space and generalized Hermite functions in velocity. The generalized Hermite functions 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 mesh-based methods. We investigate the influence of the scaling and shift of the basis functions on the numerical solution of the Vlasov equation. We study different choices of the parameters in order to find a setup with a good representation of the initial distribution and, at the same time, long-term numerical stability.

P 11.8 Tue 16:15 Redoutensaal

Investigation of optically grey electron cyclotron harmonics in Wendelstein 7-X — •Neha Chaudhary, Matthias Hirsch, Hans Oosterbeek, Robert Wolf, and W7-X Team — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald, Germany

Electron cyclotron emission (ECE) is a standard diagnostic to measure electron temperature profiles in magnetized plasmas. In W7-X with a magnetic field of 2.5T, ECE from the second harmonic X-mode (120-160GHz) is scanned using a heterodyne radiometer. For the X2 mode, re-absorption of microwaves in the plasma is strong enough for the plasma to be considered as optically thick. Hence ECE can be taken as blackbody emission representing an electron temperature.

Other than the optically black X2 mode the ECE spectrum also has higher harmonics. Due to lower absorption coefficients these harmonics are optically grey. In case of overdense plasmas the X2 mode reaches its cutoff. Then higher harmonics provide the only access to ECE emission and hence the physics of core electrons.

The aim of this work is to perform a broadband scan of the ECE spectrum using a Michelson Interferometer in W7-X and compare it to the already existing radiation transport calculations (TRAVIS). Stray radiation from non-absorbed electron cyclotron resonance heating is an issue as it is in the middle of the X2 emission spectrum. Therefore a stray radiation filter is required. The design for such a filter consisting of multiple dielectric layers has been tested and will be presented.

P 11.9 Tue 16:15 Redoutensaal

Characterisation of the Wendelstein 7-X divertor plasma with Langmuir probes — •Lukas Rudischhauser[1], Kenneth Charles Hammond[1], Michael Endler[1], Boyd Douglas Blackwell[2], and the W-7X Team[1] — [1]Max-Planck-Insitute for Plasma Physics, Greifswald, Germany — [2]Australian National University, Canberra, Australia

During the operation phase 1.2a of the stellarator Wendelstein 7-X, 40 Langmuir probes embedded in the newly installed divertor were used to investigate the scrape-off layer. Temperatures, densities and plasma potentials were measured over a range of distances from the pumping gap, sampling different topological regions of the magnetic island divertor field.

Capabilities and limitations of the diagnostic are briefly introduced. The data are combined with observations of optical and spectrographic diagnostics as well as upstream probes to characterise the behaviour of the divertor plasma with respect to global plasma parameters. We present results of experiments on impurity seeding, pellet fuelling, radiative edge cooling and discuss indications for detachment in detail.

P 11.10 Tue 16:15 Redoutensaal

Radial Electric Field Studies in the Near Scrape-off Layer of ASDEX Upgrade using Charge Exchange Recombination Spectroscopy — •Ulrike Plank[1,2], Thomas Pütterich[1,2], Marco Cavedon[1], Michael Griener[1], Eleonora Viezzer[3], Ulrich Stroth[1], and ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Faculty of Physics, Ludwig Maximilian University of Munich, Germany — [3]Department of Atomic, Molecular and Nuclear Physics, University of Seville, Spain

The high confinement mode (H-mode) is a regime of magnetically confined fusion plasmas with improved particle and energy confinement. It exhibits a transport barrier in the confined region, close to the last closed flux surface (LCFS). This barrier is caused by a shear of the radial electric field (E_r). However, it is still discussed whether the E_r shear in the near scrape-off layer (SOL), i.e. outside the LCFS, influences the formation of the transport barrier and, therefore, the transition into H-mode. In order to measure E_r in the near SOL, a new charge exchange (CX) recombination spectroscopy diagnostics was installed at ASDEX Upgrade, which is capable of measuring E_r with high radial resolution by investigating CX reactions of low-Z impurity ions with injected neutrals. The new system utilizes a piezo valve for the injection of neutrals, which provides locally high neutral densities in the near SOL. The characterization of different CX lines from fully and partially ionized impurities will be presented together with first measurements of the new diagnostics.

P 11.11 Tue 16:15 Redoutensaal

Semi-Lagrangian drift-kinetic simulations in toroidal geometries — •Edoardo Zoni[1,2], Yaman Güçlü[1], and Eric Sonnendrücker[1,2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Zentrum Mathematik, TU München, 85748 Garching, Germany

A semi-Lagrangian simulation code is currently under development within the framework of the *SeLaLib* object-oriented Fortran library [1], in order to perform global electrostatic simulations of drift-kinetic ions and adiabatic electrons in toroidal geometries. The code employs field-aligned interpolation and splitting [2] to reduce significantly the number of poloidal planes and hence the memory footprint of the simulations.

The curvature of the background magnetic field in toroidal geometries causes complications in setting up initial conditions corresponding to a stable kinetic equilibrium, in applying non-constant boundary conditions for the interpolation in the radial and the velocity domains, and in the treatment of the O-point.

Solutions to these problems are presented and discussed, including the development of the corresponding computational tools in *SeLaLib*.

Verification tests in cylindrical geometry with a screw-pinch magnetic field configuration as well as preliminary results of standard test-cases in toroidal geometries are presented. Helpful collaboration with the GySeLa team is acknowledged.

[1] *SeLaLib*: *Se*mi-*La*grangian *Lib*rary, http://selalib.gforge.inria.fr/.
[2] Latu et al., Journal of Scientific Computing, 2017, ISSN 1573-7691.

P 11.12 Tue 16:15 Redoutensaal

ELM heat loads on the ASDEX Upgrade divertor in high density discharges — •Davide Silvagni[1,2], Thomas Eich[1], Michael Faitsch[1], Bernhard Sieglin[1], Dominik Brida[1,2], Pierre David[1], and ASDEX Upgrade team[1] — [1]Max-Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]Physik-Department E28, Technische Universität München, 85747 Garching, Germany

A reliable prediction of the Edge Localised Mode (ELM) induced heat loads on the divertor of larger devices such as ITER is crucial, since it defines the operational range of future devices as well as the need for mitigation techniques. A recent scaling of the ELM (peak) energy fluence predicts unacceptable heat loads on the ITER divertor tiles in the $Q = 10$ scenario, if no mitigations are applied. For this reason, in this work the ELM power loads on the divertor of ASDEX Upgrade will be studied in discharges with high plasma edge density and detached divertor to discern whether a reduction of the ELM energy fluence can be found. However, in the presence of detachment the measurement of the divertor target temperature with standard infrared cameras is not possible because of the enhanced Bremsstrahlung radiation nearby the divertor tiles. For this reason, in 2018 ASDEX Upgrade will be equipped with a new infrared diagnostics that is expected to provide more reliable measurements of the divertor temperature (and heat flux) in plasma scenarios with high edge density. In this work, the new infrared diagnostics is presented as well as the most recent studies on ELM heat loads.

P 11.13 Tue 16:15 Redoutensaal

Assessment of particle and heat loads to the upper open divertor in ASDEX Upgrade and comparison with SOLPS simulations — •Ivan Paradela Perez[1,2], Mathias Groth[1], Andrea Scarabosio[2], and ASDEX Upgrade Team[2] — [1]Aalto University, Finland — [2]IPP Garching, Germany

Drifts and divertor geometry play a fundamental role in power, momentum and particle transport. An experiment has been carried out in the upper open divertor of ASDEX Upgrade to characterize their impact. Infra-red thermography measurements of the heat flux profiles in upper single-null, low confinement mode discharges in ASDEX Upgrade show that the heat loads onto the upper low-field side target increase by factors up to ~ 8 when changing from unfavourable ($B_T < 0$, ∇B drift downwards) to favourable ($B_T > 0$, ∇B drift upwards) toroidal field directions. The evolution of the heat loads with increasing plasma current and core density is different for both field directions. Increasing plasma current has a greater impact on heat flux profiles in favourable direction while the effect of increasing core density (in attached conditions) is more pronounced in unfavourable direction. Power detachment is observed for both B_T directions. This dependence on the B_T direction of the evolution with increasing plasma current and core density of the target profiles has also been observed in the collected ion saturation current, I_{sat}, measured by the Langmuir probes. However, the roll-over of I_{sat} is only observed for $B_T < 0$. Lower closed divertor AUG discharges and SOLPS simualtions will be used to improve the understanding of the large impact of drifts and divertor geometry.

P 11.14 Tue 16:15 Redoutensaal

SOLPS Modeling of Partially Detached Plasmas in ASDEX Upgrade — •Ferdinand Hitzler[1,2], Marco Wischmeier[1], Felix Reimold[3], Matthias Bernert[1], Xavier Bonnin[4], Arne Kallenbach[1], the ASDEX Upgrade Team[1], and the EUROfusion MST1 Team[5] — [1]IPP Garching, Germany — [2]TU München, Garching, Germany — [3]Forschungszentrum Jülich, Jülich, Germany — [4]ITER Organization, St. Paul-lez-Durance, France — [5]See author

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Power exhaust will be a critical issue for future tokamak fusion devices. The unmitigated power loads at the divertor targets can easily exceed the foreseen material limit of 10 MWm^{-2}. To prevent severe damage of plasma facing components these power loads have to be reduced significantly. This can be achieved by increased fueling and controlled seeding of impurity species like nitrogen or argon. The resulting high densities and low target temperatures lead to the so-called detachment state, which is characterized by strongly reduced target power fluxes.

In this contribution impurity seeding of nitrogen and argon is investigated via SOLPS modeling. The radiation efficiencies of the seeded impurities are discussed and compared to expectations from atomic databases. It can be observed, that the effective radiation efficiencies in the simulation are enhanced due to impurity transport which leads to a deviation from the coronal equilibrium. The code results will be validated with selected ASDEX Upgrade H-mode discharges with a particular focus on the comparison of the impurity radiation patterns using spectroscopic data and synthetic diagnostics in the simulation.

P 11.15 Tue 16:15 Redoutensaal

The bolometer diagnostic at the stellarator Wendelstein 7-X — •Philipp Hacker[1,2], Daihong Zhang[1], Rainer Burhenn[1], Birger Buttenschön[1], Thomas Klinger[1], and W7-X Team[1] — [1]Max-Planck Institut für Plasmaphysik, EURATOM Association, D-17491 Greifswald, Germany — [2]Ernst-Moritz-Arndt Universität Greifswald, D-17491 Greifswald, Germany

The bolometer diagnostic at the stellarator Wendelstein 7-X (W7-X), using metal resistive detectors, aims to investigate the features of the plasma radiation mainly from the impurities and to provide the total radiated power loss for global power balance study. A two-camera system consisting of detector arrays with blackened gold-foil absorbers has been installed at W7-X. They view the plasma at a triangular cross section horizontally and vertically, respectively. The fan-shaped lines of sight provide full coverage of the studied plasma with a spatial resolution of 5cm. Based on their line-integrated measurements the total radiated power loss of the divertor plasma has been estimated independently. The initial results for helium and hydrogen plasma at different magnetic configurations and heating powers will be presented.

P 11.16 Tue 16:15 Redoutensaal

Calibration and Operation of the Soft X-ray Tomography System (XMCTS) and the Mirnov Diagnostic in the Wendelstein 7-X Stellarator — •Natalie Lauf[1], Christian Brandt[1], Kian Rahbarnia[1], Henning Thomsen[1], Jonathan Schilling[1], Torsten Broszat[1], Alexander Card[1], Ralph Laube[1], Mirko Marquardt[1], Timo Schröder[1], Torsten Bluhm[1], Tamara Andreeva[1], Ulrich Neuner[1], Manfred Zilker[2], and the W7X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, Garching, Germany

The soft x-ray multi-camera tomography system (XMCTS) is a new diagnostic implemented for operational phase 1.2a (August - December 2017) of the Wendelstein 7-X fusion experimental stellarator. In current operation, 18 pinhole cameras mounted within the vacuum vessel cover 324 lines of sight and will measure x-ray emission from the plasma. The shape of the magnetic flux surfaces and instability dynamics are reconstructed from this data. Supplementary to this diagnostic are 125 poloidally arranged Mirnov coils measuring changes in the poloidal magnetic field component. Phase differences between coils allow mode numbers to be extracted. Calibration and operation of the XMCTS and the Mirnov diagnostic will be presented here facilitating work during following operational campaigns to correlate the reconstructed dynamics from data acquired by the XMCTS and the Mirnov diagnostics with the associated magnetic configuration and data from complementary diagnostics.

P 11.17 Tue 16:15 Redoutensaal

Core temperature collapses driven by ECCD at W7-X stellarator — •Marco Zanini, Heinrich Laqua, Torsten Stange, Robert Wolf, and W7-X Team — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, D-17491, Greifswald, Germany

The superconducting optimized stellarator Wendelstein 7-X is equipped with a flexible electron cyclotron resonance heating (ECRH) system, that allows up to 7 MW of power to be delivered to the plasma. A localized power deposition is possible and the ECRH itself can be used to drive a net current (ECCD). The negligible presence of toroidal currents makes W7-X a perfect testbed for ECCD experiments.

During ECCD operations, repetitive and periodic collapses of the central electron temperature have been observed; these collapses display a similar behavior to the well known "sawtooth oscillation" present in tokamaks.

An initial 1-D model has been developed to study the current diffusion in the plasma. An ECCD profile is simulated using the ray tracer code TRAVIS, developed at IPP. Due to Lenz's law a counter current is induced, whose time evolution is studied and analyzed. Local changes in the current density profile generate a local modification of the rotational transform, which can reach resonant values usually associated with appearance of plasma instabilities.

The characteristic timescale between the collapses is compared to the time needed by the rotational transform to reach the assumed resonant values.

P 11.18 Tue 16:15 Redoutensaal

Power balance analysis of the geodesic acoustic modes. — •Ivan Novikau[1], Alessandro Biancalani[1], Alberto Bottino[1], Garrard D. Conway[1], Peter Manz[1], Pierre Morel[2], Özgür D. Gürcan[2], and Emanuele Poli[1] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching Germany — [2]LPP, CNRS, École polytechnique, UPMC Univ. Paris 06, Univ. Paris-Sud, Observatoire de Paris, Université Paris-Saclay, Sorbonne Universités, PSL Research University, F-91128 Palaiseau, France

Turbulence in tokamaks generates radially sheared zonal flows (ZFs). ZFs are zero frequency electrostatic ExB modes, damped mainly by collisional processes.The action of the magnetic field curvature on the ZFs gives rise to oscillations of radial electric field called the geodesic acoustic modes (GAMs). GAMs are mainly damped by collisionless wave-particle resonance, i.e, Landau damping. Zonal structures can regulate and suppress turbulence, thus reducing the radial transport. Collisional ZF and collisionless GAM damping rates constitute crucial linear parameters in the nonlinear interaction between the zonal structures and the turbulence.

In this work, the dynamics of linear and turbulence-driven GAMs is investigated with the GK electromagnetic particle-in-cell code ORB5. The development and extension of the power balance diagnostics for the contribution of different particle species in ORB5 are described. Moreover, different reduced models derived from the GK theory are used to study the efficiency of the zero-frequency zonal structures, ZFs, and their oscillatory part, GAMs, in the turbulence suppression.

P 11.19 Tue 16:15 Redoutensaal

Deep Learning for Plasma Diagnostics — •Francisco Matos, Florian Hendrich, Frank Jenko, and Tomas Odstrcil — Max Planck Institute for Plasma Physics, Garching, Germany

At the ASDEX-Upgrade Tokamak, a Soft X-ray diagnostic exists which can be used to perform tomographic inversion (that is, reconstructing the 2D emissivity profile) of the plasma. However, state of the art tomographic algorithms require manual tuning to detect faulty measurements, can be too slow for real-time use, and do not always produce the most accurate profiles.

Our focus is on exploring the application of Deep Learning to convert this soft-x ray data into the full images (reconstructions) of the plasma emissivity profile, with the ultimate goal of producing accurate, noise-resistant, tomographic reconstructions at real-time speeds. The current approach consists in turning the concept of a Convolutional Neural Network upside down, with fully-connected layers processing the input signal, and transpose convolutional layers responsible for learning the image features to generate. We train this network by calculating the loss as the absolute error with respect to the pixels of existing tomograms. For this, we have a dataset consisting of approximately 120 000 measurement/image pairs.

P 11.20 Tue 16:15 Redoutensaal

Minerva neural network based surrogate models for real time inference of ion temperature profiles at Wendelstein 7-X — •Andrea Pavone[1], Jakob Svensson[1], Andreas Langenberg[1], Novimir Pablant[2], Robert C. Wolf[1], and W7-X team[1] — [1]Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald, D-17491 Greifswald, Germany — [2]Princeton Plasma Physics Laboratory, 08540 Princeton, NJ, US

At the Wendelstein 7-X stellarator, tens of diagnostics produce a massive amount of data relevant to the measurement of plasma parameters. Forward models of many diagnostics are implemented in the Minerva framework where Bayesian inference is applied to complex systems constituting multiple diagnostics and physics models. Conventional inversion routines can take hours for a single data point, but Artificial Neural Networks (ANNs) can reduce the time by several orders of magnitude, making real-time analysis possible and providing a reliable alternative to such routines. We have trained ANNs exclusively on data synthesized within the Minerva framework, so that the trained ANNs constitute a surrogate model of the full physics model. We also focused on the quantitative estimation of the uncertainties of the ANN*s output, based on the stochastic properties of the optimization and the limited parameter space coverage of the training set with respect to novel measured data points. Results from applying ANNs to ion temperature profile inference from 2D X-ray spectral measurements will be compared with standard inversion routines, showing robustness and reliability for real time plasma parameter inference.

P 11.21 Tue 16:15 Redoutensaal

Hybrid drift kinetic electron - kinetic ion computations for electrostatic fluctuations in astrophysical plasmas — •Karen Pommois[1], Simon Lautenbac[2], Daniel Told[1], and Rainer Grauer[2] — [1]Max Planck Institut fur Plasmaphysik, Garching, Germany — [2]Ruhr Universität, Bochum, Germany

Kinetic numerical simulations, applied to study local heating in the solar wind [1], are computationally expensive due to the different evolution scales involved in the dynamics. The dispersion relation of Alfvén wave and fast magnetic mode were found with different simplified models, such as hybrid fluid-kinetic and gyrokinetic, and were compared in a recent work [2]. It has emerged that hybrid kinetic is well suited to describe high frequency waves, on the other hand it misses electron kinetic effects even at ion scales. Instead, gyrokinetics is able to capture kinetic electron effects but limited to wave frequencies below the cyclotron frequencies of the species involved. Hence, to enlarge the range of frequency of validity of gyrokinetic model for simulations of astrophysical plasmas, we aim to implement a hybrid model that involves a gyrokinetic description for electrons and kinetic for ions. In this poster we will show the first results, where we implemented this new hybrid model in the case of electrostatic dynamics and drift-kinetic electrons in muphy [3], a framework designed to couple different numerical codes for solving plasma problems. References: [1] R. Bruno and V. Carbone. Living Rev. Solar Physics, 2(4), 2005. [2] D. Told et al. New J. Phys., 18(6):065011, 2016. [3] M. Rieke et al. J. Comput. Phys., 283:436-452, 2015.

P 11.22 Tue 16:15 Redoutensaal

Gyrokinetics of electron-positron plasmas — •Daniel Kennedy, Alexey Mishchenko, and Per Helander — Max-Planck-Institut für plasmaphysik

The prospects of creating electron-positron pair plasmas magnetically confined in dipole geometries have been discussed since early 2000*s (Pedersen et al. 2003). In the immediate future, the first experiment aiming at this goal will be constructed (Pedersen et al. 2012). Recently, efficient injection and trapping of a cold positron beam in a dipole magnetic field configuration has been demonstrated by Saitoh et al. (2015). This result is a key step towards the ultimate aim of creating and studying of the first man-made magnetically-confined pair plasma in the laboratory.

It has been shown by Helander (2014) and Helander and Connor (2016) that the pair plasmas possess unique gyrokinetic stability properties due to the mass symmetry between the particle species. For example, drift instabilities are completely absent in pure pair plasma in a slab geometry.

However, in creating and confining a pair plasma experimentally, there will be a timescale, during the positron injection, on which plasma quasineutrality has not yet been established. This could lead to interesting behaviour in the plasma. Here we will present the first steps in the analytical theory of non-neutral pair plasma stability.

We will also present the first steps towards the first numerical simulations of pair plasmas in a dipole geometry using the GENE code.

P 11.23 Tue 16:15 Redoutensaal

Dependence of small Edge Localized Modes on Plasma Parameters — •G. F. Harrer[1,2], E. Wolfrum[2], T. Eich[2], M. G. Dunne[2], P. Manz[2], P. T. Lang[2], H. Meyer[3], M. Bernert[2], B. Labit[4], G. Birkenmeier[2], J. Stober[2], F. Aumayr[1], the EUROFUSION MST1 Team[5], and the ASDEX Upgrade Team[2] — [1]TU Wien, Austria — [2]IPP Garching, Germany — [3]CCFE Culham, United Kingdom — [4]SPC Lausanne, Switzerland — [5]see H. Meyer et al. 2017 Nucl. Fusion 57 102014

The development of small Edge Localized Mode (ELM) scenarios is important in order to understand how to reduce the strain on plasma facing components. One such scenario can be found at high densities, in highly shaped, close to double-null plasmas as small ELMs or type-II ELMs in ASDEX Upgrade, which are characterized by a frequency $f_{ELM} > 300$Hz and a low power loss. Comparing deuterium gas and pellet fuelling showed that this small ELM regime is dependent on the separatrix density, by decoupling it from the pedestal top density. This strong local dependence of small ELMs on the scrape-off layer parameters is in agreement with a ballooning model for the separatrix region. It has also been shown, that changing the vertical plasma position and with that, the plasma shape, the small ELMs shrink in size and get replaced by large type I ELMs. One hypothesis to explain this behavior is a strong dependence of these ballooning modes on the magnetic shear (global and local).

P 11.24 Tue 16:15 Redoutensaal

An algorithm for stellarator coil optimization that takes engineering tolerances into account — •Jim-Felix Lobsien, Michael Drevlak, Thomas Sunn Pedersen, and W7-X Team — Max-Planck Institut für Plasmaphysik, Greifswald, Germany

Recently designed optimised stellarator experiments have suffered from very low construction tolerances. Deviations of the central coil system are unavoidable during fabrication of the coils, and assembly of the coil system. In this paper, we present a new approach that incorporates reduced sensitivity to construction tolerances of the coil system into the optimization routine. The approach was tested within the framework of the existing coil optimization scheme for Wendelstein 7-X. The results are compared with those of a coil set obtained by the original optimisation. The result is a coil system with higher tolerances, such that small deviations do not cause deterioration of the properties important for fusion performance.

P 11.25 Tue 16:15 Redoutensaal

First results of the Coherence Imaging Spectroscopy Systems on Wendelstein 7-X — •Valeria Perseo[1], Ralf Koenig[1], Oliver Ford[1], Dorothea Gradic[1], Florian Effenberg[2], Christoph Biedermann[1], Gabor Kocsis[3], Thomas Sunn Pedersen[1], and W7-X Team[1] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]University of Wisconsin, Madison, USA — [3]Wigner RCP, Budapest, Hungary

The Coherence Imaging Spectroscopy (CIS) system is a camera based interferometer able to measure 2D impurity flow velocities for a selected visible line from the plasma. A modulation pattern encoding the spectral line properties is generated by the usage of birefringent crystals. The CIS system 2D measuring capability and high optical throughput made the diagnostic attractive for the complex magnetic island topology of Wendelstein 7-X (W7-X). Two CIS systems have been designed and set up to face the challenging experimental conditions of W7-X. Their views is on the same island divertor, which is observed with nearly perpendicular lines of sight for an easier emission and flow interpretation in the W7-X geometry. First measurements have been performed during the second part of the last experimental campaign OP1.2a, observing the plasma at different magnetic configurations, densities and heating powers. The behavior of multiple impurities, mainly carbon and helium, have been studied. The diagnostic output will be compared with dedicated EMC3-EIRENE simulations.

P 11.26 Tue 16:15 Redoutensaal

First gas balance studies of Wendelstein 7-X — •Georg Schlisio, Uwe Wenzel, Thomas Sunn Pedersen, and W7X Team — MPI für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald, Germany

The advanced optimized stellarator Wendelstein 7-X (W7-X) is currently in its second operation phase (OP 1.2), featuring now a graphite island divertor. The first wall consists of graphite tiles and stainless steel panels. Both divertor and first wall are inertially cooled. With a divertor, plasma-wall interaction changes significantly compared to the first operation with a graphite limiter.

The first wall can act as a source or sink for particles depending on the conditions. This has great influence on the plasma particle balance. The overall gas balance consists of all sources and sinks of particles.

We discuss the methods of the gas balance of OP1.2a with an assessment of all sinks and sources. Since the wall source is not directly accessible, it has to be determined indirectly via the other terms of the balance.

A major part of the gas balance is determined by the particle removal rate Q given by Q=p*S, wherein p is the divertor pressure measured by a set of ASDEX pressure gauges at different locations in the sub-divertor region of W7-X, and S is the effective pumping speed.

Experience from OP1.1 and OP1.2a shows the critical importance of these studies for density control already for the plasmas in OP1.2b but especially for the long-pulse discharges in the upcoming next operational phases with discharge lengths that eventually will exceed 1000s.

P 11.27 Tue 16:15 Redoutensaal

Analysis and Modelling of Neon Seeded JET Discharges with High Radiative Power Fraction — •Stephan Glöggler[1,2], Marco Wischmeier[1], and JET Contributors[3] — [1]IPP, Garching, Germany — [2]Physik-Department E28, TUM, Garching, Germany — [3]See the author list of "X. Litaudon et al 2017 Nucl. Fusion 57 102001"

In future fusion devices as ITER and DEMO the power flux onto the divertor target plates will have to be reduced by impurity radiation. 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 impact the plasma confinement and the discharge stability it is crucial to determine and understand the underlying physical processes in high radiative discharges.

At JET it could be measured that with the seeding of neon the radial pedestal temperature and densisty profiles degrade at the edge but recover towards the core. An increase of the energy confinement time is observed. An inter-relation of these pedestal 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 unseeded and neon seeded discharges complement the experimental findings. The impact of neon seeding on the pedestal profiles and on the divertor conditions will be investigated within these simulations.

P 11.28 Tue 16:15 Redoutensaal

SOLPS modelling for future snowflake- and X-divertor configurations in ASDEX Upgrade — •Ou Pan[1,2], Tilmann Lunt[1], Marco Wischmeier[1], David Coster[1], and The ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [2]Physik-Department E28, Technische Universität München, 85747 Garching, Germany

High heat loads on the plasma facing components of tokamak divertors impose serious constraints on the achievable performance of future fusion reactors. Instead of a standard single null (SN), an alternative divertor configuration such as snowflake- (SF) [1] or X-divertor (XD) [2] may mitigate these problems. Here we focus on a LFS SF- configuration where a secondary X-point is located at the low field side scrape-off layer (SOL) near the primary one. The geometrical splitting of the SOL as well as the enhanced divertor volume may help to reduce the maximum heat flux. The XD could enhance the divertor thermal capacity through a flaring of the field lines only near the divertor plates. In this work, the SOLPS code package is used to model the L-mode edge plasma for LFS SF- and XD configurations of ASDEX Upgrade upper divertor that will be upgraded in the near future [3]. With sufficient input power and nitrogen gas puff, simulations predict lower heat fluxes to the targets and higher radiative fractions in the LFS SF- case than that in the SN case with similar impurity concentrations at the separatrix. [1] D. Ryutov, et al., Plasma Phys. Control. Fusion 54 (2012) 124050 [2] M. Kotschenreuther, et al., Phys. Plasmas 14 (2007) 072502 [3] T. Lunt, et al., Nucl. Mat. Energy 12 (2017) 1037

P 11.29 Tue 16:15 Redoutensaal

Fast-ion transport study in the plasma periphery of ASDEX Upgrade using FIDA spectroscopy — •A. Jansen van Vuuren, B. Geiger, P.A. Schneider, A. Jacobsen, T. Lunt, and The ASDEX Upgrade Team — Max-Planck-Institut fur Plasmaphysik, D-85748 Garching, Germany

Good confinement of fast-ions is mandatory in fusion plasmas since these supra-thermal particles are responsible for plasma heating and current-drive. However, plasma perturbations such as edge localized modes (ELMs) might degrade the fast-ion confinement and the corresponding losses could even damage plasma facing components.

One powerful tool to study confined fast ions in fusion experiments is fast-ion D-alpha (FIDA) spectroscopy which makes use of Doppler shifted radiation, emitted by fast ions after charge exchange reactions.

The FIDA method has now been applied to study the fast-ion distribution function in the plasma edge of ASDEX Upgrade. A specialized FIDA spectrometer has been designed to acquire simultaneously the FIDA emission and the un-shifted D-alpha emission from background neutrals. The latter allows to estimate the background neutral density profile, the main reaction partner for the charge exchange reaction at the edge. The new system can be operated through a burst mode, allowing measurements with exposure times down to hundreds of microseconds. First measurements show strongly reduced FIDA signal intensities after ELMs that can in part be explained by fast-ion losses.

P 11.30 Tue 16:15 Redoutensaal

Integrated modelling of tokamak plasma confinement combining core and edge pedestal physics — •Teobaldo Luda, Clemente Angioni, Mike Dunne, Emiliano Fable, Giovanni Tardini, Francois Ryter, and ASDEX Upgrade Team — Max-Planck-Institut für Plasmaphysik, Garching

A new theory-based approach to the integrated modelling of tokamak plasma confinement is being developed, which aims at predicting the total stored energy, and the plasma kinetic profiles, only using global plasma parameters of the discharge as inputs, such as the plasma current, the density and the heating powers. As a first step in the development of the model, we use the TGLF model to evaluate the turbulent transport fluxes in the core region, while in the pedestal region, transport is assumed to be purely neoclassical. With the transport code ASTRA, we investigate the applicability of the TGLF transport model to the plasma periphery, and how different assumptions on the pedestal transport affect the core, when the boundary conditions of the simulation are set at the last closed flux surface. We then check with the MISHKA MHD stability code that the heights and widths we are evaluating are consistent with the constraints imposed by peeling-ballooning modes. The long term goal is to obtain a robust model for the entire plasma which can be applied to large experimental databases, in order to identify important hidden dependencies affecting the global plasma confinement, which are difficult to capture by statistical regressions on global parameters.

P 11.31 Tue 16:15 Redoutensaal

Experimental Characterisation of Parametric Decay Instabilities at ASDEX Upgrade — •Søren Kjer Hansen[1,2], Stefan Kragh Nielsen[2], Jörg Stober[1], Jesper Rasmussen[2], Morten Stejner[2], 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

When high power wave beams are injected into a plasma, e.g. for heating, current drive or diagnostic purposes, the wave amplitude may become so large that the linear approximation breaks down and a parametric decay instability (PDI) is excited. The present work concerns PDIs occurring for gyrotron radiation near the upper hybrid resonance at the ASDEX Upgrade tokamak, and is motivated by observations of strong anomalous (PDI generated) scattering made using the collective Thomson scattering (CTS) diagnostic. We measure the frequency power spectrum generated by the PDI with the high resolution fast receiver CTS system installed at ASDEX Upgrade and characterise its dependence on the injected gyrotron power by means of fast analog modulation of said power. The experimental observations are in reasonable agreement with previously published theoretical results. Apart from characterising anomalous scattering during CTS experiments, the present results may also have relevance for O-X-B heating experiments, planned for Wendelstein 7-X, and 1st harmonic electron cyclotron resonance heating, planned for ITER.

P 11.32 Tue 16:15 Redoutensaal

Impurity studies with Charge Exchange Spectroscopy on W7-X — •Lilla Vanó, Juergen Baldzuhn, Oliver Ford, Robert C Wolf, and the W7-X team — Max-Planck-Institute for Plasma Physics, Greifswald, Germany

Wendelstein 7-X (W7-X) is an optimized stellarator with the goal of demonstrating the stellarator as a promising candidate for a future fusion power plant. Apart from the main plasma species, hydrogen, impurities enter the plasma from the surrounding walls and cause power loss by increasing plasma radiation. Understanding the transport of these ions can help us optimise the stellarator configuration to reduce impurities.

There are several diagnostics that investigate impurity transport, one of them is the Charge Exchange Recombination Spectroscopy (CXRS). On W7-X, neutrals from the Neutral Beam Injection (NBI) will transfer an electron to the fully-stripped low-Z ions in the plasma (e.g. carbon). This allows the characteristics of these ions to be examined. Until the NBI is available, the emission of the passively excited low-Z ions near the plasma edge can also be measured but with lower intensity and as line integrated measurements.

In this work, data from the passive system is analyzed, delivering the temperature profile and the distribution of the Carbon-VI ions. These results will provide information about the primary plasma impurity in the first W7-X campaign with a fully carbon divertor.

P 11.33 Tue 16:15 Redoutensaal

Relaxation of fluid theories by metriplectic dynamics: a method based on a generalization of the Landau collision operator — •Camilla Bressan[1,2], Michael Kraus[1,2], Philip James Morrison[3], and Omar Maj[1,2] — [1]Max-Planck-Institute for Plasma Physics, Garching, Germany — [2]Technische Universität München, Zentrum Mathematik, Garching, Germany — [3]The University of Texas at Austin, Physics Department and Institute for Fusion Studies, USA

The computation of general 3D MHD equilibria plays a fundamental role in Stellarator as well as in Tokamak simulations in which 3D effects (namely islands, ripples and resonant magnetic perturbations) are increasingly important.

A novel relaxation method based on the paradigm of metriplectic dynamics [P.J.Morrison, Physica D, **18**, 410-419 (1986)] is proposed. This specific relaxation mechanism has the same structure as the Landau collision operator, so that its equilibrium points can be understood in terms of local extrema of an entropy functional. No restrictive assumption on the topology of the magnetic field is made. In fact it allows for the formation of magnetic islands and stochastic regions, while maintaining a control on relaxed equilibrium profiles.

The new approach has been numerically tested on both the Euler ideal fluid equations in two dimensions and Grad-Shafranov MHD equilibria. First steps toward a proof of concept for 3D MHD are discussed.

P 12: Magnetic Confinement - Poster

Time: Tuesday 16:15–18:15 Location: Redoutensaal

P 12.1 Tue 16:15 Redoutensaal

The effect of plasma density fluctuations on the propagation of microwave beams used for plasma heating — •Alf Köhn[1,2], Lorenzo Guidi[2,3], Eberhard Holzhauer[1], Omar Maj[2], Emanuele Poli[2], Antti Snicker[2,4], Matthew Thomas[5], and Roddy Vann[5] — [1]IGVP, Universität Stuttgart, Germany — [2]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [3]Technische Universität München, Numerical Methods for Plasma Physics (M16), Garching, Germany — [4]Department of Applied Physics, Aalto University, Finnland — [5]York Plasma Institute, University of York, UK

Microwaves play an indispensable role in plasma experiments for heating and diagnostic purposes. When injected into the plasma or emitted by it the microwaves have to pass the plasma boundary, a region where strong plasma density fluctuations with fluctuation levels up to 100 % can occur. The interaction with the fluctuations can deteriorate the quality of the microwave beam resulting in reduced heating efficiencies or ambiguous diagnostics results. This is in particular a problem for the control of MHD instabilities by localized current drive using microwaves in the electron cyclotron range of frequencies. Here we present numerical simulations of the microwave interacting with the fluctuation layer by means of two different numerical codes, a full-wave code and a wave kinetic equation solver which treats the effects of fluctuations based in the Born approximation. Limitations of the latter treatment are explored and extrapolations towards ITER are drawn.

P 12.2 Tue 16:15 Redoutensaal

Completion of magnetic diagnostics and bootstrap current studies at the stellarator Wendelstein 7-X — •K Rahbarnia[1], T Andreeva[1], T Bluhm[1], B B Carvalho[2], M Endler[1], D Hathiramani[1], J Geiger[1], N Lauf[1], U Neuner[1], J Schilling[1], H Thomsen[1], Y Turkin[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

About 90% of the magnetic diagnostic system at Wendelstein 7-X (W7-X) has been put into operation during the second operational phase OP1.2a, August-December 2017. The diagnostic system consists of 3 diamagnetic loops, 6 Rogowski coils arrangements, 40 saddle coils and 125 Mirnov coils, distributed in all 5 modules of W7-X. Data recording and storing of raw signal streams into the W7-X archive database has been fully automatized via the central operation control system. Automatized data analyzing software, implemented in the MINERVA framework, calculates magnetic fluxes of all sensors, as well as the compensated diamagnetic energy and plasma current. The pre-analyzed data is written into the W7-X archive database directly after each plasma pulse. Plasma pulse duration of up to 20 s in combination with plasma density feedback control allows detailed studies of the bootstrap current. The experimental results are complemented by theoretical predictions. The minimization of bootstrap currents in dedicated magnetic field configurations, which are optimized for low plasma current and future long pulse operation, has been confirmed.

P 12.3 Tue 16:15 Redoutensaal

Langmuir probe diagnostic at the Vineta II magnetic reconnection experiment — •Tiziano Fulceri, Adrian Von Stechow, and Olaf Grulke — Max Planck Institut für Plasmaphysik, 17489 Greifswald, Wendelsteinstrasse 1, Deutschland

Vineta II is an experiment to investigate magnetic reconnection in a controlled laboratory environment. In its current setup, reproducible magnetic reconnection is driven on a timescale of the order of $10\,\mu s$ and the reconnection current sheet and magnetic topology is reconstructed using postionable probes. Central reconnection current sheet properties, such as the time evolution of electron temperature and density as well as electrostatic fields, are measured by a fast swept Langmuir probe. It is biased with an oscillating +/-200V voltage at an adjustable frequency from 50kHz to 200kHz, which allows to record the full probe characteristics on the reconnection timescale. Key parameters are the gradients of electron density and temperature, which contribute significantly to the radial force-balance of the reconnection current sheet. This contribution describes the development of the probe's experimental setup, especially with regards to high frequency circuit optimization (pickup rejection, low inductances), and presents initial measurements results.

P 12.4 Tue 16:15 Redoutensaal

Shearing rate dependence of Reynolds-Stress — •Til Ullmann, Mirko Ramisch, and Bernhard Schmid — Institut for Interfacial Process Engineering and Plasmatechnology - University of Stuttgart

Turbulence generated zonal flows (ZFs) are known to be part of regulating turbulent transport and, therefore, are suspected to be involved in spontaneous transitions from low to high confinement regimes in toroidal fusion plasmas. ZFs are driven by radial gradients of the turbulent Reynolds-Stress $\langle \tilde{v}_\theta \tilde{v}_r \rangle$, which de facto measures the tilt of vortices. Hence, equilibrium shear flows constitute a seed flow for initially tilting vortices, initiating the ZF drive and stimulating its selfamplification. In this contribution the dependence of Reynolds-Stress on background flow shearing rates is investigated experimentally. To this end, the poloidal $E \times B$ background flow in the sellarator TJ-K is controlled via plasma biasing. A ring shaped electrode is positioned in the plasma and set on a positive potential with respect to the vacuum vessel. This application even allows to equalize the pressure driven $E \times B$ background flow and, therefore, is found to be minimal. The trend of the Reynolds-Stress with the shearing rate will be analysed and compared to the development of the measured ZFs.

P 12.5 Tue 16:15 Redoutensaal

The Wendelstein 7-X Phase Contrast Imaging Diagnostic — •Adrian von Stechow[1], Olaf Grulke[1,3], Lukas-Georg Böttger[1,3], Eric Edlund[2], Miklos Porkolab[2], and The W7-X team[1] — [1]Max-Planck-Institut für Plasmaphysik — [2]MIT Plasma Science and Fusion Center — [3]Technical University of Denmark

The Wendelstein 7-X stellarator (W7-X) is in its second operation phase with full divertor geometry. W7-X is highly optimized to minimize neoclassical transport and designed to run steady state, and is thus the first stellarator in which the role of turbulent transport can be quantitatively assessed at reactor relevant parameters. These results feed back to ongoing modeling activities which predict ion temperature gradient and trapped electron modes that fundamentally differ in their scaling and spatial distribution from those observed in tokamaks.

Quantitative characterization of turbulence requires a broad range of profile and fluctuation diagnostics, including a new phase contrast imaging (PCI) system that measures spatially resolved electron density fluctuations along a sight line through the plasma center. The project is a collaboration between the MIT PSFC and IPP. An overview of diagnostic features and capabilities and exemplary results of characteristic discharge features are presented. These include remote alignment and optical reconfiguration of the CO_2 laser system to cover a broad spatial range in real (50-110 mm) and k space (5-17 cm^{-1}), absolute k-space and relative amplitude calibration by means of an acoustic speaker array, and radial localization of measurements by selective beam masking.

P 12.6 Tue 16:15 Redoutensaal

Commissioning of the soft X-ray tomography system (XMCTS) in the Wendelstein 7-X stellarator — •Christian Brandt, Natalie Lauf, Jonathan Schilling, Henning Thomsen, Alexander Card, Mirko Marquardt, Timo Schröder, Torsten Broszat, Ralph Laube, and The W7-X Team — Max-Planck-Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

The X-ray multi-camera tomography system (XMCTS) has been commissioned in the stellarator experiment Wendelstein 7-X (W7-X) during operational phase 1.2a (Aug-Dec 2017). The current setup of the diagnostic consists of 18 pinhole cameras arranged on a poloidal array at a toroidal position with up-down symmetric triangular shaped flux surfaces. The emissivity of the plasma in the X-ray range ($1-10$ keV) is measured along 324 lines-of-sight covering the poloidal cross section up to the last closed flux surface with a spatial resolution of $\approx 3-4$ cm. The data acquisition system is commissioned to record 384 channels sampled with 2 MHz at a data rate of 1.6 GB/s capable of recording discharges of 300 s length. First experimental results of X-ray emission obtained during well-defined laser blow-off experiments and gas puffs using different materials and gases are presented. To calculate the 2D emissivity profiles for different magnetic field configurations the preparations for tomographic reconstruction and calibration are discussed.

P 12.7 Tue 16:15 Redoutensaal

Gyrokinetic Studies of Inter-ELM Pedestal Evolution using GENE Code — •Karl Stimmel — Max Planck Institute for Plasmaphysics, Boltzmannstraße 2, 85748 Garching bei München

For the Deutsch Physikalische Gesellschaft conference in Erlangen, preliminary results on Inter-ELM (Edge Localized Mode) pedestal structure for ASDEX Upgrade shot 31529 are outlined. The inter-ELM region is averaged into one coherent structure which can be simulated with GENE. Preliminary results outlining 3 regions of interest relative to ELM crash onset are outlined. The scope of future work and significance of the simulation results with regards to new diagnostics on ASDEX upgrade and new capabilities of GENEcode.

P 12.8 Tue 16:15 Redoutensaal

Analysis of the impurity content in Wendelstein 7-X using VUV spectroscopic data — •Birger Buttenschön, Rainer Burhenn, Daihong Zhang, Thomas Wegner, Golo Fuchert, Andreas Langenberg, and the W7-X Team — Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, 17491 Greifswald

Throughout the second operation phase of the stellarator Wendelstein 7-X, the impurity content and their (dynamic) behaviour in various discharge configurations were carefully monitored and investigated. The main diagnostics for the determination of impurity compositions is the VUV spectrometer system HEXOS. As this device is absolutely intensity calibrated, its data is also used, in conjunction with the 1D impurity transport code STRAHL, to derive the individual impurity concentrations.

First assessments of the impurity composition and concentrations in Helium and Hydrogen discharges are presented. This comparison might give insight into the general difference in performance in the two gases, and allows for a careful discussion of possible impurity sources during this operation phase.

P 12.9 Tue 16:15 Redoutensaal

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

The magnetic dipole field permits both in planetary magnetospheres and in the laboratory exceptional charged particle confinement with an arbitrary degree of neutrality. This makes it a promising geometry for the creation and study of a maybe even more unconventional object of research - a magnetized low-energy electron-positron plasma. Basic prerequisite for its success is the development of techniques for charged-particle injection into a closed magnetic system and subsequent particle manipulation and confinement. These challenges have been addressed in positron experiments with a prototype dipole trap at NEPOMUC, the world's most intense source of low-energy positrons.

In recent injection-hold-dump experiments we observed positron confinement times ranging from 0.2 to 1.3 seconds depending on the experimental conditions. In this contribution we will discuss asymmetries and collisions with neutrals as potential loss mechanisms. Together with results from single-particle simulations this yields a reasonable explanation for the observed confinement times.

P 12.10 Tue 16:15 Redoutensaal

Transport properties of injected impurities in Wendelstein 7-X stellarator. — •Th. Wegner[1], B. Geiger[1], R. Burhenn[1], B. Buttenschön[1], D. Zhang[1], A. Langenberg[1], N. Pablant[2], and The W7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald, Germany — [2]Princeton Plasma Physics Laboratory, Princeton, NJ, USA

Impurities in the plasma mainly influence the power balance. In particular, their existences increase the radiation losses and the dilution of the plasma. Especially in stellarators, impurities can be accumulated and cause an early pulse termination by radiation collapse. Hence, the investigation of the impurity transport properties is a demanding task for plasma devices with the potential of steady-state operation. Therefore, tracer impurities were injected by means of a new laser blow-off system on W7-X in a controlled manner. After the injection, the emission of several ionization states from the X-ray to XUV wavelength range were measured in different magnetic field configurations and plasma parameters. Simulation of their temporal behavior using measured radial profiles of the electron temperature and density allow access to transport properties. In particular, the impurity confinement time, the diffusion coefficient and the convection velocity will be presented for different impurity elements, plasma parameters and main plasma species.

P 12.11 Tue 16:15 Redoutensaal

Magnetic diagnostics integration in the Minerva framework for the Wendelstein 7-X stellarator — •Jonathan Schilling[1], Tamara Andreeva[1], Oliver Ford[1], Joachim Geiger[1], Ulrich Neuner[1], Kian Rahbarnia[1], Jakob Svensson[1], Henning Thomsen[1], Samuel Lazerson[2], John Schmitt[3], and The W7-X Team[1] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Princeton Plasma Physics Laboratory, New Jersey, USA — [3]Auburn University, Alabama, USA

For the latest experimental campaign of the Wendelstein 7-X stellarator, automated preanalysis of the magnetic diagnostics data was implemented in the Bayesian data analysis framework Minerva. We present first results of a simplified reconstruction of the toroidal current profile as well as a comparison of the experimental results with theoretical predictions based on equilibrium calculations using the VMEC code. A prediction of the measured signals is computed based on the equilibrium magnetic field within the framework and compared to results from established codes as DIAGNO and Extender. In this contribution the new implementation of the magnetic diagnostics response prediction in the context of the Minerva framework is presented. Benchmarks in terms of speed and accuracy against existing codes are presented and optimization towards sufficiently fast prediction for equilibrium reconstructions during the experiment program is assessed.

P 12.12 Tue 16:15 Redoutensaal

Gyrofluid Simulations of Tokamak Edge Plasmas — •Adam Dempsey, Huw Leggate, and Miles M. Turner — Dublin City University, Dublin 9, Ireland

Filaments are field aligned structures that are known to form in the scrape-off-layer (SOL) in tokamaks. These structures are composed of hot electrons and ions. They can constitute a non-negligible thermal and particle flux on the first wall. As such the propagation of these structures to the first wall is problematic. One approach to predicting such fluxes in plasmas is to rely on simulation.

The approach described herein is to use a gyrofluid model (GEM). Gyrofluid models incorporate higher order finite Larmor radius effects more naturally that other fluid models. Initial progress towards solving this gyrofluid model in a slab geometry is presented. BOUT++ which is a framework for writing fluid and plasma simulations is used to evolve the gyrofluid moment equations. The focus of these simulations is on the effect of finite Larmor radii on filament propagation near the SOL. Of particular interest are filament-background interactions and the verification of filament velocity scaling laws which have to date largely been identified using fluid models.

P 12.13 Tue 16:15 Redoutensaal

Progress on the development of superconducting coils as confinement devices for pair plasmas — •Markus Singer[1], James R. Danielson[2], Marcel Dickmann[1], Uwe Hergenhahn[3], Juliane Horn-Stanja[3], Stefan Nissl[3], Harukiho Saitoh[3], Eve V. Stenson[3], Matthew R. Stoneking[4], Thomas Sunn Pedersen[3,5], and Christoph Hugenschmidt[1] — [1]Technische Universität München — [2]University of California, San Diego, USA — [3]Max-Planck-Institute for Plasma Physics — [4]Lawrence University, USA — [5]University of Greifswald

A plasma composed of particles with identical masses but opposite charges is predicted to feature fundamentally different phenomena compared to electron ion plasmas. Even though extensive theoretical studies have been carried out for decades, the experimental demonstration of matter-antimatter pair plasmas has not succeeded yet. The APEX project is aiming for the creation of the first magnetically confined laboratory plasma consisting of electrons and positrons, using the worlds strongest high-flux low-energy positron source NEPOMUC. Recent experiments using a prototype permanent magnet dipole trap have already demonstrated high injection efficiencies and long confinement times. The simultaneous confinement of both electrons and positrons however, requires closed unperturbed magnetic field lines. For this purpose we are developing an upgraded dipole trap using a magnetically levitated high temperature superconducting coil. This contribution will depict the progress on the transition of the confinement volume from a mechanically supported to a levitated geometry.

P 12.14 Tue 16:15 Redoutensaal

Search for signatures of non-local electron heat transport in fusion plasmas — •Klara Höfler[1,2], Tim Happel[1], Pascale Hennequin[3], François Ryter[1], Ulrich Stroth[1,2], Udo Höfel[4], the ASDEX Upgrade Team[1], and the W7-X Team[4] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Physics Department E28, Technical University Munich, Garching, Germany — [3]Laboratoire de Physique des Plasma, Ecole Polytechnique, Palaiseau, France — [4]Max Planck Institute for Plasma Physics, Greifswald, Germany

Heat transport in fusion plasmas is in general described by Fick's law which predicts a direct dependence of energy fluxes on the local gradients in plasma temperature and plasma density. Fick's law has been experimentally confirmed, however, past and current fusion devices reported experiments where under certain conditions in transient state the local heat flux is no longer a function of the local parameters only. This talk presents the search for this kind of violations on the ASDEX Upgrade tokamak and the W7-X stellarator. Transient states in electron heat flux are generated by strong and fast changes of the electron microwave heating, both with sudden power steps after stationary state as well as fast power modulation. The spatially and temporally resolved heat flux is taken from subtracting the radiated and the absorbed power from the heating power. Conclusions about non-locality are drawn from relating the heat flux to the local temperature gradient and from simulations with the transport code ASTRA which connect power steps and modulation experiments.

P 13: Low Pressure Plasmas - Poster

Time: Tuesday 16:15–18:15 Location: Redoutensaal

P 13.1 Tue 16:15 Redoutensaal

Electron Impact Excitation of Xenon — •Dirk Luggenhölscher[1], Uwe Czarnetzki[1], Oleg Zatsarinny[2], and Klaus Bartschat[2] — [1]Ruhr-Universität Bochum — [2]Drake University, Iowa, USA

A novel experimental technique is applied to measure cross sections for electron-impact excitation of the $5p^56p$ state of xenon from its $5p^6$ ground state. This is a complex collision system, for which benchmarking of theory against experiment is needed. The experiment is performed using ultrashort current pulses released from an electrode by femtosecond laser pulses with 80 MHz repetition rate. In order to minimize space charge effects, only about 10^4 electrons are generated in each pulse. Electrons are accelerated by a homogeneous electric field to energies of typically 250 eV. The fluorescence light (transition from $5p^56p$ to $5p^56s$) generated after collisions with Xe atoms at low pressure (Pa range) is observed perpendicular to the electron beam direction and provides a direct image of the energy-dependent excitation cross section. The calculations were carried out with a fully relativistic and parallelized version of the B-spline R-matrix code [1], using a 75-state close-coupling model [2] with the target structure obtained earlier [3]. The work of OZ and KB is supported by the US NSF under PHY-1403245, PHY-1520970, and XSEDE-090031.

[1] O. Zatsarinny, Comp. Phys. Commun. **174** (2006) 273
[2] O. Zatsarinny and K. Bartschat, J.Phys.B: At. Mol. Opt. Phys.**43** (2010) 074031
[3] O. Zatsarinny and K. Bartschat, Phys. Scr. T. **134** (2009) 014020

P 13.2 Tue 16:15 Redoutensaal

Spectroscopic investigations of the silyl radical using a quantum cascade laser — Andy S. C. Nave[1], Andrei V. Pipa[1], Paul B. Davies[2], Jürgen Röpcke[1], and •Jean-Pierre H. van Helden[1] — [1]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany — [2]Department of Chemistry, University of Cambridge, Cambridge, United Kingdom

Silane-based plasma enhanced chemical vapour deposition is an established process for producing hydrogenated amorphous silicon (a-Si:H) films for the solar cell industry. The most abundant product of the fragmentation of SiH4 is the silyl radical, SiH_3, next to other short-lived silicon containing species, such as SiH_2, SiH, Si and related ionic species. The development of increasingly more sensitive spectroscopic techniques to determine the concentration of these short-lived species is essential to enhance our knowledge of the complex chemical processes involved. We report on the measurement of a line strength in the ν_3 fundamental band of the silyl radical using a quantum cascade laser. Rotationally resolved lines of SiH_3 between 2085 and 2175 cm^{-1} were measured in RF pulsed plasmas containing 10% SiH4 in He and in H2. The line strength of one of these lines, free from interfering transitions, was measured by analysing the radical concentration profile when the discharge was extinguished. The absolute line strength of the silyl radical absorption feature at 2119.947 cm^{-1} from the $^pP_6(9)$ transition was determined to be $4.82 \pm 2 \times 10^{-21}$ cm^{-1} $molecule^{-1}$ cm^2.

P 13.3 Tue 16:15 Redoutensaal

Diagnostics on a hollow cathode glow discharge by means of a retarding field analyser and a calorimetric probe — •Lisa Anna-Maria Bauer, Fabian Haase, Sven Gauter, and Holger Kersten — Institute of Experimental and Applied Physics (IEAP), Kiel University, Germany

In this work a cylindrical DC hollow cathode glow discharge is combined with an axially directed magnetic field in order to increase the plasma density. By rising the magnetic field strength the efficiency of the so called hollow cathode effect can be enhanced. A retarding field analyser and a passive thermal probe are used to characterise positive ions, which impact the negative biased cathode. These ions are, for instance, responsible for sputter processes, especially, for deposition rate and homogeneity during thin film deposition. Therefore, it is important to determine their energy distribution and their energy input to the cathode surface. Varying parameters in this work are the cathode material, gas pressure, magnetic field strength, discharge mode (DC and HiPIMS) and the distance between the probes and the cathode surface.

P 13.4 Tue 16:15 Redoutensaal

Experimental studies of momentum transfer during sputtering with interferometric force probes — •Mathis Klette, Thomas Trottenberg, and Holger Kersten — Institute of Experimental and Applied Physics (IEAP), Kiel University, Germany

In this work an ion beam is focused on a plane sputter target at different angles of incidence. The resulting sputter plume is characterized using Interferometric force probes [*]. In contrast to conventional diagnostics, a force probe does not rely on charged particles, but takes also neutrals into account and supports a more comprehensive picture of the sputtering process. The force vector resulting from implanted and reflected beam particles and sputtered target atoms is measured using a double axis force probe. A second force probe is used to circle around the target scanning through the resulting plume of sputtered target atoms and beam particles. The determined forces are then compared with simulation data using SRIM [**]. The experimental setup allows a variation of angle of incidence, target material, ion energy, gas type and gas pressure.

[*] Spethmann, A., Trottenberg, T., Kerst en, H., Phys. Plasmas **24**(2017), 093501.

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

P 13.5 Tue 16:15 Redoutensaal

Quantum kinetic theory of ion-induced secondary electron emission from surfaces — Mathias Pamperin, •Franz Xaver Bronold, and Holger Fehske — Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, 17489 Greifswald, Germany

Secondary electron emission due to atomic species hitting the wall of a gas discharge is an important surface collision process strongly affecting the charge balance of the discharge. At impact energies typical for low-temperature plasmas electrons are ejected due to the transfer of the internal potential energy stored in the projectile's electronic structure. To describe this process quantitatively we set up a general quantum-kinetic approach and applied it to an He^+ ion hitting a metallic wall. Based on a semi-empirical multi-channel Anderson-Newns model, projection operator techniques, and the non-crossing approximation for the self-energies we derived rate equations for the occurrence probabilities of the projectile's electronic configurations which may become operational in the course of the collision process. From it we also deduce the electron emission spectrum as a function of impact energy and angle. Auger neutralization of the positive ion as well as Auger de-excitation of radicals and/or negative ions, temporarily formed by single-electron transfers, are treated on an equal footing. For grazing incidence we get rather good agreement with experimental data indicating our approach captures the essential physics involved. Having in mind the tailoring of the electron emission spectrum by a judicious choice of the wall material we present results for various metals. – Supported by DFG through CRC/Transregio TRR24.

P 13.6 Tue 16:15 Redoutensaal

Untersuchungen zur Trichterkompression von Plasmen koaxialer Beschleuniger — •Thomas Manegold, Parysatis Tavana, Christian Benzing, Marcus Iberler und Joachim Jacoby — Institut für Angewandte Physik, Goethe Universität Frankfurt am Main

In diesem Beitrag werden spektroskopische Messungen zur Trichterkompression von Plasmen, die durch koaxiale Elektrodengeometrien erzeugt und beschleunigt werden, präsentiert.

Der zugrundeliegende Aufbau verfügt über einen Energiespeicher von 27uF bei Spannungen von bis zu 10kV. Die aus den erzielten Strömen von bis zu 150kA resultierende Lorentzkraft beschleunigt das Plasma in eine aus Glas bestehende Trichtergeometrie wodurch das Plasma verdichtet wird und sich die Elektronendichte um einen Faktor von etwa 600 im Vergleich zur Messung ohne Trichter erhöht. Die durch die Kompression erreichten Elektronendichten liegen im oberen Bereich von $10^{17}cm^{-3}$, sodass sich die Verbreiterung der H_β-Linie nach dem linearen Stark-Effekt nur noch sehr eingeschränkt verwenden lässt. Als Alternative hierzu wurde die Verbreiterung einer Kupfer-Linie bei 479,40nm unter Verwendung des quadratischen Stark-Effekts zur Bestimmung der Elektronendichte verwendet. Zudem werden Messungen der emittierten VUV-Strahlung der Plasmen gezeigt.

P 13.7 Tue 16:15 Redoutensaal

Characterization of a portable measurement device for the determination of absolute VUV emission of low pressure plasmas — •Caecilia Fröhler[1], Roland Friedl[1], Stefan Briefi[1,2], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Photon fluxes in the vacuum ultraviolet spectral region (VUV, wavelength below 200 nm) play a role during surface treatment processes with low pressure plasmas. Depending on the photon wavelength and the application, VUV radiation can have beneficial or undesirable effects on the surface material. For obtaining wavelength-resolved information on photon fluxes, expensive and large vacuum spectrometers are neccessary which have to be calibrated specifically at the discharge setup of use. For this reason, a small and portable measurement system based on a silicon VUV diode is being under development in which spectral resolution is achieved by using bandpass or edge filters. Its calibration is independent of the setup what makes the device transferable to any type of plasma application. An absolute calibration is performed against a calibrated VUV spectrometer in a laboratory hydrogen ICP discharge (Ø15 cm, height 10 cm; 2 MHz; 2 kW). The spectral composition is investigated simultaneously with the spectrometer and the diode system for pressure and power scans in order to demonstrate the applicability as an easy-to-use diagnostic tool for VUV fluxes.

P 13.8 Tue 16:15 Redoutensaal

Protective coating for electronic assemblies against environmental influences - a high throughput low pressure plasma process for in-line integration — Fabian Utzmann[1], •Florian Eder[1], and Bastian J. M. Etzold[2] — [1]Siemens AG Corporate Technology, 91058 Erlangen, Germany — [2]Technische Universität Darmstadt, 64287 Darmstadt, Germany

Printed circuit boards need to be protected against corrosive influences in order to guarantee functionality and safety. In this regard, current varnish based solutions do not always provide a flawless conformal coating and require extensive processing efforts. Replacing these coatings by a plasma polymer will allow improving overall protection properties while reducing processing costs. Yet, current plasma coaters are not designed for a seamless integration into existing electronic production lines. The challenge is to use standard handling and transportation systems in electronic production as substrate carriers in the plasma coater. To counter these challenges a new plasma reactor was designed from scratch around a substrate carrier. This allows a coating application onto a stack of printed circuit boards as well as a corresponding development of coatings including precursor and process parameter evaluation. The deposited coatings were characterized regarding film thickness, defect density, chemical structure elucidation by fourier transform infrared spectroscopy and protection properties in standard temperature and humidity tests.

P 13.9 Tue 16:15 Redoutensaal

Application of an AC method for measuring the EEDF in low pressure plasmas by a Langmuir probe — •Adrian Heiler[1], Roland Friedl[1], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

The electron energy distribution function (EEDF) in low pressure low temperature plasmas is often non-Maxwellian and therefore needs to be measured in experiment. The most straightforward approach to determining the EEDF is to measure the I-V characteristic of a Langmuir probe and numerically differentiate it twice (Druyvesteyn correlation). However, numerical differentiation requires data smoothing techniques and leads to inevitable numerical errors. Therefore, a Langmuir probe method first proposed in the 1930s by Sloane and MacGregor (1934 *Phil. Mag.* **18**, 193) was adopted to directly measure $\mathrm{d}^2I/\mathrm{d}V^2$. This is done by superimposing a sinusoidal AC voltage on the probe DC bias and Fourier transformation of the corresponding probe current. Besides avoiding numerical errors, the AC method provides access to a higher dynamic range of the EEDF due to better signal-to-noise ratio.

The system is implemented for a sinus frequency of 13 kHz and a variable amplitude in the range of 1 V. Moreover, it is also capable of measuring and analysing the probe I-V characteristic. The system is tested in an ICP discharge (planar coil, RF 2 MHz, power up to 2 kW) in the $1-10$ Pa pressure range and compared to a conventional Langmuir probe system.

P 13.10 Tue 16:15 Redoutensaal

Investigation of a low pressure microwave plasma source for high rate etching — •Steffen Riegger[1], Andreas Schulz[1], Matthias Walker[1], Günter Tovar[1], Mario Dünnbier[2], and Klaus Baumgärtner[2] — [1]Institute of Interfacial Process Engineering and Plasma Technology IGVP, University of Stuttgart, Stuttgart, Germany — [2]Muegge GmbH, Reichelsheim, Germany

Photoresists are used in the industry for lithographic processes to produce surface structures in the sub-micrometer range. After the manufacturing processes the cured photoresist must be removed. For this purpose we investigate a remote plasma source (RPS). For the etching process pure oxygen is chosen as working gas instead of halogens to prevent environmental issues. The generated oxygen radicals react with the substrate surface atoms forming gaseous molecules. To study the processes in the RPS, the plasma is spectroscopic investigated and planar etch rates as a function of different changing parameters like the microwave power were determined. High etching rates in the range of $1 \frac{\mu m}{s}$ can be achieved. The spectrum of the here used oxygen plasma shows the typical atomic oxygen lines (777 nm and 844 nm). Also several ion molecule bands in the UV- range between 220 nm and 390 nm of the O_2^+- 2nd negative system and in the visible range between 500 nm and 600 nm of the O_2^+- 1st negative system are seen. The areas in the RPS where the ions are generated could be determined by a UV-transparent bandpass filter. The generation of the ions correlates with the microwave coupling into the plasma source.

P 13.11 Tue 16:15 Redoutensaal

Plasma enhanced chemical vapour deposition and plasma etch challenges for technological fabrication of silicon nitride photonic components — •Erik Lehmann[1,2], Harald Richter[1], Mirko Fraschke[1], Marco Lisker[1], Thomas Grabolla[1], Lars Zimmermann[1,3], and Andreas Mai[1,2] — [1]IHP, Im Technologiepark 25, 15236 Frankfurt (Oder) — [2]Technische Hochschule Wildau, Hochschulring 1, 15745 Wildau — [3]Technische Universität Berlin, HFT 4, Einsteinufer 25, 10587 Berlin

In the last years silicon nitride (SiN) is demonstrated as a high performance solution for photonic integrated circuits. SiN is emerging as a possible alternative silicon photonics platform with additional features and strength.

The present work is focused on the development of a manufacturing process for silicon nitride waveguides and grating couplers. Experiments have shown plasma enhanced CVD power is significant for high-quality SiN waveguides. An additional polish step was implemented to decrease the surface roughness. The following SiN plasma etch process using a CF chemistry results in waveguides characterized by a rectangular profile with minimal sidewall roughness. The hydrogen concentration in SIN is reduced by a final annealing step. Propagation loss values less than 0.5 dB/cm verify the technological manufacturing process quality.

P 13.12 Tue 16:15 Redoutensaal

Structural Characterization of VOx deposited by Plasma Ion Assisted Electron Beam Evaporation for Energy Storage Application — •Miguel Dias[1], Anna Frank[2], Stefan Hieke[2], Simon Fleischmann[3,4], Jens Harhausen[1], Rüdiger Foest[1], Volker Presser[3,4], Christina Scheu[2,5], and Angela Kruth[1] — [1]INP Greifswald, Germany — [2]MPIE Düsseldorf, Germany — [3]INM Saarbrücken, Germany — [4]Dept. of Mat. Sci. and Eng., Saarland University, Germany — [5]Materials Analytics, RWTH Aachen University, Germany

Vanadium oxide-based materials are of interest for electrochemical energy storage applications but controlled synthesis at large scale is still challenging. Electron beam evaporation assisted by plasma ions was performed to synthesize VOx thin layers on Si and CNT. Plasma properties such as ion velocity distributions were obtained for different O2 content of the working gas, substrate temperature, applied discharge voltage and current. Structural analysis of thin film properties was carried out by means of XRD and Raman spectroscopy as well as HR-TEM in combination with EELS. First correlation between plasma parameters and resulting structural properties were established indicating a strong dependence of the crystallinity on the ion energy and chamber temperature. VOx was deposited directly on free-standing CNT to obtain hybrid electrode materials that combine redox activity with high electrical conductivity. First electrochemical characterizations show promising activities and potential for their usage as electrodes for their use as electrodes in lithium-ion batteries.

P 13.13 Tue 16:15 Redoutensaal

An optically trapped microparticle as a probe — •Viktor Schneider and Holger Kersten — Institute of Experimental and Applied Physics (IEAP), Kiel University

In contrast to common plasma diagnostic tools, e.g. Langmuir probes, calorimetric probes, mass spectrometers etc., the μPLASMA (microParticles in a Discharge with Laser Assisted Manipulation) experiment uses optically trapped microparticles (SiO_2) as nonivasive probes. The displacement of the particle in the trap is used to measure a force while it is moving relatively to the plasma, either deeper into the sheath or towards the plasma bulk. In addition, information about the neutral gas damping of the particles is presented. Systematic measurements of the residual charges on the particle after turning off the plasma are measured, depending on the position of the particle in the plasma. Furthermore, charging of the sphere by UV radiation is investigated and discussed.

P 13.14 Tue 16:15 Redoutensaal

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

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

P 13.15 Tue 16:15 Redoutensaal

Production of a high-density plasma channel for laser acceleration — •Daiyu Hayashi[1] und Tatsuo Shoji[2] — [1]Philips Research Eindhoven, The Netherlands — [2]Nagoya University, Japan

In the framework of IZEST laser acceleration program, we develop a long (50 cm) and narrow (a few mm) plasma channel with a hollow electron density profile by helicon-wave discharges. First, we generate high-density plasmas by Helicon wave discharges in a narrow glass tube, where a hollow neutral gas profile is formed due to neutral depletion. Thereafter high-intense laser radiation will be introduced into the plasma channel to ionize fully the neutral gas of the hollow profile. In this talk, we report on the generation of high-density plasmas of 10^{14} cm^{-3} in a narrow glass tube of 4 mm in diameter and 50 cm by the m=1 mode of Helicon wave excitation under a magnetif field of 1 kG. The applied rf power is up to 3kW at the frequency of 13.56MHz. The electron density measured by a Langmuir probe was of the order of 10^{14} cm^{-3}. The formation of a hollow neutral density profile was observed by an optical emission spectroscopy.

P 13.16 Tue 16:15 Redoutensaal

Phase-resolved plasma diagnostics of a low-pressure dielectric barrier discharge — •Daniela Coenen and Slobodan Mitic — I. physikalisches Institut, Justus-Liebig-Universität Gießen, Germany

A dielectric barrier discharge (DBD) in jet configuration was investigated in a pressure range from 10 Pa to 100 Pa in argon atmosphere. A glass tube was used as dielectric and a sinusoidal voltage with a frequency of 30 kHz was applied to ignite the discharge. Various phase-resolved diagnostics were combined to get deeper insight in the temporal and spatial dynamics of DBD at low pressures. Phase-resolved emission was recorded by an ICCD camera with an exposure time of 10 ns to get information about ignition dynamics of the DBD. Density and temperature of all four 1s states (in Paschen's notation) were measured using phase-resolved tunable diode laser absorption spectroscopy

(TDLAS). Both followed distinct variations during one voltage cycle. The temporal dynamics of the 1s densities are in accordance with the results from the ICCD camera measurements. The changes in temperature of the 1s states indicate a change in production mechanism of 1s levels within one voltage cycle. In general measured temperatures are low and densities comparatively high.

P 13.17 Tue 16:15 Redoutensaal

Ellipsometric Analysis of Nanostructures in Thin SiO_2-Films — •Rahel Buschhaus, Carles Corbella, and Achim von Keudell — Experimentalphysik II, Ruhr-Universität Bochum

Nanostructure of thin films plays an important role for their performance in barrier coating applications. Ellipsometric characterisation of surfaces constitutes a non-invasive analysis of the effect of plasma surface treatment. Plastic substrates such as polypropylene (PP) are of special interest for the packaging industry. PP is deposited by spin coating on silicon wafers. Silicon dioxide layers are deposited by means of pulsed microwave plasma on thin PP layers using a gas admixture of hexamethyldisiloxane (HMDSO) and oxygen. Afterwards, these layers are ion- and plasma etched in a particle beam experiment or an inductively coupled plasma (ICP) reactor, respectively. Optical properties of the barrier films are analysed during etching by spectroscopic ellipsometry to study film in-depth uniformity.

Ellipsometric porosimetry will be carried out with a modified spectroscopic ellipsometer at atmospheric pressure. The adsorption of solvents causes the change of refractive index, thereby gaining information about the pore size and pore distribution with the selection of the appropriate ellipsometric model.

The influence of the SiO_2 deposition parameters on the porosity will be analysed.

P 14: Astrophysical Plasmas - Poster

Time: Tuesday 16:15–18:15 Location: Redoutensaal

P 14.1 Tue 16:15 Redoutensaal

Hybrid formulation of guiding-center Hamiltonian theory for astrophysical plasmas — •Felipe Nathan Oliveira[1], Simon Lautenbach[2], Rainer Grauer[2], and Daniel Told[1] — [1]Max-Planck-Institut für Plasmaphysik — [2]Ruhr-Universität Bochum

Higher-order Lie-transform perturbative methods applied to the Hamiltonian formulation of guiding-center motion are widely used to describe the dynamics of particles in plasma physics [1][2][3]. Therewithin, the elegant and compact Lagrangian formulation allows for the derivation of the equations of motion from the $\mathcal{L}$ two-form, or sympletic two-form, $w_L = -dx^i \wedge dp_i \in \Lambda^2 T * M$. Where $T * M$ represents a linear space T tangent to a manifold M [4].

In the present work, a consistent Lagrangian model that encapsulates fully kinetic ions and gyrokinetic electrons for solar wind and fusion electromagnetic turbulence is studied. Using a consistent method [5], both electrons and protons are treated with the same mathematical formalism. We plan to derive and implement a model in which high frequency waves and kinetic electron effects[6] are computed in a cost-effective way.

[1] N. Tronko and A. Brizard. Physics of Plasmas, 2015.
[2] Robert G. Littlejohn. Journal of Mathematical Physics, 1982.
[3] H. Sugama. Physics of Plasmas, 2000.
[4] Robert H. Wasserman. Tensor and Manifolds. 2004
[5] A. J. Brizard and N. Tronko. arXiv:1606.0653v1, 2016
[6] F. Muller P. Astfalk D. Told, J. Cookmeyer and F. Jenko. New Journal of Physics, 2016.

P 14.2 Tue 16:15 Redoutensaal

Nuclear excitation by electron capture in astrophysical plasmas — •Yuanbin Wu, Hyoyin Gan, Christoph H. Keitel, and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany

In hot and dense stellar plasmas in which the slow neutron capture nucleosynthesis takes place, nuclei may not be only in their ground states but also in long-lived excited states (isomers). So far studies on the thermal equilibrium of the ground and excited or isomeric nuclear states typically rely on detailed balance. In the astrophysical plasma, high charge states are available, and the timescale of collisional ionizations and photoionization is expected to be much shorter than the one of ionization by internal conversion (IC). The inverse process of IC, nuclear excitation by electron capture (NEEC) [1,2], in such plasmas is therefore not always accompanied by its detailed-balance counterpart due to the loss of the recombined electrons via fast atomic processes. Thus, the isomers might not be thermally equilibrated with the nuclear ground states. We study here the depletion of isomeric states through NEEC in dense stellar plasmas under the s-process environments. The results show that the NEEC rates for the depletion of the isomeric states ^{124m}Sb and ^{152m}Eu should be large, leading to isomer populations significantly different from what is expected via thermodynamic equilibrium.

[1] J. Gunst, Y. A. Litvinov, C. H. Keitel, and A. Pálffy, Phys. Rev. Lett. 112, 082501 (2014).
[2] Y. Wu, J. Gunst, C. H. Keitel, and A. Pálffy, arXiv: 1708.04826.

P 14.3 Tue 16:15 Redoutensaal

Beamtime U305 - High Energy Resolution Spectroscopy of the Target and Projectile X-Ray-Fluorescence — •Sero Zähter[1], Olga Rosmej[2], Ceyhun Arda[1], Philipp Beloiu[1], Björn Borm[1,2], Mohamed El Houssaini[1], Dimitri Khaghani[2], Andreas Schönlein[1], and Joachim Jacoby[1] — [1]Institut für Angewandte Physik, Goethe Universität Fankfurt, Deutschland — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Deutschland

Intense uranium beams, that will be available at the new synchrotron SIS100 in Darmstadt, can be used for volumetric heating of any type of material and generation of extreme states of matter with Mbar pressures and some eV of temperature. Investigation of their EOS is one of the main goals of the plasma physics program at FAIR. Diagnostic of such extreme states of matter demands development of new diagnostic methods and instruments, which are capable to operate in an environment with a high level of radiation damage. The precise knowledge of the energy density distribution of the U-beam on the target is a very important input parameter for numerical simulations of the hydrodynamic response of the target on deposited energy which is required for planning of experiments and interpretation of obtained experimental data. Therefore we propose to use the target and heavy ion beam X-ray fluorescence for imaging of the target expansion and mapping of the heavy ion beam distribution in the interaction region with a high spatial resolution of at least 100 μm. First pilot experiments have been carried out in 2016 at the UNILAC Z6 experimental area in collaboration with the Plasma Physics Group of GSI.

P 14.4 Tue 16:15 Redoutensaal

Mechanism of enhanced energization of heavier ions in collisionless shocks — •Adrian Hanusch[1], Tatyana Liseykina[1], and Mikhail Malkov[2] — [1]Universität Rostock - Institut für Physik — [2]University of California San Diego

The acceleration of particles to high energies is an outstanding problem in space and astrophysical plasmas. One physically simple and robust mechanism of interest is diffusive acceleration (DSA) at collisionless shocks [1]. Before acceleration to high energies can occur, particles must be pre-accelerated above the energies of the background plasma so that they may then keep on crossing the shock front and gain more energy. This injection process is still not fully understood. To simulate the evolution of collisionless shocks and the acceleration of ions we use a hybrid code in which only the plasma ions are treated kinetically and electrons as a massless fluid. In our simulations shocks are generated by sending a super-sonic flow of multi-component plasma, consisting of electrons, background protons and additional ion species with different mass to charge (A/Z) ratios, towards a reflecting wall. To investigate the elemental selectivity of the injection mechanism, we determine the injection efficiency of each particle species included in the simulation. We obtain the energy spectra of all particles downstream of the shock transition from the simulation using a logarithmic binning procedure. Comparing the distributions of the number of shock reflections vs. single particle energy for different A/Z we observe the increasing narrowness of such distribution with A/Z.

[1] A. R. Bell, *MNRAS*, 182, 147-156, (1978).

P 15: Helmholtz Graduate School IV - Plasma Wall Interaction

Time: Wednesday 14:00–16:05 Location: A 0.112

P 15.1 Wed 14:00 A 0.112

SIESTA: a new high-current ion source for angle-dependent sputter yield measurements — •Rodrigo Arredondo Parra[1,2], Martin Oberkofler[1], Thomas Schwarz-Selinger[1], and Klaus Schmid[1] — [1]Max Planck Institut für Plasmaphysik, Boltzmannstr. 2, D-85748, Garching, Germany — [2]Technische Universität München, Boltzmannstr. 15, D-85748, Garching, Germany

SIESTA (Second Ion Experiment for Sputtering and TDS Analysis) is a newly built high current ion source used for research on plasma-wall interaction issues. The ion source can be set to an acceleration potential of up to 15 kV and can be operated with H, D, He and Ar. The beam is 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 target can be rotated to study angle-dependent effects and can be positively biased to facilitate exposure to ion energies as low as 200 eV. A magnetic suspension balance allows for in-situ sputter-yield measurements. Particle flux densities of up to $3 * 10^{19}$ D/m^2/s for 10 keV D_3^+ ions were measured. As part of ongoing research on the influence of surface roughness on the sputter yield, controlled roughness samples of Fe and W were exposed to a 6 kV D_3^+ ion beam (2 keV/D) under varying angles of incidence. The resulting sputter-yields are compared to Monte-Carlo simulations, agreeing on the dependence of the sputter-yield on the incidence angle and, in the case of Fe, also on the absolute amounts. The sputter-yields for W and Au are compared to literature data, agreeing well with previous measurements at normal incidence.

P 15.2 Wed 14:25 A 0.112

Developement of Hotspot Detection System for Protection of Plasma Facing Components in Wendelstein 7-X — •Adnan Ali[1,3], Marcin Jakubowski[1], Henri Greuner[2], Thomas Sunn Pedersen[1], Rudolf Neu[2,3], 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 Greifswald — [3]Technical University of Munich (TUM), Boltzmannstrasse 15, 85748 Garching

One of the main aims of Wendelstein 7-X, an advanced stellarator, is to investigate the quasi steady state operation of magnetic fusion devices, for which power exhaust is an important issue. A predominant fraction of the energy lost from the confined plasma region will be removed by 10 so-called island divertors, which are designed to sustain maximum heat flux up to 10 MW/m2. A very important prerequisite for safe operation of a steady-state device is an automatic detection of the hot spots and other abnormal events. In this work, we present the experimental results obtained at the high heat flux test facility GLADIS in IPP Garching where we tested the newly developed algorithms for protection of W7-X plasma facing components. Two types of off-normal signals are detected steming either from delaminations formed at the connection between CFC and CuCrZr blocks and hydrocarbon surface layers formed on the material surface. The algorithms designed for early detection of defects was successfully tested in GLADIS and is now implemented in the new detection software for W7-X imaging diagnostic.

P 15.3 Wed 14:50 A 0.112

The influence of dislocations, vacancies, and vacancy clusters on deuterium trapping in tungsten — •Mikhail Zibrov[1], Matej Mayer[1], Armin Manhard[1], Dmitry Terentyev[2], Andrii Dubinko[2], and Werner Egger[3] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]SCK-CEN, Mol, Belgium — [3]Universität der Bundeswehr München, Neubiberg, Germany

The hydrogen (H) isotope inventory in tungsten (W) is governed by the presence of lattice defects acting as trapping sites for H. The aim of this study is to reveal the role of individual defect types by using samples having one dominant and well-characterized defect type.

Vacancies were introduced in single crystalline W specimens by damaging with 200 keV protons to low damage levels. The samples were annealed at temperatures in the range of 500-1800 K to investigate the stages of vacancy clustering. Dislocations were introduced in recrystallized W samples via tensile plastic deformation to various strains. The resulting defects were characterized by positron annihilation lifetime spectroscopy and transmission electron microscopy. In order to fill the defects with deuterium (D), the samples were exposed to a low-flux D plasma. The D inventory in the samples was characterized by nuclear reaction analysis and thermal desorption spectroscopy. It was observed that the dislocations have a relatively small influence on the D retention, but they may facilitate the formation of blisters. Vacancies have a considerably higher D binding energy compared to dislocations. By annealing at temperatures above 600 K vacancies agglomerate in clusters, which have even higher D binding energies.

P 15.4 Wed 15:15 A 0.112

Radiation Damage Characterization in Tungsten — •Barbara Wielunska[1,2], Matej Mayer[1], Thomas Schwarz-Selinger[1], Witold Zielinski[3], Tomasz Plocinski[3], Witold Chrominski[3], and Lukasz Ciupinski[3] — [1]Max-Planck-Institut für Plasmaphysik Garching, Deutschland — [2]Fakultät für Physik TUM, Garching, Deutschland — [3]Wydzial Inzynierii Materialowej, Warszawa, Polska

Tungsten is a candidate material for the wall of future fusion reactors due to its low erosion yield and low hydrogen solubility. However, fusion neutron irradiation will induce radiation defects in the material. It is important to study the mechanism of defect creation and its influence on hydrogen retention in tungsten. Therefore tungsten samples were damaged with different ion species (p, D, He, Si, Fe, Cu, W) at energies between 0.3 and 20 MeV to different damage levels of 0.04 dpa and 0.5 dpa. For studying hydrogen retention in defects the samples were exposed to a low-temperature D plasma. The D depth distribution was obtained by nuclear reaction analysis using the D(3He, p)α reaction. Trapped D was measured by thermal desorption spectroscopy. Tungsten damaged by heavy ions (Si, Cu, Fe, W) to identical dpa values shows similar D depth profiles and D desorption spectra, i.e., the D retention is comparable. For tungsten damaged by light ions (p, D, He) the D retention shows larger differences. The damaged region was investigated by transmission electron microscopy. Differences in the dislocation structure in tungsten damaged by Si or W are visible although the D retention of those samples is almost identical.

P 15.5 Wed 15:40 A 0.112

Characterization of CVD tungsten-fibre reinforced tungsten composite: From the bulk to the interface — •Hanns Gietl[1,2], Johann Riesch[1], Jan W. Coenen[3], Till Höschen[1], Leonard Raumann[3], and Neu Rudolf[1,2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching — [2]Technische Universität München, 85748 Garching — [3]Forschungszentrum Jülich, IEK4, 52425 Jülich

For the use in a fusion device tungsten has unique properties such as low sputter yield, high melting point and low activation. However, 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 materials* toughness. The next step in the material development is the conceptual proof for the applicability in fusion reactors by the production of larger components and for testing them under cyclic high heat flux loading. The characterization of the composites is one of the major issues to predict the material behavior within such a component. Different test methods for tungsten fibre-reinforced tungsten composites such as bending, charpy impact, and monotonic as well as cyclic tension tests were performed. The resulting fracture surfaces were examined by microstructural analysis to analyze the fracture mechanisms. In addition a single fibre pull-out test was developed to investigate the interface region between fibre and matrix which governs the overall material behavior.

P 16: Low Pressure Plasmas II

Time: Wednesday 14:00–16:00 Location: KI 1.174

Invited Talk P 16.1 Wed 14:00 KI 1.174

Diagnostics and application of reactivity of atmospheric plasmas in studies relevant for plasma medicine — •Jan Benedikt[1], Mohamed Mokhtar Hefny[2], Gert Willems[2], Pascal Vogel[2], Clara Karczewski[2], Julia Bandow[2], and Petr Lukes[3] — [1]Christian-Albrecht-Universität zu Kiel, Germany — [2]Ruhr-Universität Bochum, Germany — [3]Czech Academy of Sciences, Czech Republic

Atmospheric non-equilibrium plasmas are an effective source of large densities of reactive radicals, metastables, ions and high fluxes of photons with wavelength down to the 60 nm. The resulting high reactivity of these plasmas is due to a combination of several or all of these components, very often in a synergistic way, during the treatment and it is the key factor for the success of these plasmas in plasma medicine applications. Especially important for the understanding of the plasma treatments is the study of isolated or combined effects of the plasma components. In this contribution, the mass spectrometry for detection of neutral and ionized species and the windowless VUV spectroscopy for the plasma analysis will be discussed in detail, followed by the discussion of plasma source designs for separation of different plasma components.

P 16.2 Wed 14:30 KI 1.174

Stochastic electron heating in a periodically structured electric field — •Philipp Ahr, Tsanko V. Tsankov, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr-University Bochum, 44780 Germany

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

To realize such a periodically structured electric field, a novel plasma source, the Inductive Discharge Array (IDA), has been assembled. Here, a short overview over the theory and the construction details of the source will be given. Further, recent results from optical and Langmuir probe measurements for the characterisation of the source will be presented. These show the existence of high energetic electrons at pressures where the energy relaxation length for inelastic collisions becomes larger than the chamber dimensions. As a consequence, the distribution function of these electrons become maxwellian for energies up to 40 eV.

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

P 16.3 Wed 14:45 KI 1.174

IVDF and plasma parameters of CX dominated plasmas — •Christian Lütke Stetzkamp, Tsanko Vaskov Tsankov, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany

The properties of many laboratory plasmas are determined by charge-exchange collisions. Recently Tsankov and Czarnetzki [1] developed a new diagnostic technique for this kind of plasmas. It allows a spatially resolved access to the ion velocity distribution functions (IVDF) and the plasma parameters by a single, non-invasive measurement at the wall.

Here, their work is improved and extended. The obtained results reproduce the previous measurements in a Neon plasma, however, with an increased resolution. Further, a relation between the electric field and the drift velocity is obtained and a criterion for the validity of the diagnostic is derived. Based on this criterion measurements in an Argon plasma are performed under conditions where the technique is applicable. The radial variations of the plasma parameters obtained through the diagnostic are presented. The radial measurements are complemented by axial ones, which are needed for the evaluation of the radial data.

[1] Tsankov, Ts. and Czarnetzki, U. 2017 *Plasma Sources Sci. Technol.* **26** 055003

P 16.4 Wed 15:00 KI 1.174

Dissociative recombination and its impact on the line profile of the hydrogen Balmer series — •Roland Friedl[1], David Rauner[1,2], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

In low pressure low temperature plasmas the upper levels of the Balmer series of the hydrogen atom are populated by several excitation channels. Among them, dissociative recombination (DR) via the molecular ion H_2^+ becomes relevant—up to dominant—in so-called recombining plasmas, e.g. in a diffusive region of H_2 plasmas. Detailed analysis of the measured emission line profile of the Balmer series furthermore revealed a significant broad component. The resulting line profile resembles two Gaussian components with distinct FWHM, where the broad part contributes to 10–40 % to the emissivity, depending on the Balmer line and the plasma conditions. Collisional-radiative modeling using the code Yacora H (Wünderlich *et al.*, JQSRT **110** (2009) 62) was applied in order to determine the contribution of the different excitation channels. It turned out, that for each of the lines of the Balmer series, population via DR contributes to the total excitation with a similar share as the share of the broad component of the line profile. Hence, strong indications are given that DR accounts for the broad component in the Balmer line profiles of recombining hydrogen plasmas.

P 16.5 Wed 15:15 KI 1.174

Plasma characteristics of CERN's Linac4 H^- ion source investigated by OES and PIC modelling — •Stefan Briefi[1,2], Stefano Mattei[3], David Rauner[1,2], Jacques Lettry[3], and Ursel Fantz[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching — [2]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [3]CERN, 1211 Geneva 23, Switzerland

At CERN an upgrade of the LHC injector chain is currently being implemented what includes the installation of a linear accelerator based on negative hydrogen ions, the Linac4. The ion source of Linac4 relies on the generation of H^- ions in an inductively coupled low pressure hydrogen plasma (RF frequency 2 MHz, maximum RF power 100 kW). A dedicated optimization of the H^- yield with respect to operational parameters or design properties of the ion source requires a detailed knowledge of the plasma parameters. They have been determined by optical emission spectroscopy measurements in combination with a PIC model calculating self-consistently the spatially resolved plasma parameters as a result from the coupling of the RF field to the discharge. A detailed assessment of the H^- production and destruction processes close to the extraction aperture enabled an explanation of the experimentally observed trends in the extracted H^- currents. In the next step, the PIC model is going to be applied for predictive modelling for a further optimization of the ion source design. The gained insights are also highly valuable for a more detailed understanding of large scale RF-driven H^- sources for the neutral beam injection systems for ITER because of the similarities of the underlying processes.

P 16.6 Wed 15:30 KI 1.174

Optical beam diagnostics for high intensity heavy ion beams — •Raphael Hampf[1], Andreas Himpsl[1], Andreas Ulrich[1], and Jochen Wieser[2] — [1]Physik-Department, Technische Universität München, D-85747 Garching — [2]excitech GmbH, D-26419 Schortens

In experiments at the Munich Tandem Accelerator (Maier-Leibnitz-Laboratorium) in Garching fundamental spectroscopic studies for optical beam diagnostics are performed. A heavy ion beam is sent into a noblegas target. In a series of experiments both wavelength spectra and highly resolved photographs are recorded. Since the application is planned for beamline conditions at FAIR/GSI in Darmstadt the pressure is varied from 300mbar down to 10^{-4}mbar and various strong emission lines are examined. Results from a series of experiments from 2017 will be presented.

Funded by BMBF Verbundprojekt APPA R&D FKZ 05P15WOFA1 and Maier-Leibnitz-Laboratorium, D-85747 Garching

P 16.7 Wed 15:45 KI 1.174

Deposition of SiO_x coatings by inductively coupled plasma: effect of pulsed hexamethyldisiloxan flow — •Markus

Brochhagen[1], Sascha Chur[1], Vincent Layes[1], Marc Böke[1], and Jan Benedikt[2] — [1]Experimentalphysik II, Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum — [2]Experimentelle Plasmaphysik, Christian-Albrechts-Universität zu Kiel, Leibnitzstr. 17, 24118 Kiel

SiO_2-like films are used for barrier coatings on polymeric substrates. The lower the amount of carbon inside the layer, the better is the barrier performance. Such layers can be produced in a plasma process using evaporated HMDSO and admixed Argon or Oxygen. In this work we report on a pulsed HMDSO flow allowing a direct post treatment of the films. The process is studied under high plasma density conditions in an ICP plasma with FTIR spectrometry and XPS. Additionally the thickness is measured with a profilometer. Analysis of carbon free films from O_2/HMDSO are presented and effects of the pulsed HMDSO flow mode are reported, as well as results for films from Ar/HMDSO plasma.

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

P 17: Atmospheric Pressure Plasmas - Poster

Time: Wednesday 16:15–18:15 Location: Zelt Ost

P 17.1 Wed 16:15 Zelt Ost

Analysis and direct comparison of spark discharges in air and water in a sub-mm gap — •Hans Höft[1] and Tom Huiskamp[2] — [1]INP Greifswald, Felix-Hausdorff-Straße 2, 17489 Greifswald, Germany — [2]TU Eindhoven, Dept. of Electrical Engineering, Eindhoven 5600 MB, The Netherlands

In this study, a direct comparison was made between pulsed spark discharges in air and water. Such discharges are often used as spark-gap switches in pulsed power systems. The discharges were ignited at atmospheric pressure in the same discharge arrangement for air and water, using a solid-state microsecond pulse source with $\approx 1\,\mu$s voltage rise time ($V_{\rm max}$ up to 37 kV). Fast voltage and current measurements were combined with iCCD imaging with high spatial resolution (better than $10\,\mu$m) on symmetrical half-sphere tungsten electrodes for electrode gaps of 0.1 to 0.7 mm for air (for water $d_{\rm gap} = 0.1 \ldots 0.3$ mm). Breakdown voltages and electrical field strengths, maximal currents, transferred charges, consumed electrical energies and the discharge emission structures (e.g. discharge channel diameters) were obtained for all cases. Using the synchronisation of the electrical data and the iCCD imaging, current and energy densities were estimated for the sparks in air and water. It was found that the breakdown voltage, the discharge current, the transferred charge, and the consumed electrical energy increase with the gap distance and that this dependence on $d_{\rm gap}$ is much stronger for discharges in water (compared to air). Due to the use of the same discharge arrangement and the same applied voltage, the difference in the electrical characteristics was directly quantified.

P 17.2 Wed 16:15 Zelt Ost

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

Since electricity from renewable sources of energy is subject to fluctuations, energy storage on demand plays a crucial role to create a reliable grid system. The CO2 conversion into syngas or higher hydrocarbons via a plasma assisted gas conversion powered by renewable energy is one promising approach towards energy storage. To make this power to gas concept beneficial over other technologies it is of critical importance to improve the energy and conversion efficiency of this process. On the basis of preliminary tests and technological requirements for a microwave plasma unit for CO2 conversion a modular plasma torch consisting of a cylindrical and a coaxial resonator has been constructed. This plasma torch enables a self-ignition and stable operation of an air and CO2 plasma over a wide range of parameters as well as a flexible rearrangement of the different components to ensure the possibility to adapt to different requirements. Via the FEM-Simulation program COMSOL Multiphysics a model of this plasma torch has been developed and the electric field distribution and the gas flow inside the plasma torch have been investigated to optimize the configuration and hence establish the most suitable operation conditions.

P 17.3 Wed 16:15 Zelt Ost

Interferometric and holographic techniques for the diagnostics of axially blown arcs — •Jan Carstensen, Bernardo Galletti, Alexey Sokolov, Charles Doiron, Oguz-Han Asnaz, and Axel Jansson — ABB Corporate Research, Segelhofstr. 1K, 5405 Baden-Daettwil, Switzerland

Recently, we have used two color spatial carrier wave interferometry 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. [J. Carstensen et al., Phys. Rev. Appl. 8, 024002 (2017)]. In this contribution we will discuss options to improve the sensitivity and the accuracy of the optical setup. In particular, by changing the frequency of the two lasers the minimal detectable electron density can be lowered by one order of magnitude. Furthermore, holographic techniques can simplify the alignment of the optical components and certain imperfection along the optical path can be corrected numerically in the data processing step.

P 17.4 Wed 16:15 Zelt Ost

Studies of high-intensity arcs for switching applications — •Chayma Mohsni[1,2], Margarita Baeva[2], Sergey Gortschakow[2], Steffen Franke[2], Kamel Charrada[1], and Zouhour Araoud[1] — [1]National School of Engineering of Monastir, 5000 Rue Ibn Jazzar, Monastir 5035, Tunisia — [2]Leibniz Institute for Plasma Science and Technology, Felix-Hausdorff-Str. 2, 17489 Greifswald, Germany

Investigations of the arc dynamics during a switching-off process are important to improve the interruption performance of switching devices. Alternatives to the working gas SF6, which is classified as green-house gas with a high global warming potential have to be found for reasons of environnement protection. The presented work is concerned with modelling of an electric arc between tungsten electrodes at atmospheric pressure in various gases (Ar, Air, CO2). As a first stage, a stationary 2D arc plasma model under the assumption of the local thermodynamic equilibrium (LTE) has been established using the computational platform COMSOL Multiphysics. It accounts for the properties of the near-electrode regions in the frame of a simplified sheath model. First simulation results for various current levels will be presented and discussed. Experimental observations will be considered as a reference.

P 17.5 Wed 16:15 Zelt Ost

Electrical characterisation of an atmospheric pressure plasma jet — •Manuel Maas, Judith Golda, Franko Greiner, and Jan Benedikt — Institut of Experimental and Applied Physics, Kiel University

The measurement of rf power coupled into an atmospheric pressure plasma jet is challenging. We investigated the ability of several layouts of current and voltage probes to acquire reliable time series. The ability to extract the phase between current and voltage is tested for three different analysis methods. The power characteristics of an atmospheric pressure plasma jet operated in helium is compared to the intensity evolution of helium excimer band structures measured using optical emission spectroscopy.

P 17.6 Wed 16:15 Zelt Ost

Spatial Electron Temperature and Density Measurement of a Plasma Window Arc Discharge — •Andre Michel, Bernhard Bohlender, Joachim Jacoby, and Marcus Iberler — Institut für Angewandte Physik, Goethe Universität Frankfurt

Optical emission spectroscopy is used for measurements of the free electron density and temperature of a wall stabilized arc discharge inside a newly developed plasma window at the Institute of Applied Physics at Goethe University Frankfurt. The plasma window provides a membrane free beam transmission between two different pressure levels on short length scales, offering advantages over conventional atmospheric to low-pressure interfaces. Due to the different pressure levels, plasma parameters are expected to vary alongside the arc discharge resulting in electron density and temperature gradients. For quantitative estimation radial optical emission spectroscopy measurements were carried out at different axial positions of the discharge. First results of the plasma parameters are presented, depending on the arc current and pressures inside the plasma window.

P 17.7 Wed 16:15 Zelt Ost

Optical emission spectroscopy of excimer emission band structures in an atmospheric pressure helium plasma jet — •Tristan Winzer, Judith Golda, Franko Greiner, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Germany

Atmospheric pressure plasmas have received increasing attention in recent years due to their potential applications not only in industrial processes but also in plasma medicine. Their non-equilibrium characteristics enable treatment of surfaces which are sensitive to heat. However, diagnostics is challenging due to their small dimensions.

Optical emission spectroscopy (OES) is a non-invasive diagnostic technique providing information about species, excitation mechanisms and gas temperature. Using OES in the visible range, an atmospheric pressure dielectric barrier discharge operating in helium was investigated. The intensity of the molecular bands of helium excimers was studied under variation of gas flow and power dissipated in the plasma. Using a Boltzmann-Plot, we calculated the rotational temperature of helium molecules and drew conclusions on the gas temperature.

P 17.8 Wed 16:15 Zelt Ost

Biofilm Sterilization on Stainless steel by Synergistic Treatment of Atmospheric Pressure Plasma and Chelators — •Chen-Yon Tobias Tschang and Markus Thoma — I. Physikalisches Institut, Justus-Liebig-University Giessen, Germany

Atmospheric pressure plasma (APP) had been show to be strongly effective against bacteria. However, The efficiency drops dramatically when treating bacteria biofilm. Chelators, such as citric acid or ethylenediaminetetraacetic acid (EDTA), are organic compounds which bonds metal ions. Chelators are assumed to prevent or interrupt biofilm forming by bonding of calcium and magnesium ions. In this study, we investigate the synergistic effect of chelators and APP on E. coli biofilms on stainless steel plates. Chelators of EDTA and citric acid with different concentration were applied. The plasma source was a surface micro-discharge (SMD). Sterilization rates of different treatment time and concentration were investigated. In addition, a system of mist plasma were also utilized in order to examine the synergistic effects of chelator aerosols and APP. Live/Dead stain were applied for preventing viable but nonculturable (VBNC) state of bacteria. Results indicate that combination treatment of 7.5% of citric acid with plasma treatment increase the sterilization efficiency at least 10 times higher, while single treatment of citric acid had almost no effects. Mist plasma treatment did not result in significant change of sterilization efficacy.

P 17.9 Wed 16:15 Zelt Ost

End on spectrometric analysis of a Plasma Windows arc discharge — •Marius Dehmer, Bernhard Bohlender, Andre Michel, Marcus Iberler, and Joachim Jacoby — Goethe Universität Frankfurt, IAP, AG Plasmaphysik

The Plasma Window is a membrane free device for transmission between two different pressure ranges allowing particles to pass through. It was originally patented by A. Hershcovitch in the 1990's*. The group of Prof. Dr. Jacoby at Goethe University Frankfurt picked up his idea and has been working on an own prototype to full fill the requirements of FAIR near Darmstadt.

A Plasma Window consists of a wall stabilized arc discharge connection two regmies of different pressure. Its temperature and electron density correspond with the sealing effects of this device**. Therefore knowledge of these parameters is important. Situated in the early stages of the project, spectroscopy was realized end on the plasma window from the cathode side for estimations of the electron temperature. Furthermore electron density and the arcs composition were determined.

Additionally radial spectrometry along the discharge axis is currently in progress by Mr. A. Michel. Both Mr. A. Michels and Mr. B. Bohlenders work, who focuses on the setup of the Plasma Window, will be presented at this conference. * Hershcovitch, A. J. Appl. Phys., AIP Publishing, 1995, 78, 5283 ** Krasik, Y. E.; Gleizer, S.; Gurovich, V.; Kronhaus, I.; Hershcovitch, A.; Nozar, P. & Taliani, C. J. Appl. Phys., AIP Publishing, 2007, 101, 053305

P 17.10 Wed 16:15 Zelt Ost

Sterilization of Spacecraft Equipment using a Plasma Afterglow Circulation Apparatus — •Meike Müller[1], Hubertus Thomas[1], Julia Zimmermann[3], Gregor Morfill[3], and Petra Rettberg[2] — [1]Deutsches Zentrum für Luft- und Raumfahrt, Institut für Materialphysik im Weltraum, 82234 Wessling, Germany — [2]Deutsches Zentrum für Luft- und Raumfahrt, Institut für Luft- und Raumfahrtmedizin, 51147 Köln, Germany — [3]terraplasma GmbH, 85741 Garching, Germany

A new afterglow circulation apparatus using cold atmospheric plasma (CAP) is presented as a useful alternative sterilization method for spacecraft equipment. The developed setup uses the plasma afterglow generated by surface micro-discharge (SMD) technology and allows the control of gasflow, humidity and treatment volume. With the new setup we evaluate appropriate CAP conditions for a maximal sporicidal effect and examine the inactivation efficiency by increasing the treatment volume. The sporicidal effect of the apparatus is tested with bacterial endospores Bacillus atrophaeus.

A Fourier Transformation Infrared Spectrometer (FTIR) is used to analyse the detailed composition of the afterglow plasma. The study provides an insight into the plasma chemistry and the influence of the prevalent humidity involved in the inactivation of microorganisms.

We will give an overview on the status of the plasma decontamination project and present the first results of the plasma-gas-circulation apparatus funded by the Bavarian Ministry of Economics.

P 17.11 Wed 16:15 Zelt Ost

Geometrical dependent characterisation of a microplasma reactor with four sub-arrays — •Sebastian Dzikowski and Volker Schulz-von der Gathen — Experimentalphysik II, Ruhr Universität Bochum, Bochum, Germany

Microplasma pixel devices are interesting for large scale applications such as gas reformation. A representative is a metal grid array device, which is a stable alternative to silicon-based arrays. It consists of a dielectric sheet, a grounded and a powered electrode with symmetrically arranged cavities. The grounded electrode is realized by a magnet that pulls the grid to a simple sticked device. Typically, microplasma arrays are operated close to atmospheric pressure with noble gases like argon or helium. By applying a bipolar voltage waveform with an amplitude of 800 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 micrometers.

As a comparison for a silicon-based multiple trench array discharge reactor a first reactor consisting of four metal-grid arrays was developed. The four grids are different in their cavity diameter and spacing. Here, we present time and spatial dependent optical investigations about ignition timing and line ratios of several gas mixtures including molecular admixture by using phase resolved optical emission spectroscopy.

P 17.12 Wed 16:15 Zelt Ost

Effekt einer Amtosphärendruckplasmafackel auf humane Keratinozyten — •Niklas Nawrath, Gretel Louise Chomthon-Luthe und Dieter Ihrig — Fachhochschule Südwestfalen, Iserlohn

Um Atmosphärendruckplasmen für die Handdesinfektion einsetzen zu können, ist es notwendig, die Auswirkungen auf die menschliche Haut zu untersuchen. Dazu wurden humane Keratinozyten der Zelllinie HaCaT eingesetzt. Die Zellen wurden kultiviert, mit einem Argon-Sauerstoff-Plasma behandelt und untersucht. Analysen der Zellvitalitätsrate, der apoptotischen und nekrotischen Zellen sowie der Effekt des Plasmas auf das Medium wurden durchgeführt. Zusätzlich wurde die Genexpression von 200 ausgewählten Genen über Sequenzierungsversuche analysiert, um Rückschlüsse über die Zellsignale innerhalb der Zelle zu erhalten. Die gewählten Gene steuern unter anderem die Zellproliferation, die Apoptose, die Immunantwort, den Ceramidsignalweg sowie den Actinhaushalt.

P 18: Plasma Wall Interaction I - Poster

Time: Wednesday 16:15–18:15 Location: Zelt Ost

P 18.1 Wed 16:15 Zelt Ost

Investigation of ground state excitation of sputtered tungsten in the linear plasma device PSI-2 — •Stephan Ertmer, Oleksandr Marchuk, Albrecht Pospieszczyk, Arkadi Kreter, and Sebastijan Brezinsek — Forschungszentrum Jülich GmbH - Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany

Tungsten (W) is foreseen as plasma-facing material in future fusion reactors. Spectroscopy is an important tool for particle flux measurements into the plasma. For the interpretation of the measured W line intensities the population distribution of J levels within the fivefold ground term ^{5}D and the $^7S_3$ level of sputtered tungsten released and entering the plasma remains an open question. A local thermal equilibrium (LTE) for these levels with an effective temperature in the order of 0.1-0.3 eV is usually assumed [1]. To investigate this assumption of LTE, we exposed a W target (T_{surf}=300 K) to an argon plasma in PSI-2 and measured the intensity of several W I lines over the first few mm in front of the target with high spatial resolution of 50 μm/px. The position of the intensity maximum provides information about the temporal evolution of the level population. Thus, the assumption on LTE condition within the ^{5}D ground term of the sputtered particles entering the plasma can be studied independently. The data suggest that at a biased, monoenergetic ion energy of 100-200 eV all atoms are sputtered primarily in the lowest ground level $^5D_0$ and the other levels are populated subsequently in the plasma.

[1] I. Beigman et al. Plasma Phys. Control. Fusion 49 1833 (2007)

P 18.2 Wed 16:15 Zelt Ost

Current results of the ITER relevant large RF driven negative ion beam test facility ELISE — •Dirk Wünderlich, Ursel Fantz, Bernd Heinemann, Werner Kraus, Rudi Riedl, and the NNBI team — Max- Planck- Institut für Plasmaphysik, 85748 Garching, Germany

The negative ion beam test facility ELISE is an important intermediate step in the European R&D roadmap for the neutral beam injection (NBI) systems of ITER. The ELISE ion source has half the size of the ITER source and its aim is to demonstrate the ITER requirements regarding the extracted current density (329 A/m^2 in hydrogen, 286 A/m^2 in deuterium), the electron-ion-ratio ($<$ 1) at the required filling pressure ($\leq$ 0.3 Pa) and the pulse length (1000 s in hydrogen, one hour in deuterium).

Typically the source performance is limited by the amount and temporal stability of the co-extracted electrons, in particular in deuterium operation. In the last years several valuable tools for counteracting this increase of the electrons have been identified, mainly modifying the magnetic and electric field topologies close to the extraction system and improving the caesium management.

The presentation summarizes and discusses the latest results obtained at ELISE: using the above-mentioned measures, in short pulses (10 s beam) the ITER values have almost been reached. Additionally, the current densities obtained during long pulses were drastically increased, reaching around 66 % of the ITER requirement both in hydrogen and deuterium.

P 18.3 Wed 16:15 Zelt Ost

Powder mtallurgically produced tungsten fiber-reinforced tungsten composites — •Yiran Mao[1], Jan.W Coenen[1], Johann Riesch[2], Sree Sistla[3], Leonard Raumann[1], Martin Bram[4], Jesus Gonzalez[4], Till Höschen[2], Alexis Terra[1], Christian Linsmeier[1], and Christroph Broeckmann[3] — [1]Forschungszentrum Jülich GmbH, IEK-4, 52425 Jülich, Germany — [2]Max-Planck-Institut für Plasmaphysik, 85748 Garching b. München, Germany — [3]RWTH Aachen University, IWM, 52062 Aachen, Germany — [4]Forschungszentrum Jülich GmbH, IEK-1, 52425 Jülich, Germany

In future fusion reactors, tungsten (W) is the main candidate material for plasma facing component. The intrinsic brittleness is a concern with respect to the fusion environment - high transient heat loads, neutron irradiation. To overcome this drawback, tungsten fiber reinforced tungsten (Wf/W) composites are being developed relying on an extrinsic toughing principle. In this work, recent development progress on powder metallurgy produced Wf/W will be discussed, showing a promising avenue to produce a dense bulk Wf/W composite. The work focuses on recent progress in Wf/W manufacturing and characterization. A main difficulty during sintering is the fiber embrittlement due to carbon contamination. These issues can be solved by separating the powders and graphite tool with a tungsten foil. Preliminary mechanical testing are performed in the as-fabricated condition. It shows that the existing of the weak interface reduces the strength of the composite, but, in return, allow to realize the pseudo ductility mechanism. This discrepancy and the resulting constraints for the manufacturing will be discussed.

P 19: Codes and Modelling - Poster

Time: Wednesday 16:15–18:15 Location: Zelt Ost

P 19.1 Wed 16:15 Zelt Ost

Progress of the research data management platform InPT-Dat — •Markus M. Becker, Ionut L. Paulet, Steffen Franke, and Detlef Loffhagen — INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald

The interdisciplinary nature of current research in the field of plasma technology gives rise to the question of how research results in the different fields of science (physics, chemistry, biology, medicine and very recently agriculture) can be effectively linked together and made accessible and reusable for scientists and industry in the different fields. The project InPT-Dat (Interdisziplinäre Plasmatechnologie-Datenplattform) aims to tackle this question. The goal of this project is to establish a web-based research data management platform for the collection and provision of research data from all fields of low-temperature plasma science and to sensitize researchers for a handling of research data according to the FAIR (Findable, Accessible, Interoperable, Reusable) principles. In the present contribution the progress of the project will be reported and the current concept will be discussed to collect impressions and suggestions from the plasma physics community.

This work is supported by the Federal Ministry of Education and Research (BMBF) under grant No. 16FDM005 as part of the program “Erforschung des Managements von Forschungsdaten in ihrem Lebenszyklus an Hochschulen und außeruniversitären Forschungseinrichtungen”.

P 19.2 Wed 16:15 Zelt Ost

Towards a nested neutral–ion kinetic transport model in the plasma boundary — •Friedrich Schluck, Michael Rack, and Detlev Reiter — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung – Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany

The kinetic Monte Carlo plasma edge code EIRENE is well established for mainly three reasons: (1) broad databases of atomic, molecular, and reactive processes, (2) applicability to real geometries, and (3) integration in frequently used code packages, e.g. SOLPS and EMC3-EIRENE. Ions are typically modelled in fluid description and, thus, handled by different codes, as they are assumed to be in local equilibrium. However, simple collisionality arguments, as well as previous code results have indicated that this approach might be insufficient. They emphasized the importance of kinetic treatment in particular of short-living minority ions.

Until recently, only a strongly reduced handling of ions was implemented in EIRENE, i.e. energy relaxation along magnetic field lines, before other reactive loss mechanisms take place. The goal of our extended kinetic ion transport description within EIRENE is to fully implement all guiding center drifts, pitch-angle scattering, radial diffusion, and equilibration checks for ion ensembles. We present the current status of aforementioned upgrades for EIRENE. Moreover, we embed first simulation results in topical context as we discuss implications in transport for today's fusion devices like Wendelstein 7-X.

P 19.3 Wed 16:15 Zelt Ost

Simulation of inductive rf coupling in low pressure low temperature hydrogen plasmas — •Dominikus Zielke[1], Stefan Briefi[1,2], David Rauner[1,2], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Inductively coupled hydrogen plasmas are applied in many diverse fields, among them are materials processing and ion sources for accelerators or neutral beam heating systems for fusion. In general, it is desirable to maximize the power transfer efficiency η, i.e. the ratio of power absorbed by the plasma to the power delivered by an rf generator. Many quantities such as plasma and antenna geometry, delivered rf power, rf frequency and gas pressure influence η. In order to understand these influences quantitatively, a numerical model has been set up which simulates the inductive coupling between the antenna and the plasma self-consistently. The low pressure low temperature plasma is described using a stationary multi-fluid approach, i.e. continuity equations are used for the neutral and charged species. The electromagnetic part, which is described by Maxwell's equations in the frequency domain, is coupled to the fluid part by means of the electron energy balance. The highly nonlinear model is implemented using the finite element method and the solver of the COMSOL Multiphysics Software package. The contribution covers the model verification as well as the validation against experimentally obtained results from a cylindrical ICP.

P 19.4 Wed 16:15 Zelt Ost

Estimation, Validation and Uncertainty of the Position of the Separatrix Contour at ASDEX Upgrade — •Johannes Illerhaus[1,2], Rainer Fischer[1], Gregor Birkenmeier[1,2], Mike Dunne[1], Louis Giannone[1], Bernd Kurzan[1], Patrick McCarthy[1], Matthias Willensdorfer[1], Ulrich Stroth[1,2], and the ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Physics Department E28, TUM, Garching, Germany

To properly describe magnetic equilibria of tokamak plasmas in fusion research it is important to be able to accurately reconstruct the posi- tion of the last closed flux surface, the separatrix. Measurements of the currents of the scrape-off-layer onto the divertor plates, in the poloidal field coils and those induced in vessel components are used to apply constraints to this reconstruction. The influence of the uncertainties in these quantities on the separatrix reconstruction will be studied. In this contribution the goal is to illustrate the uncertainty and sensitivity of the reconstructed separatrix position and their respective dependence on the allowed flexibilities in the prescribed coil currents. Different ki- netic diagnostics (Thomson scattering,electron cyclotron emission and lithium beam) are used to validate the reconstructed separatrix po- sition. Additionally, different poloidal field coil arrays can be used to better understand their influence on the equilibrium reconstruction. The result will be an uncertainty quantification of the separatrix con- tour and a study of the systematic deviations of the diagnostics among themselves and with respect to the equilibrium, respectively.

P 19.5 Wed 16:15 Zelt Ost

Modelling,simulation of a 4-mirror imaging antenna for plasma diagnostics — •Peshawa Husain — Institut fur grenzflachenversahrenstechnik und plasmatechnologie

for the spatially resolved measurement of radiation from a collective thomson scattering experiment, an imaging antenna based on a 4-mirror arrangement is used, this antenna is to be modeled with a physical optics code (fortran), which needs to be revived. The results shall be cross-checked with the finite difference code ipf-fd3d.

P 19.6 Wed 16:15 Zelt Ost

PIC-Molekulardynamik-Hybrid-Code für Mikroplasmen — •Viktoria Pauw, Hartmut Ruhl und Christian Herzing — LMU München, Deutschland

Die Simulation von Plasmen ist aufgrund der komplexen elektromagnetischen Wechselwirkung und der hohen Anzahl der Teilchen eine anspruchsvolle Aufgabe. Der von uns entwickelte Plasma-Simulation-Code (PSC) kann sowohl auf Particle-In-Cell-Basis (PIC) betrieben werden, als auch molekulardynamisch, wobei die direkte Teilchen-Teilchen-Interaktion relativistisch durch Berechnung retardierter Lienard-Wiechart-Felder modelliert wird. Die Particle-In-Cell-Methode versagt für stark korellierte Systeme, da nur kollektive Plasmabewegungen dargestellt werden können. Die volle Molekulardynamik ist jedoch für Systeme mit mehr als einigen Tausend Teilchen aufgrund des quadratischen Scalings zu kostenintensiv. Wir arbeiten daher zur Zeit an einem Verfahren für eine hybride Modellierug von Plasmen. Die Unterschiede der Ansätze, die korrekte Darstellung physikalischer Prozesse und der Rechenaufwand, sowie die Möglichkeiten und das Scaling des hybriden Ansatzes werden von uns untersucht und sollen in einem Poster vorgestellt werden. Als Test-Case verwenden wir u.A. expandierende Mikroplasmen im Vakuum, mit und ohne Interaktion mit externen Laserpulsen. Anschluss an das Experiment bietet eine Kooperation zum Thema laser-getriebenen Mikroplasmen mit der Gruppe um Jörg Schreiber (LMU, Lehrstuhl für Medizin-Physik), deren Experimente bereits erfolgreich mit unserem Code modelliert wurden.

P 19.7 Wed 16:15 Zelt Ost

Kinetic Model of the Planar Multipole Resonance Probe — •Michael Friedrichs and Jens Oberrath — PPI, Leuphana University Lüneburg, 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. The planar Multipole Resonance Probe (pMRP) offers this ability and is a suitable diagnostic tool to monitor plasma processes in industrial applications. The analysis of the fluid-model of the pMRP led to a formula for the resonance frequency, which can be used to determine the electron density. To widen its field of application in terms of measuring the electron temperature additionally to the electron density another relation between the electron temperature and second resonance parameter is needed. Such a parameter is given by the half width of the resonance peak, which represents the damping of the system. In low pressure plasmas the half width depends not only on collisional damping, but also on collisionless damping. To investigate the influence of collisionless damping on the half width and to determine a relation between the half width and the electron temperature a kinetic model is required. Such a model of the pMRP, based on functional analytic methods, will be presented in this work and the result of the explicit expansion of the admittance will be shown.

The authors gratefully acknowledge funding by the German Research Foundation (DFG) within the project OB 469/1-1.

P 19.8 Wed 16:15 Zelt Ost

Higher order MHD numerics — Prabal Singh Verma[1], •Jean-Mathieu Teissier[2,3], Oliver Henze[2], and Wolf-Christian Müller[2,4] — [1]Aix-Marseille Université, Laboratoire de Physique des Interactions Ioniques et Moléculaires — [2]Technische Universität Berlin, Zentrum für Astronomie und Astrophysik — [3]Berlin International Graduate School in Model and Simulation based Research — [4]Max-Planck/Princeton Center for Plasma Physics, Princeton, NJ, USA

We present a simple fourth-order accurate finite volume scheme for solving compressible astrophysical ideal magnetohydrodynamics (MHD) problems using Cartesian meshes. Evolution of the magnetic field is realized by the constrained transport approach. Reconstruction and flux computation are performed in a dimension-by-dimension fashion to achieve better computational efficiency. Validation was performed through a variety of standard test cases.

Several reconstruction methods are employed, including Central Weighted Essentially Non Oscillatory reconstruction. In order to enhance robustness at higher Mach numbers, the reconstruction method is selected depending on the local gradient of the solution. Higher order is achieved in the dimension-by-dimension approach using a face-to-point value transformation based on a Taylor expansion. The system can be driven by external stochastical forcing such as an Ornstein-Uhlenbeck process. Lagrangian aspects can be studied by a parallelized tracking of passively advected tracer particles.

P 19.9 Wed 16:15 Zelt Ost

Ion Energy Distribution Functions in Capacitively Coupled Argon-Xenon Plasmas — •Maximlian Klich[1], Sebastian Wilczek[1], Jan Trieschmann[1], Thomas Mussenbrock[2], and Ralf Peter Brinkmann[1] — [1]Ruhr University Bochum, Bochum, Germany

— [2]BTU Cottbus - Senftenberg, Cottbus, Germany

While accurate control of the ion energy is a crucial requirement of industrial plasma processes, its intrinsics are still not fully understood. Specifically, plasmas used for etching or thin film deposition consist of various gas and ion species. Thus, the control of the ion dynamics of multiple gas and ion species is a topic of current research. In order to contribute to this topic, we investigate low-pressure argon-xenon discharges via Particle-In-Cell/Monte Carlo Collision (PIC/MCC) simulations. The main advantage of this noble gas mixture is the simple chemistry, which leads to a feasible number of ion species and collision processes to be considered. The ion energy distribution functions (IEDFs) at the electrodes of a geometrically symmetric capacitively coupled radio-frequency discharge provide information about the ion dynamics within the discharge volume. Several variations of the discharge parameters (e.g., pressure, driving voltage and gas composition) are presented in order to influence the ion dynamics. Furthermore, a power balance model is used, which allows for a better understanding of the obtained results. The final goal of this study is to achieve deeper insights about complex (e.g., bimodal) IEDFs of different ion species.

P 20: Plasma Wall Interaction II - Poster

Time: Wednesday 16:15–18:15 Location: Zelt West

P 20.1 Wed 16:15 Zelt West

3D global impurity transport modeling with WallDYN and EMC3-Eirene — •Lennart Bock[1,2] and Klaus Schmid[2] — [1]Physik-Department E28, Technische Universität München, 85747 Garching, Germany — [2]Max-Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

The wall of a fusion experiment is subject to bombardment by energetic ions from the plasma, which leads to sputtering of wall material and retention of incoming ions. Sputtered wall material is transported through the plasma and eventually redeposited on the wall. This process is called impurity migration and controls net erosion of the wall, impurity content in the plasma and retention of ions in the wall.

The global impurity migration code WallDYN calculates the surface composition and impurity fluxes self consistently by combining models for implantation, erosion and reflection of impurities with a model for impurity transport through the plasma. In WallDYN the impurity transport is described by the 2D code DIVIMP and thus limited to toroidally symmetric geometries. While for tokamaks the plasma is essentially toroidally symmetric, the first wall is not. Including the effect of toroidally asymmetric wall features like poloidal limiters or modeling other devices like stellarators therefore requires switching to a full 3D impurity transport model. For WallDYN this means switching from the 2D code DIVIMP to the 3D code EMC3-Eirene.

In this contribution the implementation of EMC3-Eirene to WallDYN is described and impurity transport models of DIVIMP and EMC3-Eirene are compared with focus on their validity range.

P 20.2 Wed 16:15 Zelt West

Development of a Methode to Determine the Crystal Surface Orientation Dependenc of Tungsten oxidation — •Karsten Schlüter[1,2], Martin Balden[1], and Tiago Fiorini da Silva[3] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [2]Fakultät für Maschinenwesen, Technische Universität München, D-85748, Garching, Germany — [3]Physics Institute of University of São Paulo - Rua do Matão, trav. R 187, 05508-090 São Paulo, Brazil

The crystal orientation influences the properties of tungsten (W), thus affecting their performances in applications like fusion plasma devices. In this regard, it will be necessary to study the dependency of W properties (e.g. oxidation resistance or sputtering) on its crystal orientation to probably optimize the texture of the material. To evaluate a crystal orientation analyses for all, the low and high index surfaces, a measuring method was developed.

The grain orientations on a polycrystalline W sample were analyzed using electron backscatter diffraction. Subsequently, the samples were 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 high index surfaces are visualized in an inverse pole figure (IPFz).

P 20.3 Wed 16:15 Zelt West

Ultra-precise Machining of Surfaces Using Microwave-driven Cl-based Plasma Etching — •Faezeh Kazemi and Thomas Arnold — IOM Leibniz-Institute of Surface Engineering, Leipzig, Germany

Reactive plasma jet machining (PJM) is a technology for ultra-precise surface shape generation which can provide high etch rates due to its chemical characteristic. The basis of reactive plasma etching is the reaction between gas-phase radicals generated in a plasma discharge and the solid surface in order to form a volatile etch product. Etching processes for silicon-based materials have been mostly investigated using fluorine-based reactive plasmas since most of fluoride-silicon compounds are volatile. However, Al and some other elements do not form volatile etch products in fluorine-based plasmas. Therefore, extending the choice of reactive etch gases is required for the applicability to a new range of materials.

The aim of this study is to develop and use a plasma jet that contains reactive chlorine compounds and some other non-halogenated etch gases which are admixed to inert plasma gases like argon and helium. For this purpose, we investigate a fine-focused microwave powered plasma jet. Reactive species like atomic chloride or hydrogen are generated in the plasma jet by dissociation of suitable process gases. The etching behavior and reaction kinetics in a chlorine-based plasma jet process are examined for different substrate materials aiming to clarify the chemical kinetics of surface reactions.

P 20.4 Wed 16:15 Zelt West

Aufbau eines Gegenfeldanalysators zur Untersuchung der Plasma-Wand-Wechselwirkung in HF-Plasmen — •Felix Georg, Thomas Trottenberg und Holger Kersten — Institut für experimentelle und angewandte Physik (IEAP), Uni Kiel, Deutschland

Für die Untersuchung der Plasma-Wand-Wechselwirkung in kapazitiv gekoppelten HF-Plasmen wurde ein Gegenfeldanalysator (RFA) entwickelt, welcher, neben der Möglichkeit verschiedene Materialien als Kollektor-Material zu verwenden, auch in Verbindung mit einer passiven Thermosonde (PTP) verwendet werden kann. Der Aufbau des RFA ist so gewählt, dass der Kollektor unabhängig von den anderen Gittern (Screen Grid, Scan Grid und Sekundär-Elektron-Repeller) ausgetauscht werden kann. Dadurch kann der direkte Einfluss (z.B. Sekundär-Elektronen-Emission) verschiedener Materialien auf die Randschicht im Plasma untersucht werden, indem das Kollektor-Material an das als Elektrode im Plasma verwendete Material angepasst wird. Schließt man zusätzlich ein Thermoelement an den Kollektor an, kann neben der Ionenenergieverteilung auch der Energieeintrag der einfallenden Ionen auf das Material bestimmt werden. Der verwendete Aufbau lässt zusätzlich eine Untersuchung der Plasmaparameter mittels Langmuirsonden-Diagnostik zu und bietet die Möglichkeit sowohl den RFA, als auch eine einzelne PTP in die Gegenelektrode einzubauen.

P 20.5 Wed 16:15 Zelt West

Assessment of nitrogen enrichment in plasma discharges cooled by nitrogen gas puffing in ASDEX Upgrade — •Thomas Reichbauer[1,2], Volker Rohde[1], Aleksander Drenik[1], and the ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Physics Department E28, TUM, Garching, Germany

To avoid divertor damage by overheating, intrinsic divertor radiation which dissipates power is too low. In ASDEX Upgrade (AUG) nitrogen is seeded into the divertor to reduce its power load. But nitrogen seeding leads to ammonia formation which could become an issue for gas handling plants and cryo pumps of future fusion devices. A direct measurement of the interacting nitrogen with D on the surface is not possible. The produced ammonia is measured with residual gas analyzers. The detection of ammonia is still not a straight forward procedure because all molecules are created in a mixed D/H environment with unknown ratio. Therefore the ratios of H_2O, CH_4 and NH_3 overlap. A fit routine was constructed to gain partial pressures of the different gases. For working reliably, the calibration is a key aspect. After N_2 seeded discharges nitrogen is implemented in walls and stays in AUG for the following ones. The connection of nitrogen and ammonia is established in the following discharges. This could give a better insight of the amount of interacting nitrogen during N_2 puffing. First results on the NH_3/N_2 ratios during legacy discharges are presented and how they could be used to gain information about the formation mechanism of ammonia during N_2 seeded discharges.

P 20.6 Wed 16:15 Zelt West

A piezoelectric particle injector for ASDEX Upgrade — •Alexander Bauer[1,2], Volker Rohde[1], Rudolf Neu[1,2], and the ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technical University Munich, Garching, Germany

In the Tokamak ASDEX Upgrade a significant amount of small (W) tungsten spheres with the size of over 1 μm is found during dust investigations, which are presumably produced by arcing. Macroscopic particles have a higher penetration probability into the core plasma compared to atoms, possibly causing a substantial W influx. To study their penetration a small injector, developed at KSTAR [1], will be put in operation at ASDEX Upgrade. In this contribution we report on laboratory investigation on characterization and commissioning. The mechanic is driven by a piezo motor that compresses a spring. When the spring expands a cylinder gets accelerated and injects particles supplied from a small reservoir. The device is of compact size and is capable to operate under vacuum conditions and strong magnetic fields. During the characterization different parameters were investigated. Tests were carried out at atmospheric pressure and under vacuum, mostly using high speed cameras to record the particle trajectories. Different methods are used to illuminate the launched particles. In the plasma the particles will be heated and get visible due to them glowing. For the injected amount of particles tests resulted in a W mass per shot of 24 ± 11 mg. The videos have shown initial velocities of 1.55 m/s in air and ranges of 8 cm. [1] H.Y.Lee et al., RSI, 85 (2014), 11D862

P 20.7 Wed 16:15 Zelt West

Microscopic modeling of Ar atom scattering from a Pt(111) surface: a combined molecular dynamics and rate equation approach — •A. Filinov[1,2,3], D. Loffhagen[2], and M. Bonitz[1] — [1]ITAP, CAU Kiel, Leibnizstr. 15, 24098 Kiel — [2]INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald — [3]Joint Institute for High Temperatures, Izhorskaya Str. 13, 125412 Moscow

A combination of molecular dynamics (MD) simulation with a rate equation model is presented and applied to the trapping and scattering of rare gas atoms from metal surfaces. The temporal evolution of the atom fractions being either adsorbed or scattered into the continuum is investigated. We consider trapped, quasi-trapped and scattering states for this description, which are distinguished by an energetic criterion. The rate equations contain the transition probabilities between the states that can be uniquely determined from an analysis of the particle trajectories generated by MD. Once the system reaches quasi-equilibrium, the rates converge to stationary values, and the subsequent thermal adsorption/desorption dynamics is completely described by the rate equations without the need to perform time-consuming MD simulations. As a proof of our model, we present studies for Ar atoms interacting with a Pt(111) surface and obtain good agreement with the experiment. The dependence of the rates, kinetic energy and the energy-loss distribution functions on the incidence conditions and the lattice temperature is analyzed. Our model is important for the plasma-surface modeling as it allows to extend accurate simulations to longer time scales.

P 20.8 Wed 16:15 Zelt West

Two-dimensional particle-in-cell simulation of gas discharges — •Michael Marsand[1], Peter Hartmann[2], and Hanno Kählert[1] — [1]ITAP, Christian-Albrechts-Universität zu Kiel — [2]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Budapest, Hungary

The simulation of gas discharges is a challenging task. At low pressure, particle-in-cell simulations with Monte Carlo collisions have become the method of choice as they allow for a fully kinetic description of the plasma species. However, they are computationally very demanding, in particular, if the specific geometry of the discharge must be taken into account. Here, we present our progress towards two-dimensional simulation models. We discuss their numerical implementation and compare with the results of one-dimensional codes. One of the central goals for the 2D codes is an accurate description of the interaction between plasmas and surfaces, where both the shape and the properties of the material are accurately accounted for.

P 21: Laser Plasmas - Poster

Time: Wednesday 16:15–18:15 Location: Zelt West

P 21.1 Wed 16:15 Zelt West

The Hosing Instability in AWAKE — •Mathias Hüther[1,2], Allen Caldwell[1,2], and Patric Muggli[1,3] — [1]Max-Planck-Institut für Physik, München — [2]Technische Universität München — [3]CERN, Genf, Schweiz

AWAKE (Advanced Wakefield Experiment) is located at CERN. It is world's first proton-driven plasma wakefield accelerator. It aims for acceleration of externally injected electrons in gradients up to the GeV/m scale. It uses a 12 cm long proton bunch from the CERN Super Proton Synchotron (SPS) that propagates through a 10 m long Rubidium plasma channel (with a particle density of 1-10 $\cdot 10^{14}$ cm^{-3}), induced by a high-power short laser pulse (pulse duration $\tau = 120$ fs, pulse energy $E = 450$ mJ).

The process of Seeded-Self Modulation (SSM) results in the break-up of the long proton bunch into a train of micro-bunches separated by a distance on the order of the plasma wavelength by the Self-Modulation Instability (SMI), a transverse plasma instability. The SMI growth is mainly competing with the Hosing-Instability (HI). Under certain conditions this can lead to unstable SMI growth process and eventually to no development or even a destruction of the micro-bunch structures.

In this talk, we give a short introduction to SSM, SMI and HI-processes. Furthermore, we discuss conditions for a growth of the HI as well as possibilities for its suppression.

P 21.2 Wed 16:15 Zelt West

Studying filament instabilities in laser irradiated hydrogen targets by preplasma scanning: a PIC code approach — •João Branco[1,2], Karl Zeil[1], Lieselotte Obst[1,2], Ulrich Schramm[1,2], Thomas Kluge[1], and Michael Bussmann[1] — [1]HZDR, Dresden, Deutschland — [2]TU Dresden, Dresden, Deutschland

We present simulation results on laser ion acceleration using hydrogen targets irradiated by ultra-intense, ultra-short laser pulses. These targets promise to produce pure proton beams that could be used for cancer therapy at high repetition rates. We address critical issues concerning the acceleration process that potentially hinders the application of these beams in clinical scenarios.

For achieving proton energies suitable for the treatment of deep seated tumors it is important to increase the laser intensity. At high intensities, plasma instabilities both at the target surfaces and bulk can create electron filaments that in turn result in non-uniform proton beams, detrimental for delivering spatially uniform dose distributions.

By varying the laser contrast it becomes possible to change the preplasma scale length to influence the formation of instabilities. Other means of controlling proton beam properties are, for example, variations in terms of target geometry or laser polarization. We present results of 2D3V particle-in-cell simulations at realistic density conditions that study the influence of these effects on the plasma dynamics and final beam properties and discuss their relevance regarding future applications of solid hydrogen targets for laser-driven proton tumor therapy.

P 21.3 Wed 16:15 Zelt West

The influence of the CEP on the electrons emitted from a laser plasma created on a solid surface — •Florian

Kleeschulte, Maximilian Münzberg, and Georg Pretzler — Heinrich-Heine-Universität Düsseldorf

We present experiments in which ultrashort laser pulses (7 fs FWHM) were focused to intensities of $\approx 5 \cdot 10^{17}$ W/cm^2 on flat aluminum targets. We measured the spectra of the ejected electrons with angular resolution, obtaining energies up to 400 keV. The carrier-envelope-phase (CEP) was stabilized, and when the laser CEP was varied, we observed a strong variation of the total number of emitted electrons of the order of a few tens of percent, which is to our knowledge the first time such a strong effect is detected in this interaction regime. We present a theoretical model which might explain this unexpected effect, and we discuss further possibilities.

P 21.4 Wed 16:15 Zelt West

QED cascades in the collision of two ultra-intense laser pulses — •Archana Sampath, Matteo Tamburini, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

QED cascades are complex avalanche processes of electron-positron and hard photon creation driven by ultra-strong electromagnetic fields. They play a fundamental role in astrophysical environments such as the magnetosphere of pulsars, rendering an earth-based implementation with intense lasers attractive. A number of analytical and numerical studies has been performed to investigate the onset and development of QED cascades as a function of the laser intensity in the collision of two counter-propagating laser pulses [1]. However, it has been recently demonstrated that the onset of QED cascades is also strongly influenced by the shape of the laser pulses, such as the laser pulse waist radius [2], even at intensities around 10^{26} W/cm^2. In this work we investigate the effect on the onset of QED cascades of: (a) the laser pulse duration, (b) the presence of a relative delay for the peak of the laser pulses to reach the focus, (c) the existence of a mismatch between the laser focal axis of the two laser pulses.

[1] A. Di Piazza *et al.*, Rev. Mod. Phys. **84**, 1177 (2012).
[2] M. Tamburini *et al.*, Sci. Rep. **7**, 5694 (2017).

P 21.5 Wed 16:15 Zelt West

Optimal conditions for laser-plasma generation of monoenergetic ion beams — •Maitreyi Sangal, Matteo Tamburini, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Radiation pressure acceleration in the light sail (LS) regime is an attractive ion acceleration mechanism where an ultra-thin solid-density foil illuminated by a super-intense laser pulse can, in principle, be accelerated as a whole, therefore yielding a very dense and quasi-monoenergetic ion beam. However, especially due to the onset of instabilities and to the foil deformation, the quasi-monoenergetic features of the ion beam spectrum are still unsatisfactory for several important applications such as ion-beam therapy.

In our study, we aim at identifying the optimal laser and target parameters to produce dense and collimated ion beams with substantially improved monoenergetic features. Simple analytical modeling is supported by multidimensional particle-in-cell (PIC) simulations.

P 21.6 Wed 16:15 Zelt West

Stable quasi-monoenergetic ion acceleration from the laser-driven shocks in a collisional plasma — •Shikha Bhadoria, Naveen Kumar, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics

Effect of collisions on the shock formation and subsequent ion acceleration from the laser-plasma interaction is explored by means of particle-in-cell simulations. In this setup, the incident laser pushes the laser-plasma interface inside the plasma target through the hole-boring effect and generates hot electrons. The propagation of these hot electrons inside the target excites a return plasma current, leading to filamentary structures caused by the Weibel/filamentation instabilities. Weakening of the space-charge effects and the partial suppressions of the hot electron generation and subsequent return current filamentation, due to collisions result in a smoother shock front formation -with a higher density jump- than in a collisionless plasma [1] and stable quasi-monoenergetic acceleration of ions. [1] S. Bhadoria, N. Kumar, C.H. Keitel, arXiv:1707.03309 [physics.plasm-ph] (2017)

P 21.7 Wed 16:15 Zelt West

Ion acceleration from gaseous targets — Anna-Marie Schroer[1], Rajendra Prasad[1], Bastian Aurand[1], Stephanie Brauckmann[1], Mirela Cerchez[1], Oswald Willi[1], •Tatyana Liseykina[2], and Andrea Macchi[3] — [1]Heinrich-Heine-Universität Düsseldorf, Institut für Laser- und Plasmaphysik, Germany — [2]Universität Rostok, Institut für Physik, Germany — [3]CNR/INO, Adriano Gozzini laboratory, Pisa, Italy

In the experimental campaign at the ARCTRUS laser facility (University of Düsseldorf) we have studied ion acceleration from gaseous targets irradiated by intense laser beams. By changing experimental parameters we realized different acceleration regimes and studied transitions between acceleration mechanisms. In our experiments two ultra-short ($\sim 30\,$fs) laser beams were focused perpendicular to each other on a H_2 or He gas jet of a density $3 \cdot 10^{-5} - 1.3 \cdot 10^{-3}$g/cm^3. The Heater laser beam was focused to the intensity of $2.4 \cdot 10^{19}$W/cm^2 by an f/10 off-axis parabola (OAP) or to $6.6 \cdot 10^{17}$W/cm^2 by an f/25 OAP. The Driver beam reached an intensity of $1.5 \cdot 10^{20}$W/cm^2 focused by an f/2 OAP. Two Thomson parabola spectrometers aligned in the direction transverse to the Heater beam were used for diagnostics. Additionally, the laser plasma interaction region was examined by optical and charge particle probing. We detected protons and Helium ions accelerated up to 400 keV in a single or a double beam interaction. We identified the range of the gas density and the laser beam parameters where the monoenergetic features in the ion spectra are observed. Our experimental results were validated by numerical simulations.

P 21.8 Wed 16:15 Zelt West

Observation of two expansion phases of a sub-10-fs laser-produced plasma on an aluminum surface — •Michael Stumpf and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

We measured the temporal development of the spatial electron distribution in front of a laser-pumped aluminum surface using a novel pump-probe setup with a time resolution below 15 fs. The laser pulse reached a maximum intensity of $2.4 \cdot 10^{17}$ W/cm^2 over a pulse duration of 9 fs. We can clearly separate two phases of expansion with different time scales. This indicates two different mechanisms, namely a fast laser-driven and a slower plasma-driven one. We developed an intuitive model to describe these expansion processes qualitatively and compared the results quantitatively with numerical simulations.

P 21.9 Wed 16:15 Zelt West

Gamma-rays with orbital angular momentum via nonlinear Compton scattering — •Yue-Yue Chen[1], Jian-Xing Li[2], Karen Z. Hatsagortsyan[3], and Christoph H. Keitel[4] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Xian Jiaotong University, Xian, China — [3]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [4]Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Gamma-rays with a large angular momentum are very attractive tools to control the rotation of nuclei and facilitate nuclear fission. We propose a scheme to generate well-collimated gamma-ray beams with orbital angular momentum by nonlinear Compton scattering of a strong laser pulse of twisted photons by ultra-relativistic electrons. Angular momentum conservation between absorbed laser photons, quantum radiation and electrons are numerically demonstrated in the quantum electrodynamic regime, which reveals that the angular momentum of the laser photons is not directly transferred to the emitted gamma-photons. The efficiency of the angular momentum transfer depends on laser and initial electron properties. We investigate the optimal parameter regime to enhance the orbital angular momentum of the gamma-beam.

P 21.10 Wed 16:15 Zelt West

Propagation of high-intensity laser light in two-dimensional transient plasma photonic crystals — •Camilla Willim and Götz Lehmann — Institut für Theoretische Physik I, Heinrich-Heine Universität, 40225 Düsseldorf

The ponderomotive force of intense laser pulses allows to volumetrically modulate the plasma density of underdense plasma on the scale of the laser-wavelength. These spatially structured plasmas can act as photonic structures and may have lifetimes between a few to tens of picoseconds [1]. The optical damage threshold of these plasmas supersedes solid-state materials by many orders of magnitudes, making them very attractive as novel photonic devices for ultra-short high-intensity laser pulses [1-3]. We study the propagation of ultra-short, high-intensity laser pulses in two-dimensionally structured plasmas by combining particle-in-cell simulations and semi-analytical models. The dispersion relations for s- and p-polarized light are obtained. Based on these results applications as Bragg-type mirrors, wave-plates and further possible future applications of plasma photonic crystals are identified.

[1] G. Lehmann and K.H. Spatschek, Phys. Rev. Lett. 116, 225002 (2016), [2] G. Lehmann and K.H. Spatschek, Phys. Plasmas 24, 056701 (2017), [3] P. Michel, L. Divol, D. Turnbull, and J.D. Moody, Phys. Rev. Lett. 113, 205001 (2014)

P 22: Complex Plasmas and Dusty Plasmas - Poster

Time: Wednesday 16:15–18:15 Location: Zelt West

P 22.1 Wed 16:15 Zelt West

Operando size meansurements of microparticles using angular resolved mie scattering — •Niklas Kohlmann, Oguz Han Asnaz, Franko Greiner, and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Besides structural and dynamic processes in complex plasmas, the particles themselves are recently more and more in focus of research. Important parameters are the particle size, shape and surface topology. However, non-invasive in-situ or even operando methods to determine the named parameters during plasma operation are missing. Angular resolved mie scattering measurements can fill this gap and provide particle sizes with high precision. An out-of-focus imaging technique similar to ILIDS is used to obtain the angular-dependent scattering intensities. Correlating the so called phase function to the data provided by the Lorenz-Mie theory for spherical objects the particle size and refractive index can be obtained. The particle size measurements are validated with complimentary measurements using a long distance microscope. It is found that the sizes are in good agreement for both methods. Further applications, like the detection of changes of particle surface topology due to plasma-particle interaction or the decrease in particle size due to prolonged plasma exposure, are discussed as well.

P 22.2 Wed 16:15 Zelt West

Controlled transport and extraction of charged nanoparticles through the plasma-sheath in an acetylene RF plasma — •Zahra Marvi, Erik von Wahl, Thomas Trottenberg, and Holger Kersten — Institute of Experimental and Applied Physics, Kiel University, Germany

As nano-sized dust particles have been shown to exhibit interesting properties, which can be applied in innovative materials, there is a strong need to control the extraction of these dust particles from the plasma. One of the most important challenges about dust transport is the accurate description of the force balance which is coupled with the ion and electron currents onto the dust particle surface in electrostatic field along the plasma-sheath.

In this work, we propose a multi-fluid approach to investigate the charging process, force balance and transport of the nanoparticles through the plasma sheath between a nanodust forming CCRF plasma and a biased silicon substrate. The requirements for the extraction of nanoparticles for differently biased substrates are investigated both in simulation and experiment, respectively, and the results are compared with together.

P 22.3 Wed 16:15 Zelt West

Mach cones in inhomogeneous plasma crystals — •Sven Werner Schmidt, Frank Wieben, and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Complex plasmas are ideal systems to study wave phenomena in strongly coupled system at the kinetic level. The sound speed of dust acoustic waves depends on charge-to-mass ratio and screening strength κ. The Mach cones which are generated by a supersonic perturbation can thus be used as a diagnostic tool. Most experiments and simulations investigate Mach cones only in the central parts of a 2D crystal where a homogeneous density is assumed. This contribution investigates Mach cones in inhomogeneous media. Especially for small dust systems the parabolic confinement yields to a notable radial density gradient. In order to correctly measure q/m or κ in an inhomogeneous system it is essential to analyse the Mach cone shape. Mach cones in a plasma crystal are excited by a moving laser beam. Using a model for Mach cone curvature in inhomogeneous media [1] a reliable measurement of the sound speeds is shown to be possible.

This work was supported by the Deutsche Forschungsgemeinschaft DFG in the framework of SFB TR24 Greifswald Kiel, Project A3b and of Research Grant BL555/3-1.

[1] S.K. Zhdanov et. al., Phys. Rev. E **69**, 026407 (2004)

P 22.4 Wed 16:15 Zelt West

Local extraction of nanoparticles from a dusty CCRF discharge — •Erik von Wahl[1], Zahra Marvi[1], William Desdions[2], Isabelle Géraud-Grenier[2], Véronique Massereau-Guibaud[2], Maxime Mikikian[3], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]GREMI, UMR7344 / Univ. Orléans, F-18020 Bourges, France — [3]GREMI, UMR7344 / Univ. Orléans, F-45067 Orléans, France

Contrary to microparticles, clouds of nanoparticles can easily levitate inside a plasma due to little importance of the gravitational force. As each particle collects ions and electrons, it changes the plasma in its vicinity. Having particles distributed in a large volume of the discharge the effect of nanodust on the entire discharge is yet to be fully understood.

In this study, nanoparticles are extracted by a biased silicon substrate at different locations inside the plasma and then examined by scanning electron microscopy. In order to fully comprehend the extraction method the shape of the dust particle cloud is observed by laser light scattering at the wavelength of 350 nm. Differences in the collection results due to the choice of the substrate position are discussed.

P 22.5 Wed 16:15 Zelt West

Ekoplasma - The Future of Complex Plasma Research in Space — •Christina Knapek[1], Peter Huber[1], Daniel Mohr[1], Erich Zaehringer[1], Vladimir Molotkov[2], Andrey Lipaev[2], Vadim Naumkin[2], Uwe Konopka[3], Hubertus Thomas[1], and Vladimir Fortov[2] — [1]DLR, Institut für Materialphysik im Weltraum, Wessling, Germany — [2]Joint Institute for High Temperatures, Moscow, Russia — [3]Auburn University, Auburn, AL, USA

Complex plasmas consist of highly charged micrometer-sized grains injected into a low temperature noble gas discharge. The particles interact with each other via a screened Coulomb potential, and can form gaseous, liquid or solid states. On ground, gravity compresses the system and prevents the generation of larger, three-dimensional particle clouds. The Ekoplasma project, a Russian-German cooperation, is the future laboratory for the investigation of complex plasmas under microgravity conditions on the International Space Station (ISS). The essential part of Ekoplasma is the newly developed Zyflex chamber – a large, cylindrical plasma chamber with parallel, rf-driven electrodes and a flexible inner geometry. It is designed to extend the accessible experimental parameter range and to allow an independent control of the plasma parameters, therefore increasing the experimental possibilities and expected knowledge gain significantly. The experimental setup and the current project status will be presented, as well as selected results of experiments on earth and in parabolic flights, which demonstrate the scientific possibilities of this new laboratory.

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

P 22.6 Wed 16:15 Zelt West

Experimental investigation of 3D vortex motion in a dusty plasma — •Matthias Mulsow, Michael Himpel und André Melzer — Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, 17487 Greifswald

In low-temperature plasmas micrometer-sized particles are able to form highly ordered structures. Using a harmonic three-dimensional trapping potential strongly coupled finite systems can be created, the Yukawa-balls.

Under certain conditions the particles of such a ball are able to perform a vertical vortex motion, which can be observed by a four-camera stereoscopic system. From the camera images three-dimensional positions and velocities of the individual particles in the vortex can be reconstructed.

By analyzing the three-dimensional dust flow of clusters consisting of 50 to 1000 particles we were able to find a dependency between the vorticity and the cluster size. Furthermore, we identified radial gradients of the ion drag force as a possible drive of the vortex.

This contribution presents the experimental setup we used as well as the characteristics of the investigated vortex motion.

P 23: Plasma Wall Interaction II

Time: Thursday 10:30–12:00 Location: A 0.112

Invited Talk P 23.1 Thu 10:30 A 0.112

Advanced Materials for a Damage Resilient Divertor for DEMO — •Jan Willem Coenen[1], Johann Riesch[2], Hanns Gietl[2,3], Yiran Mao[1], Leonard Raumann[1], Rudolf Neu[2,3], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich GmbH, Institut fuer Energie und Klimaforschung, 52425 Juelich — [2]Max-Planck-Institut für Plasmaphysik, 85748 Garching — [3]Technische Universität München, Boltzmannstrasse 15, 85748 Garching

Material issues pose a significant challenge for future fusion reactors like DEMO and highly integrated approach is required. Cracking, oxidation as well as fuel management are driving issues when deciding for new materials. Neutron induced effects e.g. transmutation adding to embrittlement are crucial to material performance. Here advanced materials e.g. Wf/W composites allow the step towards a fusion reactor. Recent developments in the area of Wf/W will be presented showing a possible path towards a component based on standard tungsten production technologies. Damage resilient materials, with an increased operational temperature range facilitate component design with higher exhaust capabilities. The maximization of operational performance can only be achieved, if improvements of material properties, mechanical and thermal, are well balanced Wf/W contributes here to advanced material strength and crack resilience even after embrittlement. Rigorous testing with respect to plasma-wall-interaction and high heat-flux performance are ongoing. Prototype components are envisioned in the ner future.

P 23.2 Thu 11:00 A 0.112

Plasma chemical studies of nitrocarburizing with an active screen made of carbon — •Alexander D. F. Puth[1], Stephan Hamann[1], Lukas Kusyn[2], Igor Burlacov[3], Anke Dalke[3], Heinz-Joachim Spies[3], Horst Biermann[3], Jürgen Röpcke[1], and Jean-Pierre H. van Helden[1] — [1]INP Greifswald, 17489 Greifswald, Germany — [2]Masaryk University, 60200 Brno, Czech Republic — [3]Institute of Materials Engineering, TU Bergakademie Freiberg, 09599 Freiberg, Germany

Active screen plasma nitrocarburizing (ASPNC) is an advanced technology for the surface treatment of steel components. A new approach of this method is the usage of an active screen made of solid carbon as a substitute for carbon-containing gas supplements. The investigations have been carried out in the laboratory scale reactor PLANIMOR.

We will present the results of spectroscopic studies of N_2-H_2 containing pulsed DC discharges. The concentrations of CH_3, CH_4, C_2H_2, C_2H_4, C_2H_6, C_2N_2, NH_3, HCN, and CO have been determined with infrared laser absorption spectroscopy (IRLAS), using tunable diode lasers (TDL) and external cavity quantum cascade lasers (EC-QCL). Futhermore, the gas temperature of the stable molecular species and of the CH_3 radical has been determined using Bolzmann plot and line profile analysis, respectivly. The concentrations being measured as a function of the plasma power at the active screen, the gas pressure and the feed gas composition, ranged between 10^{12} and 10^{16} molecules cm^{-3}.

P 23.3 Thu 11:15 A 0.112

Tungsten Smart Alloys for the First Wall Armour of Fusion Power Plants — •Felix Klein[1], Andrey Litnovsky[1], Tobias Wegener[1], Marcin Rasinski[1], Xiaoyue Tan[1,2], Janina Schmitz[1,3], Jesus Gonzalez-Julian[1], Jan Willem Coenen[1], Martin Bram[1], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich, Institut für Energie- und Klimaforschung, 52425 Jülich, Germany — [2]School of Materials Science and Engineering, Hefei University of Technology, Hefei, 23009, China — [3]Department of Applied Physics, Ghent University, 9000 Ghent, Belgium

In order to operate future fusion power plants reliably and safely, tungsten (W) is considered as a prime candidate as first wall armour material. However, in accidental conditions with a loss of coolant and air ingress, the nuclear decay heat will cause the radioactive W to oxidise and volatilise, imposing a severe hazard for the environment. Smart alloys aim at preserving the properties of W during plasma operation and suppressing the release of radioactive material in case of an accident. This goal is approached by alloying with chromium (Cr) and yttrium (Y). Bulk samples for full testing were consolidated by field assissted sintering technology. A relative density of 99 % is achieved. The accident is resembled by oxidation at 1273 K in air: the Cr diffuses to the surface forming a protective Cr_2O_3 layer and stopping WO_3 formation - after 44 h the layer has a thickness of 1.3 μm. This process is supported by the Y. After oxidation times of more than two days W-containing oxides form and a sublimation rate of 10^{-6} mg $cm^{-2}s^{-1}$ is measured. After three weeks the oxide layer has a thickness of 0.1 mm.

P 23.4 Thu 11:30 A 0.112

Extending *ab initio* plasma-surface simulations to experimentally relevant scales — •Michael Bonitz — Institut für Theoretische Physik und Astrophysik, CAU Kiel

Reliable and predictive plasma-surface modeling is crucial, both, for fundamental understanding and for many applications of low-temperature plasmas. The available approaches comprise phenomenological models of different complexity and quality as well as *ab initio* approaches that include density functional theory, quantum kinetic theory and molecular dynamics. While the former suffer from a lack of reliable input parameters, the latter often are reliable but extremely time consuming and are, therefore, typically, applicable only to very short times and/or system size. Here I present a general concept how the *ab initio* methods can be extended, both, in length and simulation time. The idea is to properly combine *ab initio* simulations with lower level models. I discuss how and when this can be done rigorously and present some examples.

P 23.5 Thu 11:45 A 0.112

Determination of the Cs distribution along a line of sight by the Zeeman splitting in an inhomogeneous magnetic field — •Christian Wimmer, Maria Lindauer, Ursel Fantz, and the NNBI Team — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

A Tunable Diode Laser Absorption Spectroscopy (TDLAS) is installed in a pulsed-driven (plasma pulses up to one hour) low-temperature, low-pressure hydrogen plasma, into which caesium is evaporated, for the determination of the neutral Cs density and its temperature. Permanent magnets are attached to the side walls creating an inhomogeneous magnetic field (field strength of 3–30 mT) along the chosen line of sight. The laser is tuned over the resonance transition of Cs at 852 nm in order to obtain the Doppler-broadened spectrum. A clear Zeeman-splitting appears at the high field strength, i.e. close to the side walls, whereas no significant splitting occurs at the lower B-field strength in the center. By analyzing the measured Zeeman-split spectra, it could be observed that neutral Cs is depleted in the central part of the line of sight during long plasma pulses, whereas the Cs density stays considerably high close to the side walls. Cs is used in this ion source for the surface-conversion of hydrogen atoms to negative ions, with the main conversion surface being located close to the center of the line of sight. With this new insight, the vanishing of the correlation of the Cs density with the performance of the ion source can be explained.

P 24: Laser Plasmas II

Time: Thursday 10:30–12:00 Location: KI 1.174

Invited Talk P 24.1 Thu 10:30 KI 1.174

Transient plasma photonic crystals as novel optical devices for high-intensity lasers — •Götz Lehmann and Karl-Heinz Spatschek — Institut für Theoretische Physik I, Heinrich-Heine Universität, 40225 Düsseldorf

The ponderomotive beat of counter-propagating laser pulses can lead to the formation of very strong plasma density modulations. These modulations are transient and can act as a plasma photonic crystal and may be used to manipulate high-intensity laser pulses. The damage threshold of these plasma structures is more than five orders of magnitudes larger than for conventional solid-state devices. Plasma photonic crystals have been proposed as highly reflective Bragg-type mirrors [1,2] for high-intensity lasers. Wide band-gaps make these mirrors suitable for ultra-short (20 fs) and intense laser (10^{17} W/cm^2) laser pulses. The periodic density modulations can also lead to birefringence and thus allow to use plasma as a phase-plate for high-intensity lasers [3]. The presentation will discuss the generation of plasma photonic crystals and their application as mirrors and phase-plates. Possible further future applications based on more complex plasma structures will be presented in the outlook.

[1] G. Lehmann and K.H. Spatschek, Phys. Rev. Lett. 116, 225002 (2016), [2] G. Lehmann and K.H. Spatschek, Phys. Plasmas 24, 056701 (2017), [3] P. Michel, L. Divol, D. Turnbull, and J.D. Moody, Phys. Rev. Lett. 113, 205001 (2014)

P 24.2 Thu 11:00 KI 1.174

Tailoring laser-generated plasmas for efficient nuclear excitation by electron capture — •Jonas Gunst, Yuanbin Wu, Christoph H. Keitel, and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

In the process of nuclear excitation by electron capture (NEEC), the energy gained when a free electron is recombining into a bound state of an ion is simultaneously transfered to the atomic nucleus which is thereby excited. Recently, we have shown that this process can play the leading role for nuclear excitation in cold, high-density plasmas created by an x-ray free-electron laser (XFEL), even higher than the direct photoexcitation channel using the XFEL beam on resonance [1,2]. However, the actual nuclear excitation rates are still small, strongly constrained by the attainable plasma conditions.

In contrast to XFELs, optical petawatt (PW) lasers generate hot plasmas. Here, we investigate how PW lasers can be exploited to generate plasma conditions where NEEC is maximized, employing a scaling-law model for low-density scenarios and PIC simulations for high electron densities [3]. Considering the case of ^{93}Mo isomer triggering, we find that a total increase of 6 orders of magnitude in the excitation can be achieved in comparison to the resonant-XFEL scenario.

[1] J. Gunst, Yu. A. Litvinov, C. H. Keitel, A. Pálffy, PRL **112**, 082501 (2014). [2] J. Gunst, Y. Wu, N. Kumar, C. H. Keitel, A. Pálffy, Phys. Plasmas **22**, 112706 (2015). [3] Y. Wu, J. Gunst, C. H. Keitel, A. Pálffy, arXiv:1708.04826 [physics.plasm-ph] (2017).

P 24.3 Thu 11:15 KI 1.174

Electron dynamics in twisted light modes of relativistic intensity — •Christoph Baumann and Alexander Pukhov — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

In the past two decades, twisted light beams have been extensively studied according to their unique properties. A Laguerre-Gaussian (LG) laser beam, for instance, describes such a twisted mode that can be obtained as a higher-order solution to the paraxial wave equation. In contrast to common lasers, these twisted beams are characterized by their well-defined orbital angular momentum. As a result, they can enable completely new insights into the dynamics of a physical system, thus leading to a wide range of applications in quantum information, spectroscopy, etc. It is therefore important to understand how particles behave in such a field configuration. Due to that the present work considers the interaction of an electron cloud with different circularly-polarized LG modes of relativistic intensity in the framework of numerical simulations. It is found that the electron dynamic is not only very sensitive to the LG mode parameters, but also to the helicity of the laser pulse.

P 24.4 Thu 11:30 KI 1.174

Ion wave breaking acceleration in laser-driven near-critical relativistically transparent plasma — •Bin Liu[1], Jürgen Meyer-ter-Vehn[2], and Hartmut Ruhl[1] — [1]Institute for Computational and Plasma Physics, Ludwig-Maximilian-Universität, München, 80333 München, Germany — [2]Max-Planck-Institut für Quantenoptik, D-85748 Garching, Germany

A major direction of effort in laser-driven plasma-based ion acceleration is to produce high-energy high-quality ion beams in a controllable and robust way. Here, with the help of theoretical analysis and simulations, we show that ion wave breaking acceleration is promising for this purpose. When propagating an ultra-intense ($> 10^{20}$W/cm^2) laser pulse in near-critical relativistically transparent plasma, a comoving cold ion wave is produced as a response to laser-driven charge-separation field. When driven strongly, the ion wave breaks, such that background ions are self-trapped and accelerated to high energy [1]. This regime has not been studied in sufficient detail, so far. The most interesting point is that the trapping process is self-regulating and self-stops when only a fraction of ions is trapped. The trapping dose can be controlled by external parameters such as laser intensity and target density. It allows to design ion pulses with low energy spread and beam emittance. Furthermore, when an ion wave breaks, a singularity of ion-fluid-Poisson equations appears. The singular behaviour in the vicinity of the wave breaking point is characterised by a set of power-law exponents, and makes the ion trapping process robust. Reference: [1] B. Liu, et.al., Phys. Rev. Accel. Beams 19, 073401 (2016).

P 24.5 Thu 11:45 KI 1.174

Ultra-high energy density physics in aligned nanowire arrays — •Vural Kaymak[1], Alexander Pukhov[1], Vyacheslav N. Shlyaptsev[2], and Jorge J. Rocca[2,3] — [1]Institut für Theoretische Physik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany — [2]Department of Electrical Computer Engineering, Colorado State University, Fort Collins, Colorado 80523, USA — [3]Department of Physics, Colorado State University, Fort Collins, Colorado 80513, USA

The creation of ultra-high energy density (UHED, $> 1 \cdot 10^8$J/cm^3) plasmas in compact laboratory setups enables studies of matter under extreme conditions and can be used for the efficient generation of intense x-ray and neutron pulses. An accessible way to achieve the UHED regime is the irradiation of vertically aligned high-aspect-ratio nanowire arrays with relativistic femtosecond laser pulses. These targets have shown to facilitate near total absorption of laser light several micrometers deep into near-solid-density material. We investigate the depth of the volumetric heating and a mechanism causing the wires to pinch, thereby delaying the hydrodynamic expansion and achieving extremely high energy and particle densities.

P 25: Annual General Meeting of the Plasma Physics Division

Time: Thursday 12:00–13:00 Location: A 0.112

Duration 60 min.

P 26: Magnetic Confinement II - Helmholtz Graduate School V

Time: Thursday 14:00–16:30 Location: A 0.112

P 26.1 Thu 14:00 A 0.112

Improved Measurements of Satellite Modes in 140 GHz Wendelstein 7-X Gyrotrons: An Approach towards an Electronic Stability Control — •Fabian Wilde[1,2], Torsten Stange[1], Hans Oosterbeek[1], Stefan Marsen[1], Heinrich Laqua[1], Konstantinos Avramidis[2], Ioannis Pagonakis[2], Stefan Illy[2], Manfred Thumm[2], Gerd Gantenbein[2], John Jelonnek[2], Robert Wolf[1], and W7-X Team[1] — [1]Max-Planck Institute of Plasmaphysics, Wendelsteinstraße 1, 17491 Greifswald, Germany — [2]Institute for Pulsed Power and Microwave Technology, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany

The stellarator Wendelstein 7-X (W7-X) uses electron cyclotron resonance heating (ECRH) by high-power microwave sources (gyrotrons). At the limit of operational stability, the stray radiation level in the gyrotron is increased due to excitation of parasitic and satellite modes, often resulting in a mode loss. The stray radiation by those modes is proposed as a mode-loss precursor. The hysteretic gyrotron behavior after a mode loss was investigated to demonstrate the feasibility of an automated mode recovery. The satellite modes around 137.3 GHz and 142.5 GHz were identified as possible mode-loss precursor candidates in shot spectrograms of the stray radiation at the gyrotron relief window. The activity of the latter was measured with a 142 GHz highpass filter and upto two RF detectors. In order to improve the signal stability, an overmoded setup was evaluated, using a satellite mode bandpass, realized as a dielectric disc filter in an overmoded waveguide and a resonator volume with upto five RF detectors.

P 26.2 Thu 14:25 A 0.112

Development of Heating Scenario to Reduce the Impact of Bootstrap Currents in Wendelstein 7-X — •Priyanjana Sinha, Hauke Hölbe, Joachim Geiger, Yuriy Turkin, and Thomas Sunn Pedersen — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Wendelstein 7-X is a low-shear stellarator with 10 modular island divertor units designed for particle and heat exhaust. For the proper working of the island divertor concept, the edge magnetic field topology has to have a certain resonant structure, so-called magnetic islands, at the boundary of the plasma .The bootstrap current (BSC), affects strongly the location of the edge islands thus changing their interaction with the divertor plates. Previous studies have predicted an overload problem due to the evolving BSC near the pumping gap of the divertor. A new plasma-facing component referred to as scraper element (SE) has been proposed to mitigate this overload problem. However, calculations predict a drop in pumping efficiency which may result in a degraded divertor performance. Therefore, to avoid the necessity of the SEs, alternative experimental scenarios are investigated where the critical range of BSC is reached and exceeded at reduced heating power levels. For this study, the numerical tools used are the Variational Moments Equilibrium Code (VMEC) and the EXTENDER-code to calculate the magneto-hydrodynamic equilibrium field produced by the plasma and the external coils in the entire vacuum chamber. The plasma currents are calculated self-consistently by iterating between various codes until changes are negligible.

P 26.3 Thu 14:50 A 0.112

Microwave beams in plasmas: numerical study of scattering and reflections in the semiclassical limit. — •Lorenzo Guidi[1,2], Omar Maj[1,2], Antti Snicker[1,3], Alf Köhn[1,4], Hannes Weber[1], Caroline Lasser[2], and Emanuele Poli[1] — [1]Max-Planck-Institut für Plasmaphysik, D-85748 Garching (DE) — [2]Technische Universität München, D-85748 Garching (DE) — [3]Institute of Interfacial Process Engineering and Plasma Technology, Univeristy of Stuttgart, D-70569 Stuttgart (DE) — [4]Department of Applied Physics, Aalto University, FI-00076 Aalto (FI)

Due to the large use of microwaves in nuclear fusion related experiments, fast and reliable numerical simulations of their behaviour are crucial to both understand present devices (e.g., ASDEX Upgrade) and guide the design of future ones (e.g., ITER). We will show how in the short-wavelength approximation (semiclassical limit) one can build rigorously such for the following two problems:

1. The problem of scattering induced by fluctuations of the plasma density can be formulated by means of the so called wave kinetic equation, whose solution provides the average effect of fluctuations on the beam. We designed a Monte-Carlo scheme for it, and implemented it in a code - WKBeam - which can simulate realistic ITER scenarios.

2. In the framework of reflectometry studies, the asymptotic methods routinely used in the fusion community generally fail to describe the beam in the neighborhood of turning points. We show how we can solve this issue by reconstructing the beam from an opportunely initialized wave packet.

P 26.4 Thu 15:15 A 0.112

ICRH heating and antenna performance in magnetically perturbed 3D tokamak plasmas — •Guillermo Suarez Lopez[1,2], Roman Ochoukov[1], Matthias Willensdorfer[1], Volodymyr Bobkov[1], Mike Dunne[1], Helmut Faugel[1], Helmut Funfgelder[1], Jean-Marie Noterdaeme[1,3], Erika Strumberger[1], Wolfgang Suttrop[1], Hartmut Zohm[1,2], ASDEX Upgrade team[1], and EUROfusion-MST1 Team[1] — [1]Max Planck Institute for Plasma physics, Garching b. Munchen, Germany — [2]Ludwig Maximillians University, Munich, Germany. — [3]University of Ghent, Ghent, Belgium

Ion Cyclotron resonant heating (ICRH) is an efficient process in which an antenna excites the fast magnetosonic acoustic wave in a magnetically confined plasma in order to increase the energy of the plasma ions via wave damping. The fast wave is, however, evanescent in low-density plasmas, such as the one in the edge region of a tokamak, where such an antenna is usually installed. This means that only a fraction of the total power sent to the antenna is coupled to the plasma wave. Analytically, the amount of power that can be coupled is very well understood for simple cases, such as a one-strap antenna radiating to a uniform plasma. More complex problems require the use of numerical computations. In this work, we study the coupling of the fast wave in an intrinsic 3D geometry, namely, a tokamak plasma with applied magnetic perturbations (MP). Both experimental data and numerical MHD simulations are presented. A relation between applied MP phasing, plasma 3D displacement, and ICRH coupling is found.

P 26.5 Thu 15:40 A 0.112

New insights into fast ion induced turbulence stabilization — •Alessandro Di Siena, Tobias Goerler, Hauke Doerk, Emanuele Poli, and Roberto Bilato — Max Planck Institute for Plasma Physics, Boltzmannstr.2, 85748 Garching, Germany

The beneficial effect of fast ions on plasma turbulence has been observed in several experimental discharges and in different tokamak devices, e.g. ASDEX Upgrade and JET. Such energetic particles, usually created by auxiliary heating systems such as external neutral beam injection (NBI) and ion cyclotron resonance heating (ICRH) may strongly suppress plasma turbulence, possibly increasing the performance of future fusion reactors. Although, these findings have been reproduced in numerical gyrokinetic simulations the physics of the significant fast ion stabilisation is still mostly unknown and usually highlighted as nonlinear electromagnetic stabilisation. In the contribution at hand, a wave-energetic particle resonance stabilising mechanisms is presented with both gyrokinetic GENE simulations and a reduced Vlasov-Poisson theoretical model. Key parameters controlling the role of the fast ions are identified and various ways of optimising their beneficial impact are explored. Experimental evidences of this effect are shown and ITER extrapolations are drawn.

P 26.6 Thu 16:05 A 0.112

Development and evaluation of a synthetic helium beam diagnostic for Wendelstein 7-X — •Wladimir Zholobenko[1], Michael Rack[1], Detlev Reiter[1], Motoshi Goto[2], Bettina Küppers[1], and Petra Börner[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Cluster (TEC), 52425 Jülich, Germany — [2]National Institute for Fusion Science, Toki 509-5292, Japan

Helium beam emission spectroscopy is an established diagnostic for the determination of temperature and density in the edge region of magnetically confined plasmas. It is also applied for the study of the divertor plasma at Wendelstein 7-X. However, its applicability in the whole possible parameter range and 3D geometry is still debated [1].

Our approach is to implement a synthetic diagnostic in the established 3D Monte Carlo transport code EMC3-EIRENE to study the propagation of the helium beam into a divertor plasma and its emission. The first step was to upgrade the He collisional-radiative model in EIRENE with the more recent one from M. Goto [2], which contains an internationally evaluated data set. Numerical investigation shows the importance of the often neglected higher excited states.

The extended diagnostic module enables simulation of HeI emission patterns in complex geometries in a few seconds computing time. Detailed evaluation of given (simplified) atomic models allows improvement of the diagnostic for the experiment and parameters of interest.

[1] M. Krychowiak et al., Plasma Phys. Control. Fusion 53, 035019 (2011)
[2] M. Goto, J. Quant. Spectrosc. Radiat. Transfer 76, 331-344 (2003)

P 27: Complex Plasmas and Dusty Plasmas II

Time: Thursday 14:00–15:55 Location: KI 1.174

Fachvortrag P 27.1 Thu 14:00 KI 1.174

Self-diffusion in single-component Yukawa fluids — •Sergey Khrapak[1,2], Boris Klumov[1,3], and Lenaic Couedel[1] — [1]Aix Marseille University, CNRS, Laboratoire PIIM, Marseille, France — [2]Institut fuer Materialphysik im Weltraum, Deutsches Zentrum fuer Luft- und Raumfahrt (DLR), Wessling, Germany — [3]Joint Institute for High Temperatures, Russian Academy of Sciences, Moscow, Russia

It was suggested in the literature that the self-diffusion coefficient of simple dense fluids can be approximated as a ratio of the squared thermal velocity of the atoms to the "fluid Einstein frequency." We have tested this suggestion using a single-component Yukawa fluid as a reference system. Yukawa fluid is particularly suitable for such a test, because the Einstein frequency is trivially related to the important thermodynamics property, excess internal energy, relatively well known in a wide parameter regime. The available simulation data on self-diffusion in Yukawa fluids, complemented with new data for Yukawa melts, are carefully analyzed. It is shown that although not exact, this earlier suggestion nevertheless provides a very sensible way of normalization of the self-diffusion constant. Additionally, we demonstrate that certain quantitative properties of self-diffusion in Yukawa melts are also shared by systems like one-component plasma and liquid metals at freezing. The observations are briefly discussed in the context of the theory of momentum transfer in complex (dusty) plasmas.

P 27.2 Thu 14:25 KI 1.174

Plasma dynamics around a dust cluster embedded in the sheath of a rf discharge — Jens Schleede, Lars Lewerentz, •Franz Xaver Bronold, Ralf Schneider, and Holger Fehske — Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, 17489 Greifswald, Germany

We employ a PIC-MCC/PPPM simulation to investigate the plasma dynamics around a three-dimensional dust cluster of 44 particles embedded in the sheath of an argon rf discharge. Our approach tracks self-consistently the charge of the particles and the plasma flow towards and through them. The geometry of the cluster, its position in the sheath, both assumed to be fixed, and the plasma parameters are essentially identical to the experimental setups for investigating dust clouds in plasmas. We find strong shadowing and focusing effects leading to a broad distribution of the charges accumulated by the grains suggesting that theoretical models studying dynamical effects of the cluster which assume identical charges and reciprocal forces between the grains may have to be modified to be also applicable to dust arrangements trapped in the sheath of a rf discharge. From the time-resolved electron fluxes, visualized by tracer particles, we moreover identify density fronts and convection patters driven by the repulsion between the incoming electrons and the electrons collected by the particles. As expected the electron flux is neither isotropic nor laminar. Charging models developed for an isolated particle are thus also not applicable to an arrangement of grains trapped in the sheath of a rf discharge. – Supported by DFG through CRC/Transregio TRR24.

P 27.3 Thu 14:40 KI 1.174

Measuring the full Stokes vector of scattered light for in situ kinetic Mie ellipsometry via division of aperture. — •Andreas Petersen, Franko Greiner, and Sebastian Groth — Institute of Experimental and Applied Physics, Kiel University, Germany

Nanodusty plasmas are of interest to basic plasma physics as well as to plasma technology. The confinement provided by the discharge and the interparticle forces are the major factors which determine particle density. To investigate the plasma, size and spatial distribution of the particles are needed. We present a new setup featuring a division of aperture camera in combination with a liquid crystal retarder. This allows us to measure the four Stokes parameters of laser light scattered by the probed nanoparticles. This method builds upon and expands Imaging Mie [1]. It uses a kinetic approach [2] to allow in situ measurement of particle radii.

[1] F. Greiner et al., Plasma Sources Sci. Technol. 21, 065005 (2012)
[2] S. Groth et al., J. Phys. D: Appl. Phys. 48, 465203 (2015)

P 27.4 Thu 14:55 KI 1.174

Particle size estimation of optical thick nanoparticle clouds — •Franko Greiner[1], Nils Rehbehn[1], Florian Kirchschlager[2], and Sebastian Wolf[3] — [1]Institute of Experimental and Applied Physics, Kiel University — [2]Department of Physics and Astronomy, UCL London — [3]Institute of Theoretical Physics and Astrophysics, Kiel University

Up till now the basic physics of nanodusty plasmas is only little examined. Such plasmas have a very high dust density and therefore a high degree of electron depletion, i.e. the Havnes parameter is high compared to unity. The density and size of the nanoparticles are the key parameters for the understanding of the nanodusty plasma. In the interesting regime of high particle size and/or density, the nanodusty plasma becomes optical thick and standard Mie ellipsometry, which relies on single scattering, fails. Recently we have presented a method to include multiple scattering into Mie ellipsometry. We used 3D Monte-Carlo polarized radiative transfer simulations which allow us to calculate the characteristics of light scattered by the nanoparticle cloud with arbitrary optical depth [1]. Including the spatio-temporal development of the experimental density profile into the simulation enables us to estimate the particle radius for high optical depths.

[1] F. Kirchschlager et al., Appl. Phys. Lett. **110**, (2017)

P 27.5 Thu 15:10 KI 1.174

A second look at void closure in complex plasmas — •Erich Zaehringer, Igor Semenov, Christina A. Knapek, Milenko Rubin-Zuzic, Daniel P. Mohr, Peter Huber, and Hubertus Thomas — DLR German Aerospace Center, Institute of Materials Physics in Space

Complex Plasmas are small micrometer sized particles injected into a low temperature rf-plasma. The particles are getting charged by electron and ion fluxes and form systems with gaseous, liquid and solid properties. Normally complex plasmas are compressed to 2D systems in laboratory conditions while they form a 3D cloud in micro-gravity with a particle free region in the center which is called void. The void can be suppressed by gas flow or additional electric fields, however, both ways add stress to the system. Another way is the reduction of rf-power, which was successfully used on the ISS before. The comparison of simulations and emission patterns reveal a lot of open questions, which were targeted by experiments of the 29. DLR parabolic flight campaign. The absence of a void in 1D self-consistent simulations indicates that the void is caused by 2D effects or more difficult geometries. In the experiments we could close and reopen the void by decreasing and increasing the rf-power. Other effects, such as particle mixtures in the former void region and dust density waves across the particle cloud, were observed.

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

P 27.6 Thu 15:25 KI 1.174

Two dimensional dust density wave diagnostics (DDW-D) of nanoparticles in an argon radio frequency discharge — •Oguz Han Asnaz, Benjamin Tadsen, Franko Greiner, and Alexander Piel — Institute of Experimental and Applied Physics, Kiel University, Germany

The wavevector and wave frequency of self-excited dust density waves (DDW) in a nanodusty plasma can be used as a tool for plasma diagnostics, giving spatially resolved information about ion and electron densities, dust charge and the plasma potential. The presented approach expands upon the analysis presented in Ref. 1 and examines the complete two-dimensional cross-section of the wave field. This approach will be used to investigate changes in the nanodusty plasma parameters, when the reactive gas for growing nanoparticles is changed from acetylene to silane. Comparing the resulting wave fields for a-C:H and a-Si:H particles provides insight into the influence of the particle surface properties on the plasma parameters.

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

P 27.7 Thu 15:40 KI 1.174

Pulsed rf-Discharge in Zyflex-Chamber — •Peter Huber[1], Christina A. Knapek[1], Daniel P. Mohr[1], Erich Zaehringer[1], Andrey M. Lipaev[2], Vladimir I. Molotkov[2], Hubertus M. Thomas[1], and Vladimir E. Fortov[2] — [1]DLR, Institut für Materialphysik im Weltraum, Weßling, Deutschland — [2]Joint Institute for High Temperatures, Moscow, Russia

Interrupting rf-discharge is a well known method to control processes in plasmas. For example, in semiconductor processing it can be used to control growth of particles from material out of the plasma phase. By switching off the discharge, "fog" of grown particles can be driven out of the plasma by gravity. On the other hand, pulsing the plasma gives a good possibility to tune effective electron temperature independently from plasma density. So you could tune interactions in complex plasma systems in a more flexible way.

Ekoplasma will provide Plasmalab, the future lab for complex plasma research on the international space station ISS. Together with its large cylindrical chamber Zyflex it will have many features to cover a wide range of physics in complex plasma research. It also includes a multifunctional rf-generator which can be pulsed at different frequencies with on/off times even less than 50 μs. Combining the feature of switching the discharge on and off with micro gravity conditions it will be possible to tune plasma parameters without losing particles due to gravitational forces.

In this contribution, we will show first results of particles levitated in a pulsed gas discharge in the current lab setup of Ekoplasma.