Fachverband Plasmaphysik (P)

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Übersicht der Hauptvorträge und Fachsitzungen

(H20 und H21; Poster Foyer Nordbau)

Hauptvorträge

P 2.1	Mo	11:15–11:45	HS 20	**Diagnostics of nanodusty plasmas** — •Franko Greiner, the SFB-TR24 Team
P 3.1	Mo	11:15–11:45	HS 21	**Plasma-based surface modification for life-science applications** — •Katja Fricke, Klaus-Dieter Weltmann
P 4.1	Mo	14:00–14:30	HS 20	**Characterisation of Dielectric Barrier Discharges for analytical applications** — •Joachim Franzke, Alexander Schütz, Sebastian Brandt, David Klute, Sebastian Burhenn, Pascal Vogel
P 5.1	Mo	14:00–14:30	HS 21	**On plasma-surface model coupling realized through machine learning** — •Jan Trieschmann, Florian Krüger, Tobias Gergs, Thomas Mussenbrock
P 6.1	Mo	16:30–17:00	HS 20	**Plasmas in leading-edge semiconductor device fabrication: Importance and analysis** — •Sven Zimmermann, Micha Haase, Norbert Lang, Henrik Zimmermann, Jürgen Röpcke, Stefan Schulz, Thomas Otto
P 7.1	Mo	16:30–17:00	HS 21	**3-D physics of the tokamak edge** — •Matthias Willensdorfer, Tyler Cote, Michael Griener, David Ryan, Erika Strumberger, Wolfgang Suttrop, Nengchao Wang, Dominik Brida, Marco Cavedon, Severin Denk, Mike Dunne, Rainer Fischer, Christopher Ham, Chris Hegna, Matthias Hoelzl, Andrew Kirk, Nils Leuthold, Marc Maraschek, Hartmut Zohm, The ASDEX Upgrade Team
P 9.1	Di	11:00–11:30	HS 21	**Laser diagnostics of plasmas using fs- and ps-lasers** — •Stephan Reuter
P 10.1	Di	14:00–14:30	HS 20	**HiBEF: New vistas into high-field and laser-plasma science** — •Toma Toncian
P 11.1	Di	14:00–14:30	HS 21	**Electrical and optical characterisation of pulsed, single-filament dielectric barrier discharges on a water surface** — •Hans Höft, Manfred Kettlitz, Ronny Brandenburg
P 12.1	Di	16:30–17:00	HS 20	**Hydrogen permeation and retention in ITER steel** — •Anne Houben, Jana Scheuer, Arkadi Kreter, Marcin Rasiński, Bernhard Unterberg, Christian Linsmeier
P 14.1	Mi	11:00–11:30	HS 20	**Plasmas and the tailoring of nanomaterials** — •Uros Cvelbar
P 15.1	Mi	11:00–11:30	HS 21	**Turbulence in the Wendelstein 7-X Stellarator** — •Adrian von Stechow
P 15.2	Mi	11:30–12:00	HS 21	**Reduction of microwave beam quality due to plasma density fluctuations** — •Alf Köhn, Pavel Aleynikov, Lorenzo Guidi, Eberhard Holzhauer, Omar Maj, Emanuele Poli, Michael Brookman, Antti Snicker, Thomas Matthew, Roddy Vann, Hannes Weber
P 17.1	Do	14:00–14:30	HS 21	**Impurity Transport Investigations at the Wendelstein 7-X Stellarator** — •Rainer Burhenn, W7-X Team

P 17.2	Do	14:30–15:00	HS 21	**The role of the radial electric field in the edge of fusion plasmas** — •Marco Cavedon, Gregor Birkenmeier, Ralph Dux, Tim Happel, Ulrike Plank, Thomas Pütterich, Francois Ryter, Ulrich Stroth, Eleonora Viezzer, Matthias Willensdorfer, Elisabeth Wolfrum, The Asdex Upgrade Team

Hauptvorträge des fachübergreifenden Symposiums SYPA

Das vollständige Programm dieses Symposiums ist unter SYPA aufgeführt.

SYPA 1.1	Mi	14:00–14:30	Plenarsaal	**Laser-driven ion acceleration in plasmas** — •Jörg Schreiber
SYPA 1.2	Mi	14:30–15:00	Plenarsaal	**Laser-driven electron acceleration in plasmas** — •Jeroen van Tilborg
SYPA 1.3	Mi	15:00–15:30	Plenarsaal	**Beam-driven electron acceleration in plasmas** — •Richard D'Arcy
SYPA 1.4	Mi	15:30–16:00	Plenarsaal	**Solar energetic electron events: Trying to understand the role of the shock** — •Nina Dresing, Max Bruedern, Raúl Gómez-Herrero, Bernd Heber, Andreas Klassen, Manuela Temmer, Solveig Theesen, Astrid Veronig
SYPA 2.1	Mi	16:30–17:00	Plenarsaal	**Plasma Wakefield Acceleration: Instabilities and Stabilization** — •Alexander Pukhov
SYPA 2.2	Mi	17:00–17:30	Plenarsaal	**LUX - A Laser-Plasma Driven Undulator Beamline** — •Andreas R. Maier
SYPA 2.3	Mi	17:30–18:00	Plenarsaal	**Magnetic reconnection as a particle accelerator** — •Michael Hesse
SYPA 2.4	Mi	18:00–18:30	Plenarsaal	**Experimental demonstration of proton bunch self-modulation and of electron acceleration in a 10m-long plasma** — •Patric Muggli

Hauptvorträge des fachübergreifenden Symposiums SYPP

Das vollständige Programm dieses Symposiums ist unter SYPP aufgeführt.

SYPP 1.2	Do	11:15–11:45	HS 3	**30 years of Pulsed Power in medical Excimer laser** — •Claus Strowitzki
SYPP 1.3	Do	11:45–12:15	HS 3	**Frontiers of Electroporation, from Mechanisms to Applications: Unraveling new key molecular level aspects using computational chemistry** — •Mounir Tarek
SYPP 1.4	Do	12:15–12:45	HS 3	**Calcium electroporation - a novel, low-cost anti-cancer treatment** — •Stine Krog Frandsen, Julie Gehl
SYPP 2.1	Do	14:00–14:30	HS 3	**Pulsed Electric Fields for the Manipulation of Cancer Cells** — Anna Steuer, Fukun Shi, Christina M. Wolff, •Juergen F. Kolb
SYPP 2.2	Do	14:30–15:00	HS 3	**Pulsed electric field use in food industry - process and equipment design** — Robin Ostermeier, Julian Witt, •Stefan Töpfl
SYPP 2.3	Do	15:00–15:30	HS 3	**Pulse Generators for a Scale-Up of an Electroporation Device for Mash** — •Martin Sack, Martin Kern, Hermann Armbruster, Johannes Fleig, Dennis Herzog, Martin Hochberg, Georg Mueller
SYPP 2.4	Do	15:30–16:00	HS 3	**Spark discharges as tool for the extraction of microalgal compounds** — •Katja Zocher, Raphael Rataj, Anna Steuer, Juergen F Kolb

Fachsitzungen

P 1.1–1.2	So	16:00–18:00	HS 3	**Tutorial Plasma Physics (joint session AKjDPG/P)**
P 2.1–2.5	Mo	11:15–12:45	HS 20	**Complex and Dusty Plasmas I**
P 3.1–3.5	Mo	11:15–12:45	HS 21	**Plasma Surface Interaction I**
P 4.1–4.6	Mo	14:00–15:45	HS 20	**Atmospheric Pressure Plasmas I**
P 5.1–5.5	Mo	14:00–16:10	HS 21	**Helmholtz Graduate School I**
P 6.1–6.7	Mo	16:30–18:30	HS 20	**Low Pressure Plasmas I**
P 7.1–7.5	Mo	16:30–18:30	HS 21	**Helmholtz Graduate School II - Magnetic Confinement I**
P 8.1–8.6	Di	11:00–12:30	HS 20	**Laser Plasmas I - Codes and Modelling I**
P 9.1–9.5	Di	11:00–12:40	HS 21	**Atmospheric Pressure Plasmas II - Helmholtz Graduate School III**
P 10.1–10.5	Di	14:00–15:30	HS 20	**Laser Plasmas II**
P 11.1–11.5	Di	14:00–15:30	HS 21	**Atmospheric Pressure Plasmas III**

P 12.1–12.6	Di	16:30–18:35	HS 20	**Plasma Surface Interaction II - Helmholtz Graduate School IV**
P 13	Di	18:45–20:00	HS 20	**Mitgliederversammlung / General meeting of members**
P 14.1–14.5	Mi	11:00–12:40	HS 20	**Complex and Dusty Plasmas II**
P 15.1–15.5	Mi	11:00–13:05	HS 21	**Helmholtz Graduate School V - Magnetic Confinement II**
P 16.1–16.5	Do	11:00–12:25	HS 21	**Low Pressure Plasmas II**
P 17.1–17.5	Do	14:00–16:15	HS 21	**Helmholtz Graduate School VI**
P 18.1–18.127	Do	16:30–18:30	Foyer Nordbau	**Postersitzung**

Mitgliederversammlung Fachverband Plasmaphysik

Dienstag 18:45–20:00 HS 20

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

Zeit: Sonntag 16:00–18:00 Raum: HS 3

Tutorium P 1.1 So 16:00 HS 3

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

Plasmas at atmospheric pressures are known from lightnings, but are also of great industrial importance. Technically they can be operated in many different electrode geometries, discharge regimes, and, with a great variety of their basic plasma parameters. In particular nonthermal as well as thermal plasmas exists at elevated pressures. While thermal plasmas are used for material processing (e.g. welding and spraying) and chemical conversion, non-thermal plasmas have been intensively studied in the context of surface treatment, environmental remediation, ozone generation, flow control, analytics, light sources and life-science applications. The first part of the tutorial will give an overview about the classification and application of plasmas at atmospheric pressure.

The research on atmospheric pressure non-equilibrium plasmas intensified over the last two decades leading to a large variety of plasma sources. Although the fundamental understanding of these discharges is emerging, there are still numerous unexplained phenomena in these complex plasmas. The properties of these plasmas span over a huge range of electron densities as well as heavy particle and electron temperatures. The second part of the tutorial will provide an overview of the key processes for its generation and stabilization as well as for their unique physical and chemical properties.

Tutorium P 1.2 So 17:00 HS 3

Introduction to High Temperature Plasma Physics — •Felix Warmer — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491, Greifswald

This introductory lecture explores the physics properties of the fourth fundamental state of matter: the plasma, i.e. the most common state of baryonic matter of the visible universe. Plasmas offer a plethora of interesting physics such as collective behaviour and long-range collisions owing to the Coulomb nature of the interaction. Of specific interest are high temperature plasmas as found in space as well as their artificial counterpart on earth for application to magnetic confinement fusion. High temperature plasmas, like in fusion devices, are also often magnetised adding a wealth of additional interesting effects – a considerable fraction of which is highly non-linear affecting plasma transport properties by more than an order of magnitude. In particular, plasma turbulence is a fascinating subject challenging our intellectual faculties and fascination. Based on these examples, this lecture will provide an introduction to the topic of high temperature plasma physics suited for students and physicists from other fields.

P 2: Complex and Dusty Plasmas I

Zeit: Montag 11:15–12:45 Raum: HS 20

Hauptvortrag P 2.1 Mo 11:15 HS 20

Diagnostics of nanodusty plasmas — •Franko Greiner and the SFB-TR24 Team — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel

In plasma technology reactive nanodusty plasmas are widely used. In contrast the basic physics of nanodusty plasmas is only little examined. Nanodusty plasmas can have a very high nanoparticle density and therefore a high degree of electron depletion, i.e., the Havnes parameter is high compared to unity. The diagnostic of nanodusty argon plasmas consisting of ions, electrons and nanoparticles is challenging. When it comes to reactive plasmas, the plasma chemistry plays a major rule and the diagnostic of the multi component plasma is even more challenging. Standard diagnostics like Langmuir probes disturb the plasma and coating of the probe obscures the I(U) characteristic. Optical emission spectroscopy and laser spectroscopy are difficult due to the light scattered or absorbed by the nanoparticles, especially under optical thick conditions.
During the last years we have developed new methods like I-Mie and DDW-D for the diagnostic of nanoparticles and nanodusty plasmas [1]. This talk presents an overview of the available methods and the new insight they give.

[1] F. Greiner et al, Eur. Phys. J. D (2018) 72: **81**
https://doi.org/10.1140/epjd/e2017-80400-7

P 2.2 Mo 11:45 HS 20

Experiments on Surface Floating Potential of Spherical Object in the Magnetized RF Discharge Plasma — •Mangilal Choudhary, M. H. Thoma, R. Bergert, and S. Mitic — I. Physikalisches Institut, Justus-Liebig Universität Gießen

The floating potential of magnetic and non-magnetic spherical probes, which can be used as model of a dust grain, immersed in the magnetized RF discharge plasma are experimentally measured. The discharge is ignited between a transparent indium tin coated (TIO) glass electrode and a metal electrode after applying the 13.56 MHz RF signal. A strong superconducting electromagnet (0 to 4 T) with Helmholtz coils configuration is used to magnetize the plasma spices in the discharge column. The size of spherical probes (r) are taken either in the range or greater than the electron Debye length (λ_{De}). To get the floating surface potential, plasma potential is measured using the emissive probe for the given discharge conditions at which the floating potential of spherical objects or probes is measured. The surface potential of spherical probe first increases (or more negative) at lower magnetic field, attains maximum value at some B-field value and after that it starts to decrease with increasing the magnetic field. The floating surface potential of magnetic spherical probe in plasma is observed to be higher (more negative) than the non-magnetic spherical probe in the presence of magnetic field. The variation of floating potential or negative charges on the spherical probes is understood on the basis of modification of collection currents to the spherical object due to the cross field diffusion in the presence of external magnetic field.

P 2.3 Mo 12:00 HS 20

In-situ Measurements of the Temperature Gradient in Complex Plasmas — •Aleksandr Pikalev, Mikhail Pustylnik, Christoph Räth, and Hubertus Thomas — DLR, Institut für Materialphysik im Weltraum, Gruppe Komplexe Plasmen, Münchener Str. 20, 82234 Weßling

Complex or dusty plasma is a medium containing ionized gas and micron-sized solid particles. The microparticles are sensitive to the thermophoretic force. Thermophoresis is often a disturbing factor in microgravity complex plasma experiments or a way to control the microparticle suspensions. In spite of that, no attempts to measure the temperature gradient in-situ in complex plasma are known in the literature. We present such measurements performed in Ar rf discharge used for complex plasma experiments with the help of laser spectroscopy.

The experiments were performed in the PK-3 Plus chamber, where we could control the axial temperature gradient up to 5 K/cm by heating the bottom electrode. We used tunable diode laser absorption spectroscopy (TDLAS) and laser induced fluorescence (LIF) for the temperature measurement from Doppler profiles. In the case of TDLAS, two parallel laser beams passed through the discharge with a height difference of 1.5 cm. They allowed us to measure line-integrated temperatures at those two positions. The temperature differences could be measured with accuracy better than 0.5 K. The fluorescence was observed with a video camera through a narrow bandpass filter in a direction, perpendicular to the laser beam, hence the temperature could be determined locally in both axial and radial directions.

P 2.4 Mo 12:15 HS 20

Size, density and charge analysis of Al_2O_3 nanoparticles in argon discharges — •Harald Krüger and André Melzer — Institute of Physics, University of Greifswald

Dusty plasmas with nanoparticles have attracted increased attention in the last few years. Beside the existing experimental setups with nanoparticles grown in the rf discharge, we present the insertion of industrial, nanoscaled Al_2O_3 dust with a gas jet injection setup.

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

Furthermore, theoretical calculations have shown a charge dependent shift in the infrared spectral range of the particles. Existing experiments have already given a proof of concept, but did not show a charge variation due to a low resolution of the FTIR spectrometer yet. Therefore, new experiments with a higher resolution have been carried out and first results will be presented.

P 2.5 Mo 12:30 HS 20

High precision size measurement of microparticles during plasma operation — •Niklas Kohlmann, Frank Wieben, Oguz-Han Asnaz, Franko Greiner, and Dietmar Block — Kiel University, 24098 Kiel, Germany

Besides structural and dynamic processes in complex plasmas, the particles themselves are recently more and more in the focus of research. Important parameters are the particle size, shape and surface topology. However, non-invasive in-situ methods to determine the named parameters during plasma operation are missing. Angle-resolved Mie scattering measurements can fill this gap and provide particle sizes with high precision. An out-of-focus imaging technique similar to Interferometric Laser Imaging for Droplet Sizing (ILIDS) is used to obtain the angle-dependent scattering intensities. Correlating the measured data to those provided by the Lorenz-Mie theory for spherical objects, particle size and refractive index can be obtained. It is shown that the method allows to measure the particle size with an accuracy of a few nanometers if the polarization state of the laser light is taken into account. 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.

P 3: Plasma Surface Interaction I

Zeit: Montag 11:15–12:45 Raum: HS 21

Hauptvortrag P 3.1 Mo 11:15 HS 21

Plasma-based surface modification for life-science applications — •Katja Fricke and Klaus-Dieter Weltmann — Leibniz Institute for Plasma Science and Technology e.V. (INP), Felix-Hausdorff-Strasse 2, 17489 Greifswald, Germany

Materials with tailored chemical and morphological properties provide an indispensable platform to induce a certain response when exposed to biological systems. Hence, bioactive surfaces are of growing interest for a vast number of applications such as biochips, biosensors, drug delivery systems, implants and tissue engineering. Plasma enhanced surface modifications are the key applications for plasma technology since decades. Due to the fact that these processes are environment-friendly, highly reproducible, and most importantly, enable changes in surface properties for nearly every material. Furthermore, the high flexibility in terms of geometry and electrode configuration, process gases and operation parameters, qualify both, low-pressure and atmospheric-pressure plasma sources especially for surface engineering. This contribution reports on the plasma-based surface modification to improve the attachment of bioactive compounds and living cells. Recent innovations in the functionalization of surfaces and the deposition of high-quality functional thin films by using atmospheric-pressure plasma processes are presented.

P 3.2 Mo 11:45 HS 21

Development of a 3D model for hydrogen outgassing from ion-irradiated materials — •Md Al-Beruni, Dmitry Matveev, Bernhard Unterberg, and Christian Linsmeier — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung, 52425 Jülich, Germany

In future fusion reactors such as ITER and DEMO, plasma-material interactions impose limitations on the plasma performance. High heat and particle loads, implantation of hydrogen isotopes cause deterioration of material properties and build-up of radioactive tritium in the plasma-facing wall components, which represents a safety concern. Together with dedicated experiments, computational modeling is utilized to understand the fundamental processes of hydrogen transport and retention. Trapping and de-trapping of hydrogen from lattice defects of materials, hydrogen diffusion, as well as recombination of hydrogen atoms to molecules leading to molecular desorption can be modeled by systems of coupled non-linear PDEs. So far, those non-linear PDE systems have been successfully solved numerically in 1D. However, in some cases, non-uniform distributions of the ion flux, material properties, temperature, as well as other geometrical effects require a consistent 3D description. In this contribution, examples of 3D simulations implemented in Wolfram Mathematica and COMSOL Multiphysics will be presented and compared with respective 1D simulations.

P 3.3 Mo 12:00 HS 21

Light reflection in the line shape of sputtered atoms of high-Z plasma facing components in the linear plasma device PSI-2 — •Stephan Ertmer, Oleksandr Marchuk, Sven Dickheuer, Arkadi Kreter, and Sebastijan Brezinsek — Forschungszentrum Jülich GmbH - Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany

Linear plasma devices like PSI-2 are useful tools to study plasmas-wall-interaction and test possible plasma facing materials. Spectroscopy is a powerful means to determine the particles fluxes, e.g. by S/XB values at the plasma edge. In the last decades enormous efforts are undertaken to improve the understand the underlying physics as well as experimental conditions. It is demonstrated in argon plasmas ($T_e \approx 3\,eV, n_e \approx 3.5 \cdot 10^{12}\,cm^{-3}, E_{ion} = 40 - 160\,eV$) that the light reflection at aluminum and tungsten surfaces has a strong impact on the line intensities and the line shapes of sputtered particles. Thus for instance the emission is increased by a factor two for line-of-sights terminating at surfaces. Moreover, the degradation of the optical properties of surfaces polished aluminum was detected in the line shape of emission by sputtered particles. The experiments are performed in PSI-2 plasmas, where other bordering mechanisms such as the Zeeman effect can be neglected because of a magnetic field in the order of 0.1 T. The clear difference between spectra observed at different lines-of-sight is detected. The studied effect must included in evaluating the S/XB values and existing codes such as ERO.

P 3.4 Mo 12:15 HS 21

Towards an understanding of the force low-temperature plasmas exert on walls — •Thomas Trottenberg and Holger Kersten — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, D-24098 Kiel

Low-temperature plasmas exert tiny forces ($\mu N\,cm^{-2}$) on their solid bondaries. Recent force measurements, where small test surfaces were brought in contact with a plasma, have shown that the “plasma pressure” is in the order of magnitude of the electron pressure [1,2]. However, the measured forces range from significantly smaller forces up to a few times the electron pressure force. So far, only qualitative descriptions of the underlying mechanisms for this behavior could be presented [1,2]. A one-dimensional fluid model (including spherically symmetric geometry) was applied in a general treatment of the problem, and it was concluded that the pressure at the wall should equal the electron pressure in the center of the discharge [3]. However, the found systematic deviations remained unexplained. In this study, we provide a short summary of the experiments performed in Kiel so far with force measurements in capacitively-coupled radio-frequency discharges and microwave-generated plasmas, and we report on our latest attempts to understand the observed features of the force.

[1] Trottenberg, Richter, and Kersten, *Eur. Phys. J. D* **69**, 91 (2015).
[2] Trottenberg and Kersten, *Plasma Sources Sci. Technol.* **26**, 055011 (2017).
[3] Czarnetzki and Tsankov, *Eur. Phys. J. D* **69**, 236 (2015).

P 3.5 Mo 12:30 HS 21

Decoupling of ion- and photon-activation mechanisms in polymer surfaces exposed to low-temperature plasmas —

•Rahel Buschhaus[1], Maik Budde[1], Carles Corbella[2], and Achim von Keudell[1] — [1]Experimentalphysik II, Ruhr-Universität Bochum — [2]Department of Mechanical and Aerospace Engineering, The George Washington University, Washington, USA

The treatment of polymers by plasmas and ion beams is a common technique to optimize surface properties e.g. regarding roughness. The impact of plasma components, namely ions, neutrals, electrons and photons, were analyzed separately to investigate synergistic effects. The elementary processes on surfaces are mimicked by sending quantified beams of ions and atoms to the polymers in an ultra-high vacuum reactor. Polypropylene (PP) and Polyethylene (PET)[1] layers, are exposed to argon ions (200eV, 500eV), which are extracted from an electron-cyclotron-resonance (ECR) plasma source. This ion beam is separated from the photons (UV and VUV) generated in the plasma volume by an ion beam deflector. Fourier transformed infrared spectroscopy (FTIR) is applied in situ for analyzing etching rate and chemical state of the surfaces. Etching measurements are performed with either Ar^+ or Ar^+ plus photons by removing the ion beam deflector. With a surface coverage model, we will describe the time dependency of etched thickness, calculate sputter yields and discuss the ion-and photon activation mechanisms. Additionally, reactive sputtering is mimicked by adding neutral oxygen beams to the Ar measurements. [1]M. Budde et al., Plasma Process Polym, 15(4):1700230(2018)

P 4: Atmospheric Pressure Plasmas I

Zeit: Montag 14:00–15:45 Raum: HS 20

Hauptvortrag P 4.1 Mo 14:00 HS 20

Characterisation of Dielectric Barrier Discharges for analytical applications — •Joachim Franzke, Alexander Schütz, Sebastian Brandt, David Klute, Sebastian Burhenn, and Pascal Vogel — ISAS - Leibniz-Institut für Analytische Wissenschaften - ISAS - e.V., Bunsen-Kirchhoff-Str. 11, 44139 Dortmund, Germany

Two decades ago the potential of dielectric barrier discharge plasma was presented for use in analytical element spectrometry [1]. It was a miniature planar DBD, characterized by small size, low power consumption, low gas temperature and excellent dissociation capability for molecular species. Several years later a capillary shaped DBD was presented by Na et al. [2] applied as an efficient method for molecular mass spectrometry resulting in the development of a variety of methods now commonly termed Ambient Mass Spectrometry (AMS), which experienced a very rapid development during the last years. Here themes will be presented and tried to be characterized where dielectric barriers were used in the field of Analytical Chemistry like diode laser spectrometry at low pressure DBDs [1], DBD as soft ionization source at ambient air[3,4].

[1]*M. Miclea, K. Kunze, G. Musa, J. Franzke, K. Niemax, Spectrochim Acta Part B At Spectrosc, 56 (2001) 37. [2]*N. Na, C. Zhang, M.X. Zhao, S.C. Zhang, C.D. Yang, X. Fang, X.R. Zhang, J. Mass Spectrom., 42 (2007) 1079. [3] S. Brandt, FD. Klute, A. Schütz, J. Franzke, Analytica Chimica Acta, 951 (2017)16. [4]*FD. Klute, A. Schütz, S. Brandt, S. Burhenn, P. Vogel, J. Franzke, J.Phys.D.: Appl.Phys.51 (2018) 341003.

P 4.2 Mo 14:30 HS 20

Analyzing plasma-chemical processes in RF-excited atmospheric pressure plasmas using vacuum ultra-violet and visible optical emission spectroscopy — •Judith Golda, Fenja Severing, Carmelo Setaro, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Germany

Non-thermal atmospheric pressure plasma jet devices effectively generate reactive species at low gas temperature such as atomic oxygen or nitric oxide. Hence, they are commonly used for surface modification and biomedical applications. To tailor species densities, detailed knowledge and profound understanding of the plasma-chemical processes is crucial. However, due to their small dimensions, diagnostic techniques are limited.

Here, we present optical emission spectroscopy measurements of an RF-excited atmospheric pressure plasma jet operated in helium with admixtures of molecular nitrogen or oxygen. High energetic photons, such as the helium excimer continuum, are analyzed using windowless VUV spectrometry. Reaction kinetics of plasma-chemical processes and rotational temperatures will be estimated by analyzing the spatial variation of emission in the visible range of a nitrogen afterglow using a high-resolution echelle spectrometer.

P 4.3 Mo 14:45 HS 20

Formation pathways of HO_2 in a cold atmospheric pressure plasma jet investigated by cavity ring-down spectroscopy — •Sarah-Johanna Klose[1], Ansgar Schmidt-Bleker[1], Katherine Manfred[2], Helen Norman[2], Michele Gianella[2], Sioned Press[2], Grant Ritchie[2], and Jean-Pierre van Helden[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Department of Chemistry, University of Oxford, Oxford, United Kingdom

The kINPen, a plasma jet operated in argon, is often employed in biomedical applications, as it provides important species for the plasma to cell interaction, such as H_2O_2. In order to investigate the complex chemical reaction network of the plasma effluent, we analysed the production and destruction pathways of HO_2, which is an important intermediate in the production cycle of H_2O_2. Respective diagnostic methods, such as absorption spectroscopy, are challenging considering the small diameter of the effluent (about 4 mm). Moreover, due to their short lifetime, highly reactive species like radicals have to be measured directly in the effluent. An option to increase the optical path length through a small plasma volume is cavity ring-down spectroscopy (CRDS). We will present HO_2 densities obtained from CRDS measurements, varying the O_2 fraction in the surrounding nitrogen gas curtain. Additionally, we will show spatial distributions of HO_2, gained from Abel inversion, at different axial positions. The most important formation and destruction mechanisms of HO_2, identified by a simple reaction kinetics model, will be discussed.

P 4.4 Mo 15:00 HS 20

Radio-frequency driven atmospheric pressure microplasma jets: voltage waveform tailoring and its effect on electron heating — Yue Liu[1], Ihor Korolov[2], Julian Schulze[2], Torben Hemke[2], and •Thomas Mussenbrock[1] — [1]Brandenburg University of Technology Cottbus-Senftenberg, 03046 Cottbus, Germany — [2]Ruhr University Bochum, 44780 Bochum, Germany

Capacitive microplasma jets driven at atmospheric pressure by sinusoidal or particularly tailored voltage waveforms are employed as efficient plasma sources for surface modification and other processes. One special variant is the micro atmospheric pressure plasma jet (μAPPJ). In this contribution the characteristics of the μAPPJ driven by different voltage waveforms in a helium-oxygen mixture are studied by numerical simulations in conjunction with experiments. The electron dynamics, as well as the dynamics of reactive species are investigated in both the region between the electrodes and within the effluent, particularly with regard to the effect of different driving voltage waveforms. — Financial support granted by the German Research Foundation in the frame of SFB 1316 (project A4) is gratefully acknowledged.

P 4.5 Mo 15:15 HS 20

Energy flux measurements in atmospheric pressure plasmas — •Luka Hansen[1], Kristian Reck[1], Stephan Reuter[2], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Department of Computer and Electrical Engineering, Lublin University of Technology, Lublin, Poland

Passive thermal probes (PTPs) have been successfully used to diagnose energy dissipation in low pressure discharges relevant for plasma surface interaction in e.g. film growth, and surface cleaning and activation. The present work implements PTP diagnostics to study plasma surface interaction at atmospheric pressure, where mass transport by convection and diffusion plays an important role for the energy transfer. The gained insight may proof useful for many industrial and biomedical applications.

Measurements on a surface barrier discharge (DSCBD) and on a cold atmospheric pressure plasma jet (CAPjet) are presented to show the role of fluid dynamics on the energy flux. Variation of the working gas for the DCSBD demonstrate the influence of gas- and surface reactivity on the energy flux. For the CAPjet, first time Rayleigh measurements of flow regime in combination with the PTP measurements show the effect of laminar vs. turbulent flow on energy dissipation. Charging of the (biased) PTP by the impinging jet with varying gas composition and flow indicate that Penning ionization and ion recombination time scales are relevant factors for the energy transfer from the plasma to surface.

P 4.6 Mo 15:30 HS 20

On the plasma bullet shape of He and He/O2 capillary plasma jet devices and interaction with dielectric surface — •Constantinos Lazarou[1,2], Charalambos Anastassiou[2], Ionut Topala[3], Alina Chiper[3], Ilarion Mihaila[4], Valentin Pohoata[3], and George Georghiou[1,2] — [1]FOSS, University of Cyprus, Nicosia, Cyprus — [2]ENAL, University of Cyprus, Nicosia, Cyprus — [3]IPARC, Alexandru Ioan Cuza University of Iasi, Iasi, Romania — [4]CERNESIM, Alexandru Ioan Cuza University of Iasi, Iasi, Romania

In this study, a two-dimensional axi-symmetric model has been used to study the evolution of capillary helium plasma jets with and without oxygen admixtures and their interaction with a dielectric surface placed normal to the jet axis. The model considers the gas mixing of helium and ambient air and the analytical chemistry between helium, nitrogen and oxygen species.

In particular, this work examines, from first principles, the shape and speed of the of the plasma bullet, the intensity of the induced electric (IEF) field on a dielectric surface and the underlying dominant chemical reactions of the plasma. Furthermore, this work provides insight and understanding into the mechanisms behind many experimental observations such as the torus (or donut) and sphere plasma bullet shapes for pure Helium and He/O2 plasma, respectively.

P 5: Helmholtz Graduate School I

Zeit: Montag 14:00–16:10 Raum: HS 21

Hauptvortrag P 5.1 Mo 14:00 HS 21

On plasma-surface model coupling realized through machine learning — •Jan Trieschmann, Florian Krüger, Tobias Gergs, and Thomas Mussenbrock — Brandenburg University of Technology Cottbus-Senftenberg, Electrodynamics and Physical Electronics, Siemens-Halske-Ring 14, 03046 Cottbus, Germany

The time and length scales of the dynamics at the solid surface and in the gas-phase during sputter deposition span orders of magnitude. While methods to kinetically describe the surface processes and the gas-phase transport take advantage of solving the respective subproblem independently, their consistent coupling is a prerequisite. A viable plasma-surface model bridges these sub-models, allowing for complex surface and gas compositions encountered in reactive sputtering. For this objective, a machine learning plasma-surface interface is proposed based on a multilayer perceptron network. The latter has been trained and verified with sputtered particle energy and angular distributions obtained from TRIDYN simulations [1] for Ar sputtering an Al-Ti composite target. As verified with reference data, the trained network accurately predicts sputtered particle distributions for arbitrary incident ion energy distributions, which have not been previously trained. To conclude, additional examples where machine learning model interfaces may establish a reliable sub-model coupling are discussed.

This work is supported by the German Research Foundation (DFG) in the frame of transregional collaborative research centre SFB-TR 87.

[1] W. Möller and W. Eckstein, Nucl. Instr. and Meth. B2, 814 (1984)

P 5.2 Mo 14:30 HS 21

Machine learning approximations of Bayesian models — •Andrea Pavone[1], Jakob Svensson[1], Andreas Langenberg[1], Sehyun Kwak[1], Udo Hoefel[1], Novimir Pablant[3], Matthias Brix[2], and Robert C. Wolf[1] for the The Wendelstein 7-X Team-Collaboration — [1]Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald, D-17491 Greifswald, Germany — [2]Princeton Plasma Physics Laboratory, 08540 Princeton, NJ, US — [3]Culham Centre for Fusion Energy, Culham Science Centre, Abingdon OX14 3D8, UK

Neural network (NN) models are trained as approximations of Bayesian models for fast data processing, opening the way to the possibility of quick inter-shot data analysis in cases where it was not possible due to computation time limitations. The NN models were tested on different diagnostic data for the inference of plasma parameters such as electron and ion temperature profiles at W7-X and JET experiments. The Bayesian models upon which they are based are developed within the Minerva framework: a common framework for modeling complex systems allows to formalize the training procedure in a way that it is mostly general and abstracted way from the single, specific diagnostic model. The training data are collected exclusively by sampling from the joint distribution of the model, so that the trained NN constitutes a surrogate of the full Bayesian models. The NN inferred plasma parameters are compared to the full Minerva Bayesian inference results. Moreover, in order to assess the reliability of the NN predictions, uncertainties of the NN output are calculated within a Bayesian framework of the NN training.

P 5.3 Mo 14:55 HS 21

PIC simulations of the extraction region of one beamlet of an ITER NBI relevant ion source — •Ivar Mauricio Montellano Duran, Serhiy Mochalskyy, Dirk Wünderlich, and Ursel Fantz — MaxPlanck-Institut für Plasmaphysik, 85748 Garching, Germany

For ITER NBI ion sources will be used to produce large and intense negative hydrogen or deuterium ion beams. Negative ions are produced predominantly by the surface process in a low temperature plasma. In order to gain a better understanding of the complex ion source physics, close to the surface, self-consistent models are needed. The magnetic field topology close to the extraction system demands 3D models to study the particle transport in the plasma. The 3D Particle in cell (PIC) ONIX code has been already validated and applied for the extraction of negative hydrogen ions and co-extracted electrons for one extraction aperture of the ITER NBI prototype source. The source performance is typically limited by the amount of co-extracted electrons which is significantly higher in deuterium than in hydrogen. In the experiments several parameters can be modified to reduce the co-extracted electron current such as strength and topology of the magnetic fields. Simulations with different magnetic field configurations were done to study their effect on the electron transport. A comparison between deuterium and hydrogen plasma simulations was realized to obtain an insight of the isotope effect. The results of these simulations and a discussion on the transport of the electrons are presented.

P 5.4 Mo 15:20 HS 21

Gyrokinetic Vlasov-Maxwell equations from variational averaging — •Edoardo Zoni[1,2] and Stefan Possanner[1,2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Technische Universität München, Zentrum Mathematik, 85748 Garching, Germany

Nonlinear gyrokinetics is the major formalism used in theoretical and numerical studies of low-frequency microturbulence in magnetized fusion plasmas. A set of gyrokinetic Vlasov-Maxwell equations is derived with the method of variational averaging (Possanner, 2018) in a field-theoretic framework, without relying on the more complex mathematical formalism of Lie transform perturbation theory. The gyrokinetic ordering considered in this work is obtained by introducing a rigorous normalization scheme for the Vlasov-Maxwell equations and looking at physical scenarios relevant for realistic fusion devices. The gauge invariance of the resulting gyrokinetic model is also discussed.

P 5.5 Mo 15:45 HS 21

Relaxation to magnetohydrodynamics equilibria via collision brackets — •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

It is well known that three-dimensional Magnetohydrodynamic (3D MHD) equilibrium equation has multiple solutions. In order to select a unique solution, existing numerical approaches either constrain suitable plasma parameters or relax an initial condition by means of suitable relaxation terms added to ideal MHD equations (relaxation methods). Concerning in particular the latter approach, ideas and results from Geometric Mechanics have been successfully applied to select a unique solution of the equilibrium problem which is consistent with external constrained profiles. The method presented fits into the framework of metriplectic dynamics, developed by Morrison ([Morrison, 1984, *Phys. Lett. A*, **100**, 423-7], [Morrison, 1986, *Physica D*, **18**, 410-9]), in which energy-preserving dynamics is combined with entropy dissipation. Convergence to the desired equilibrium state compatible with experimental data can be investigated by techniques similar to the Boltzmann's H-theorem [Lenard, 1960, *Ann. of Phys.*, **3**, 390-400]. Relevant applications of the new approach are presented: the vorticity form of the 2D Euler equations, the Grad- Shafranov equation, Taylor-relaxed states (3D Beltrami fields).

P 6: Low Pressure Plasmas I

Zeit: Montag 16:30–18:30 Raum: HS 20

Hauptvortrag P 6.1 Mo 16:30 HS 20

Plasmas in leading-edge semiconductor device fabrication: Importance and analysis — •Sven Zimmermann[1,2], Micha Haase[1], Norbert Lang[3], Henrik Zimmermann[3], Jürgen Röpcke[3], Stefan Schulz[1,2], and Thomas Otto[1,2] — [1]Chemnitz University of Technology, 09126 Chemnitz, Germany — [2]Fraunhofer ENAS Chemnitz, 09126 Chemnitz, Germany — [3]INP Greifswald, 17489, Greifswald, Germany

The further scaling of device dimension in modern semiconductor technologies results in an increasing complexity of plasma processes. Especially patterning processes in the state of the art 22 nm-technology-node become more and more the limiting factor for device performance, reliability and power consumption. Such processes are often multistep recipes with an intermediate change in chemical plasma composition and additional purges. The optimization of such single-step-chains on the empirical way fails due to the unmanageable couple of adjustable parameters and their dependencies. Additional novel materials show often more complex chemical interactions with plasma species.

The talk exemplifies typical challenges for plasma processes in state of the art integration schemes, down to 22 nm, with respect to transistor functionality and performance of the interconnect system. The plasmas were analyzed with several electric and spectroscopic methods and correlations with process results, e.g. material degradations and geometrical aspects, will be illustrated. Finally, drawbacks and furthers requirements of modern plasma diagnostic methods will be given.

P 6.2 Mo 17:00 HS 20

Spectra of the planar Multipole Resonance Probe determined by a Kinetic Model — •Michael Friedrichs and Jens Oberrath — Institute of Product and Process Innovation, Leuphana University Lüneburg, Germany

The planar Multipole Resonance Probe (pMRP) is a measurement device for plasma processes, especially suited for industrial applications. Due to its planar design, the probe can be mounted directly into a chamber wall of a reactor and offers the ability to monitor the plasma during the process. The calculation of plasma parameters requires an appropriate mathematical model to obtain a proportional relation between the resonance and the plasma parameters. A fluid model of the probe-plasma interaction offers the ability to calculate the electron density by measuring the resonance frequency. The information of the electron temperature can be obtained by analyzing another resonance parameter like e.g. the half width of the resonance peak. However, it requires a kinetic description of the resonance phenomenon. In this work a kinetic model, adapted to the pMRP, is analyzed using functional analytic methods. An approximated solution for the admittance of the probe-plasma interaction will be investigated and a study of the influence of the truncation on the resonance spectrum will be shown.

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

P 6.3 Mo 17:15 HS 20

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

The electron energy distribution function (EEDF) in low pressure plasmas is typically evaluated by using the second derivative d^2I/dV^2 of a Langmuir probe characteristic (Druyvesteyn formula). Since measured I-V characteristics are inherently noisy, two-time numerical differentiation requires data smoothing techniques which can lead to a loss of information especially in the low energy range of the resulting EEDF. Therefore, an AC probe method was adopted to measure d^2I/dV^2 directly. This is done by superimposing a sinusoidal AC voltage of 13 kHz and amplitude in the range of 1 V on the probe DC bias and Fourier analysis of the resulting probe current. With this technique the EEDFs are accessible with high accuracy in the low energy range compared to EEDFs determined via numerical differentiation.

The system is applied to several gases (Ar, H_2, D_2, N_2) at an ICP discharge (planar coil, 2 MHz RF frequency, up to 2 kW power). Parameters like the modulation amplitude and number of applied sine oscillations per voltage step of the DC ramp were carefully chosen by systematic parameter variations. The shape of the EEDF for low electron energies, especially important in molecular gases (vibrational excitation processes), is investigated in particular and compared to simulations performed with the Boltzmann solver BOLSIG+.

P 6.4 Mo 17:30 HS 20

The absolute calibration of an energy-selective mass spectrometer with the reference IVDF from a 1D PIC simulation of a symmetrical RF plasma — •Christian Schulze[1], Hanno Kählert[2], Michael Marsand[2], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Institute of Theoretical Physics and Astrophysics, Kiel University, Germany

Energy-selective mass spectrometry (ESMS) is a broadly used diagnostic in plasma research due to its versatile applications like residual gas analysis, determination of velocity distributions of ions and neutrals as well as the identification of metastable species. Despite of its frequent use there are very few information about the main artifacts like chromatic abberation, energy dependence of the acceptance angle and mass discrimination that can strongly distort the measurement. Especially the ion lens system with its unknown transmission behavior has a crucial influence on the measured ion signal. Therefore, ESMS provides mainly qualitative information about ion fluxes.

We constructed a symmetric RF CCP setup with the ESMS sampling orifice integrated in the grounded electrode to study IVDFs of the ions that are accelerated in the sheat. The symmetry of the discharge allows for direct comparison to 1D MCC-PIC simulation. The simulation provides angular and velocity resolved absolute ion fluxes. Therefore, the comparison of measured and simulated IVDFs is used to investigate the effects of distortions and calibrate the measured ion signal to the simulated absolute ion flux.

P 6.5 Mo 17:45 HS 20

Operation of INCA with molecular gases — •Christian Lütke Stetzkamp, Philipp Ahr, Tsanko Vaskov Tsankov, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany

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

Here the discharge is analysed further and the newest experimental results regarding discharge operation in molecular gases are presented and discussed.

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

P 6.6 Mo 18:00 HS 20

Phase resolved optical properties of magnetized transient plasma created by a low-pressure dielectric barrier discharge jet — •Roman Bergert and Slobodan Mitic — Justus-Liebig-

Universität Gießen

Dielectric barrier discharge (DBD) jet with the influence of an external constant magnetic field (0.3 T) at low pressure (100 Pa) were investigated by tuneable diode laser absorption spectroscopy in perpendicular observation to the magnetic field. With this configuration each π and σ polarized transitions of Argon 1s at 842.47 nm and 1s at 801.48 nm were phase resolved by using unpolarized laser light. The changes within a discharge cycle for each polarization transition and sublevel density were observed to investigate the transient plasma during different regimes. To increase accuracy of our model, we calculate the individual Einstein coefficient for spontaneous decay between magnetic sublevel transitions. This enabled us to observe a significant change in the optical properties of transient plasma with an external magnetic field. This results in a changed average selfabsorption coefficient by almost 0.5 compared to an unsplitted case with same total 1s densities. This shows that the plasma becomes more transparent under the influence of an external magnetic field. The individual transition properties are necessary for a correct description of the plasma emission and absorption with an external magnetic field.

P 6.7 Mo 18:15 HS 20

Measurements of VUV/UV photon fluxes in planar ICP discharges at low pressure — •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) and in the ultraviolet (UV, wavelength between 200 nm and 400 nm) play a role in plasma treatment processes. They can have beneficial or undesirable effects on the surface material depending on the absolute flux, the photon energy and the application. Therefore, VUV/UV photon fluxes of the gases H_2, N_2, O_2, Ar and mixtures are investigated in a planar ICP discharge (Ø15 cm, height 10 cm; 2 MHz; $\leq$ 2 kW; 0.3 - 10 Pa) in pressure and power scans with a special focus on the spectral composition. For that purpose, an 1 m McPherson VUV spectrometer is used which can be equipped either with a solar-blind photomultiplier or with a windowless Channel Electron Mulitiplier. Thus, the VUV spectrometer allows measurements in the wavelength range from 50 nm to 300 nm, with an absolute intensity calibration available between 116 nm and 300 nm. Additionally, the results are compared with measurements using a VUV diode system which is under development. In contrast to the VUV spectromter, the diode system is small, portable and its absolute intensity calibration does not depend on the plasma setup of use.

P 7: Helmholtz Graduate School II - Magnetic Confinement I

Zeit: Montag 16:30–18:30 Raum: HS 21

Hauptvortrag P 7.1 Mo 16:30 HS 21

3-D physics of the tokamak edge — •Matthias Willensdorfer[1], Tyler Cote[2], Michael Griener[1], David Ryan[3], Erika Strumberger[1], Wolfgang Suttrop[1], Nengchao Wang[4], Dominik Brida[1], Marco Cavedon[1], Severin Denk[1], Mike Dunne[1], Rainer Fischer[1], Christopher Ham[3], Chris Hegna[2], Matthias Hoelzl[1], Andrew Kirk[3], Nils Leuthold[1], Marc Maraschek[1], Hartmut Zohm[1], and The ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]University of Wisconsin-Madison, Madison, Wisconsin 53706, USA — [3]CCFE, Culham Science Centre, Abingdon, Oxon, OX14 3DB, UK — [4]AEET, SEEE, HUST, Wuhan 430074, P R China

Non-axisymmetric perturbation coils in tokamaks are commonly used to modify the properties of the plasma edge. This can be beneficial for future fusion, since it allows to influence possible harmful edge instabilities.

Recent research has shown that the perturbation field from these coils excite static ideal magnetohydrodynamic (MHD) modes at the edge, which significantly distort the axisymmetry of tokamaks. This three-dimensional (3D) tokamak geometry is well described by MHD equilibrium codes originally developed for stellarators. Moreover, measurements of small (helically) localised instabilities combined with stability analysis demonstrate that the induced 3D geometry produces regions of lower stability on the plasma surface.

P 7.2 Mo 17:00 HS 21

A ballooning mode description of small ELMs — •G.F. Harrer[1], E. Wolfrum[2], M.G. Dunne[2], T. Eich[2], M. Griener[2], P. Hennequin[3], B. Labit[4], P. Manz[2], L. Radovanovic[1], F. Aumayr[1], the ASDEX Upgrade Team[2], and the EUROfusion MST1 Team[5] — [1]Institute of Applied Physics, TU Wien, Fusion@ÖAW, Vienna, Austria — [2]Max Planck Institute for Plasma Physics, Garching, Germany — [3]Laboratoire de Physique des Plasmas, CNRS, Ecole Polytechnique, Palaiseau, France — [4]Swiss Plasma Center, EPFL, Lausanne, Switzerland — [5]see author list in H. Meyer et al. Nuclear Fusion 57 102014 (2017)

The foreseen operational scenario for future fusion devices is the high confinement mode, which is characterized by a strong increase in confinement due to the formation of a transport barrier at the plasma edge. The periodic crash of this so-called pedestal is caused by large edge localized modes (type-I ELMs) which can lead to possibly intolerable heat and particle loads if not controlled. In ASDEX Upgrade, discharges with high separatrix collisionality $\nu_e^* \propto n_e/T_e^2$, comparable to ITER, exhibit small ELMs at good confinement, if the plasmas are strongly shaped. In the experiment, type-I ELMs and small ELMs can coexist. In this contribution a model is proposed that explains how the small ELMs modify the shape of the pedestal close to the separatrix in such a way that it is stable against large type-I ELMs. The manifestation of small ELMs at reactor-like separatrix conditions as filamentary transport rather than large bursts offers a possible route to tolerable heat loads at high pedestal top pressure in future devices.

P 7.3 Mo 17:25 HS 21

Linear and nonlinear dynamics of GAMs and EGAMs — •Ivan Novikau[1], Alessandro Biancalani[1], Alberto Bottino[1], Peter Manz[1], Garrard D. Conway[1], Alessandro Di Siena[1], Philipp Lauber[1], Emanuele Poli[1], Emmanuel Lanti[2], Laurent Villard[2], Noé Ohana[2], and Asdex Upgrade Team[1] — [1]IPP, Garching, Germany — [2]SPC-EPFL, Lausanne, Switzerland

Turbulence in tokamaks generates radially sheared zonal flows (ZFs), that can reduce the radial transport in the system. Their oscillatory counterparts, geodesic acoustic modes (GAMs), appear due to the action of the magnetic field curvature. The GAMs can be driven by energetic particles leading to the formation of EGAMs. In addition to ion Landau damping (LD), both the GAMs and EGAMs have been found to be subject to the electron LD. Due to that, the EGAMs can spread energy from the fast particles to the thermal plasma. To investigate the influence of the electron LD on the EGAMs, a Mode-Particle-Resonance diagnostic has been implemented in the global gyrokinetic (GK) PIC code ORB5. Based on the projection of the energy transfer terms on the velocity domain, the diagnostic gives an opportunity to estimate the contributions of different resonances to the mode's dynamics. It has been applied in electromagnetic GK simulations of the NLED AUG shot #31213 to show the influence of the drift-kinetic electrons on the EGAM dynamics. The second part of the talk is dedicated to the nonlinear interaction of zonal structures and turbulence in AUG shot #20787. GAM excitation by ITG instabilities will be shown with a good numerical prediction of the GAM frequency scaling.

P 7.4 Mo 17:50 HS 21

Investigation of enhanced transport due to magnetic perturbations — •Nils Leuthold[1,2], Wolfgang Suttrop[1], Matthias Willensdorfer[1], Marco Cavedon[1], Mike Dunne[1], Luis Gil[3], Tim Happel[1], Andrew Kirk[4], Jose Vicente[3], the ASDEX Upgrade Team[5], and the EUROfusion MST1 Team[6] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Ludwig-Maximilian-Universität, München, Germany — [3]Instituto de Plasmas e Fusao Nuclear, Instituto Superior Tecnico, Universidade de Lisboa, Portugal — [4]CCFE, Culham Science Centre, Abingdon, Oxon, OX14 3DB, UK — [5]See the author list "H. Meyer et al 2019 Nucl. Fusion (in preparation)" — [6]See the author list "H. Meyer et al 2017 Nucl. Fusion 57 102014"

Since Edge Localized Modes have the potential to damage the first wall in a tokamak, magnetic perturbations are currently investigated as a tool to mitigate or suppress them. At low collisionalities relevant for future fusion devices, magnetic perturbations also cause an enhancement of outward particle and heat transport.

The influence of this so called 'pump-out' effect on the temperature and density of the plasma is shown. Also, first insights into its driving mechanism are discussed. No significant increase of neoclassical transport due to field penetration to resonant magnetic surfaces at the pedestal top has been observed. However, broadband density fluctuations can be measured in the plasma edge. Their toroidal asymmetry is seen in scans of the surface corrugation of the perturbed 3D equilibrium.

P 7.5 Mo 18:15 HS 21

Influence of magnetic islands on plasma profiles and dynamics in the Scrape-Off-Layer of Wendelstein 7-X — •Carsten Killer[1], Olaf Grulke[1,2], Philipp Drews[3], Alexander Knieps[3], Dirk Nicolai[3], Guruparan Satheeswaran[3], and W7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald, Germany — [2]Department of Physics, Technical University of Denmark, Lyngby, Denmark — [3]IEK4-Plasmaphysik, Forschungszentrum Jülich, Germany

The W7-X divertor concept employs large resonant magnetic islands at the plasma edge to control the heat and particle fluxes to the divertor. Using reciprocating probe measurements, we show that the presence and particular topology of magnetic islands significantly affects the Scrape-Off Layer (SOL) profiles of electron temperature, density and electric field, as well as the fluctuation characteristics, turbulence-induced radial transport, and plasma flows. These quantities are explored in different magnetic configurations and the role of central plasma heating and fuelling is discussed.

As a key result, we report on particularly broad SOL temperature and density profiles in the presence of magnetic islands, resulting in very large effective SOL widths up to 5 cm (with a strongly non-exponential profile shape) which is favourable as it results in a broader heat flux distribution on the divertor. In these situations, the islands can feature a local minimum of the plasma potential accompanied by a direction reversal of $E \times B$ driven dynamics, indicating that the islands with connection lengths of a few 100 m can act as plasma confining regions.

P 8: Laser Plasmas I - Codes and Modelling I

Zeit: Dienstag 11:00–12:30 Raum: HS 20

P 8.1 Di 11:00 HS 20

Adaptive Multi-Physics Simulations of Collisionless Plasmas — •Simon Lautenbach and Rainer Grauer — Ruhr University Bochum

Collisionless plasmas, mostly present in astrophysical and space environments, often require a kinetic treatment as given by the Vlasov equation. Unfortunately, the six-dimensional Vlasov equation is inherently expensive to compute and thus can only be solved on very small parts of the considered spatial domain. However, in some cases, e.g. magnetic reconnection, it is sufficient to solve the Vlasov equation in a localized domain and solve the remaining domain by appropriate fluid models. We present an adaptive hierarchical treatment of collisionless plasmas ranging from fully kinetic, over a 10-moment fluid model incorporating a simplified treatment of Landau damping, to a 5-moment fluid description. To account for separation of electron and ion physics, hybrid stages of mixed electron and ion models are also allowed. To test this multiphysics approach, the full physics-adaptive hiearerchy is applied to the Geospace Environmental Modeling (GEM) challenge of magnetic reconnection.

P 8.2 Di 11:15 HS 20

A new relativistic interaction model for 2D and 3D Wigner crystals in a plasma bubble — •Johannes Thomas, Lars Reichwein, and Alexander Pukhov — Institut für Theoretische Physik 1, Heinrich-Heine-Universität Düsseldorf

The spatial structure of an ultralow-emittance electron bunch in the plasma wakefield bubble regime is studied. The full Liénard-Wiechert potentials are considered for mutual inter-particle interactions in the framework of an equilibrium model. This model uses a quasi-static theory which allows to solve the Liénard-Wiechert potentials without knowledge of the electrons* history. The 2D equilibrium structure we find is similar to already observed hexagonal lattices in [1] and shows more topological defects [2]. These defects reduce the stress onto the lattice, which is important for higher energies since a transition between the hexagonal lattice structure and the parabolic confinement of the external field needs to be made. To calculate the 3D equilibrium structure, we use a Lorentz transformation in propagation direction to model the retarded Coulomb interaction between the electrons inside the bunch. We find three-dimensional filaments in the direction of propagation, while the hexagonal structure in perpendicular direction is preserved. From a physical point of view, it is clear that the scaling originates from different competing structures that minimize the system's energy. [1] Johannes Thomas, Marc M. Günther, and Alexander Pukhov, Phys. Plasmas 24, 013101 (2017) [2] Lars Reichwein, Johannes Thomas, and Alexander Pukhov, Phys. Rev. E 98, 013201 (2018)

P 8.3 Di 11:30 HS 20

Probing the strong-field frontier of quantum electrodynamics — •Christoph Baumann and Alexander Pukhov — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

The success of QED is related to its very precise predictions that are in excellent agreement with experimental data. However, according to Ritus and Narozhny [1] and recently revisited by Fedotov [2], perturbative strong-field QED is conjectured to break down at $\alpha\chi^{2/3} \simeq 1$, thus entering a novel and fully non-perturbative regime of QED for which no reliable theoretical calculations exist so far. Regarding ultra-fast radiation losses in such an extreme environment, this regime is thought to be out of experimental reach. Using the QED-PIC code VLPL [3], the present contribution, however, proposes several setups that might be promising for probing this exotic regime in the not too distant future. All setups have in common that the switching time of the strong background field is significantly shortened to reduce radiation losses. This can be done, for instance, by the collision of two high-current, tightly focused and tightly compressed electron beams [4], by the conversion of an optical laser pulse to an ultra-intense attosecond pulse [5] or by using the fact that the penetration depth in laser-solid interactions is limited to the skin depth [6].

[1] V. I. Ritus, Ann. Phys. 69, 555 (1972); N. B. Narozhny, Phys. Rev. D 21, 1176 (1980); [2] A. Fedotov, J. Phys.: Conf. Ser. 826, 012027 (2017); [3] C. Baumann *et al.*, Phys. Rev. E 94, 063204 (2016); [4] V. Yakimenko *et al.*, arXiv:1807.09271 (2018); [5] C. Baumann *et al.*, arXiv:1811.03990 (2018); [6] C. Baumann *et al.*, in preparation (2018)

P 8.4 Di 11:45 HS 20

Ultra-high energy density physics and ion acceleration in nano- and microstructures — •Vural Kaymak[1], Alexander Pukhov[1], Vyacheslav N. Shlyaptsev[2], Jorge J. Rocca[2,3], Bastian Aurand[4], and Oswald Willi[4] — [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 — [4]Institut für Laser- und Plasmaphysik, Heinrich-Heine Universität, 40225 Düsseldorf, Germany

The creation of ultra-high energy density (UHED, $> 1 \cdot 10^8\,\mathrm{J/cm^3}$) 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. Spherical shaped targets on the microscale have shown to enhance the laser acceleration of proton beams compared to flat targets, making them promising sources for cancer radiotherapy and measurements of magnetic and electric fields with high spatiotemporal resolution. We investigate ways to generate UHED matter in nanowire arrays and the enhanced proton beam acceleration by spherically shaped microstructures.

P 8.5 Di 12:00 HS 20

Investigation of Plasma Expansion on Solid Surfaces Interacting with an Ultrashort Laser Pulse in the Weakly-Relativistic Intensity Regime — •Steffen Mittelmann[1], Götz Lehmann[2], and Georg Pretzler[1] — [1]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf — [2]Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

The dynamics of plasma generation and expansion of a solid surface irradiated by a few-fs, ultra-high contrast weakly-relativistic laser pulse is studied by particle-in-cell simulations. The aim is to observe the onset and the dynamics of plasma expansion on a time-scale less than 100 fs after the main interaction, which is a challenging regime for experimental observations. These dynamics have been previously investigated in the PHASER (Phase-Stabilized Heine Laser) lab in Düsseldorf. A pump-probe experiment was used to detect a spatially structured plasma expansion. Our investigations are made with the simulation code EPOCH and give insight into a potential origin of the observed structured expansion. We are able to identify the plasma behaviour investigated in the experiment and we can show that an important role is attributed to the fact that the used target is a layered system of aluminium coated on a fused quartz substrate.

P 8.6 Di 12:15 HS 20

Laser-driven shock acceleration of ions in the collisional and ultra-relativistic regime — •Shikha Bhadoria, Naveen Kumar, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, Heidelberg

The effect of collisions and quantum electrodynamic effects like radiation reaction and pair production on shock formation and subsequent ion acceleration from laser-plasma interaction are 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 instability. The collisional weakening of the space-charge effects results in the formation of a shock with a higher density jump than in a collisionless plasma. This stronger shock leads to stable quasi-monoenergetic acceleration of ions [1]. In the ultra-relativistic regime, both radiation reaction and pair plasma formation tend to slow down the shock velocity which makes the quasi-monoenergetic ion acceleration lasting on longer timescales. [1] S. Bhadoria, N.Kumar, C.H. Keitel. Stable quasi-monoenergetic ion acceleration from the laser-driven shocks in collisional plasmas ArXiv:1707.03309[physics.plasm-ph]

P 9: Atmospheric Pressure Plasmas II - Helmholtz Graduate School III

Zeit: Dienstag 11:00–12:40 Raum: HS 21

Hauptvortrag P 9.1 Di 11:00 HS 21

Laser diagnostics of plasmas using fs- and ps-lasers — •Stephan Reuter — Princeton University, MAE-Department, Princeton, USA — Lublin Technical University, Lublin, Poland

Dynamics in plasma jets at atmospheric pressure span orders of magnitude in time scales, ranging from picosecond (ps) time scales of electron dynamics and energy transfer to heavy particles, to mass transport on a micro- and millisecond time scale by convection and diffusion into open atmosphere. Recent advances in ultrafast laser diagnostics, adapted from methods developed for combustion and aerospace engineering, allow highly resolved plasma diagnostics: Picosecond time and micrometer space resolved electric field measurements were recently achieved using a femtosecond (fs)-laser sheath in a plasma jet effluent: Electric field induced second harmonic (E-FISH) light generation is utilized to quantify the electric field induced by the fast ionization wave of the plasma jet. Comparing fs-1D resolved to ps-point wise measurements shows the potential of fs-E-FISH. Fs-lasers can also be used for recently developed fs-electronic excitation tagging (FLEET) to study the plasma jet's gas flow field into open atmosphere. Quantitative 1D gas velocity vector fields are determined by using the emission of excited nitrogen molecules as tracer. The great potential as well as challenges of ultrafast lasers for plasma diagnostics conclude the talk. Funding by Alexander von Humboldt Foundation and Princeton University is gratefully acknowledged.

P 9.2 Di 11:30 HS 21

Channel Reillumination in Pulsed Corona-like Discharges in Water — •Raphael Rataj, Hans Höft, and Juergen F. Kolb — INP Greifswald, Felix-Hausdorff-Straße 2, 17489 Greifswald

Investigations of corona-like discharges in water have shown the importance of the fall time of sub-microsecond high-voltage pulses regarding a reignition of discharge channels. So far it was reported that, despite similar pulse durations and amplitudes, a reillumination starts either during the high-voltage plateau, the falling edge of the pulses or not at all. Furthermore, a reillumination of a single filament or all previously formed channels were reported. For a detailed study, single, reproducible voltage pulses with adjustable fall times between 20 and 45 ns, amplitudes of 50 kV and 100 ns duration were applied to a point-to-plane geometry in deionized water. Time-resolved measurements of voltage, current and emitted visible light intensity were obtained for individual discharges, and plasma current, discharge energy and channel length could be calculated accordingly. In addition, subsequent images of single discharge events were taken with a framing camera and compared to the electrical measurements. While no change in discharge development was found for the initial phase during the high-voltage plateau, a reillumination was observed only during the falling slope for all applied pulses. A transition from a reignition of single filaments to a reillumination of every channel with decreasing fall time was visible both in the framing camera images and the plasma current. The detailed investigation for each fall time will be presented and a possible explanation for the observed transition will be given.

P 9.3 Di 11:45 HS 21

Analysis of a dielectric barrier discharge in argon for wide pressure and frequency ranges — •Marjan Stankov, Markus M. Becker, Robert Bansemer, and Detlef Loffhagen — Leibniz Institute for Plasma Science and Technology (INP), 17489 Greifswald, Germany

Dielectric barrier discharges (DBDs) are widely used plasma sources e.g. in plasma medicine, for surface treatment and ozone generation. Here, a laboratory DBD is investigated by means of fluid modelling and electrical measurements. It has a symmetric plane-parallel geometry with electrodes covered by quartz glass dielectric. A specific feature of this device is that gas pressure and frequency of the sinusoidal voltage signal can easily be adapted in the pressure range from 100 to 1000 mbar and for frequencies between 10 and 100 kHz. Argon is used as a reference gas. The time-dependent, spatially one-dimensional fluid model comprises balance equations for the particle densities and the electron energy density involving the drift-diffusion approximation for the fluxes. Poisson's equation is solved to determine the axial electric field, and the accumulation of surface charges on the dielectric surfaces is included as a boundary condition. First modelling results of the electrical discharge characteristics are presented and discussed providing a detailed understanding of surface and volume memory effects over the whole pressure and frequency range. In general, good agreement with measurements of the discharge current are obtained.

Funded by the Deutsche Forschungsgemeinschaft (DFG) - project number 368502453.

P 9.4 Di 12:00 HS 21

Influence of a catalyst on CO_2 dissociation in a non-equilibrium atmospheric pressure helium plasma jet — •Theresa Urbanietz, Steffen Schüttler, Christoph Stewig, Marc Böke, Volker Schulz-von-der-Gathen, and Achim von Keudell — Experimental Physics II, Ruhr-University Bochum, 44780 Bochum

Excitation of CO_2 in an atmospheric pressure plasma may be an energy efficient method to generate solar fuels from renewable energies. The non-equilibrium excitation of specific states of the molecules in the plasma can cause of high energy efficiency. The influence of a catalyst can even enhance the energy and dissociation efficiency. The dissociation of CO_2 in an atmospheric helium RF plasma jet in the presence of a catalyst is analyzed for varying absorbed plasma powers and compared with measurements without catalyst. Fourier transform infrared spectroscopy is used to evaluate the concentration of CO_2 and CO as well as the rotational and vibrational temperature of the species. A strong non-equilibrium excitation of CO_2 and CO with rotational temperatures around 400 K and vibrational temperatures up to 1600 K has been found. The dependence of these excitation temperatures on the plasma power is rather weak.

P 9.5 Di 12:15 HS 21

Phase-resolved study of single microdischarges in cathodic pin polarity of a metal pin-to-hemispherical dielectric-covered electrode arrangement — •Sina Jahanbakhsh[1], Volker Brüser[1], and Ronny Brandenburg[1,2] — [1]Leibniz-Institut für Plasmaforschung und Technologie (INP), Felix-Hausdorff-Str. 2, 17489 Greifswald — [2]Institut für Physik, Universität Rostock, Albert-Einstein-Straße 23*24, 18059 Rostock

Single microdischarges (MDs) in a barrier corona arrangement are investigated. The discharge is operated in atmospheric pressure, and dry air at 300 SCCM flowrate is used to flush the discharge cell. The radius of curvature of stainless steel pin and the hemispherical alumina-covered electrode are 0.2 and 2 mm, respectively. A sinusoidal voltage at the frequency of 7.5 kHz and amplitude of 11.5 kVpp is applied. Using an ICCD camera and a Rogowski coil current probe, images and current pulses of MDs are recorded simultaneously. Multi-dimensional time correlated single photon counting (TC-SPC) is used to record the phase-resolved spatio-temporal development of the MDs. The properties of MDs apearing in the two polarities of the sinusoidal voltage differ significantly. This contribution will focus on the results of the cathodic pin polaritty. In this polarity, MDs have an erratic behavior in terms of inception phase and current pulse amplitude. Using phase-resolved diagnostic techniques, it is shown that, depending on the inception phase, the development and properties of the MDs vary significantly. MDs appearing in low and high applied voltages are similar to DBD microdischarges and transient sparks, respectively.

P 10: Laser Plasmas II

Zeit: Dienstag 14:00–15:30 Raum: HS 20

Hauptvortrag P 10.1 Di 14:00 HS 20

HiBEF: New vistas into high-field and laser-plasma science — •Toma Toncian — Helmholtz-Zentrum Dresden-Rossendorf, Schenefeld, Germany

Helmholtz International Beamlines for Extreme Fields is an international user consortium of over 80 groups from more than 60 institutes across 16 countries serving a wide scientific community. HiBEF will establish high-repetition-rate ultra-high intensity (200 TW at 10 Hz) and high energy lasers (100 J at 10 Hz), as well as pulsed high-field magnets (up to 60 T in 1 ms, single shot) and diamond anvil cells, and integrate these into the HED instrument at the European XFEL. These will allow researchers to drive plasmas, matter and materials to extremes of pressure, temperature, magnetic and electric fields, and compression at high strain- rate. This will open new vistas in high energy density and plasma physics, strong-field physics, magnetic materials and correlated electron systems, high-pressure physics, planetary science, and material dynamics. A status of the ongoing commissioning and exemplary science cases will be given.

P 10.2 Di 14:30 HS 20

Hot electron dynamics in ultra intense laser plasma experiments revealed from detection of bremsstrahlung spectra — •Maria Molodtsova[1,2], Anna Ferrari[1], Alejandro Laso Garcia[1], Josefine Metzkes-Ng[1], Stephan Kraft[1], Benjamin Lutz[1], Irene Prencipe[1], Manfred Sobiella[1], Daniel Stach[1], David Weinberger[1], Tim Ziegler[1,2], Ulrich Schramm[1,2], and Thomas Cowan[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf (HZDR) — [2]Technische Universität Dresden

Using high-intensity short-pulse lasers ($I \sim 10^{21} W/cm^2$), plasma generation, extreme states of matter and new accelerator concepts are explored, enabling technological breakthrough in material science and medicine. A critical component is the characterization of relativistic electrons that are accelerated and transported in the ionized material of the target, generating ultra-intense bremsstrahlung. Measuring this bremsstrahlung spectrum is therefore a crucial aspect of plasma diagnostics. In this work it is shown how photon spectra can be reconstructed using calorimetric techniques, making possible to study the hot electron dynamics in the laser-generated plasma. Calorimeters with different readouts are under development at HZDR for this purpose. Absorption properties of different targets were studied in a measurement campaign at the in-house Terawatt laser DRACO. A large data set was taken both with passive and active calorimeter prototypes to find correlations between target material and thickness and the resulting electron and ion spectra. Results from this campaign together with the detector concepts are presented here.

P 10.3 Di 14:45 HS 20

Energy enhancement of the target surface electron by using a 200 TW sub-picosecond laser — •Jingyi Mao[1], Olga Rosmej[2], Liming Chen[3], and Thomas Kuehl[2] — [1]Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences, Chongqing 400714, China — [2]GSI Helmholtzzentrum, Darmstadt 64291, Germany — [3]Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China

Compared to the traditional initial confinement fusion (ICF) mechanism, fast ignition greatly lowers the demands of its experimental conditions. Ignition by target surface electrons (TSE) has many advantages[1]; for example, it can be driven by laser pulses, and the beam is of high charge, collimation and mono-energetic property. In our recent work[2], one order of magnitude energy enhancement of the target surface electron beams with central energy at 11.5 MeV is achieved by using a 200 TW, 500 fs laser at an incident angle of 72° with a prepulse intensity ratio of 5x10E(-6). The experimental results demonstrate the scalability of the acceleration process to high electron energy with a longer (sub-picosecond) laser pulse duration and a higher laser energy (120 J). The total charge of the beam is around 400 pC (E>2.7 MeV). Such a high orientation and mono-energetic electron jet would be a good method to solve the problem of the large beam divergence in fast ignition schemes and to increase the laser energy deposition on the target core. [1]J. Y. Mao et al., Phys. Rev. E. 85, 025401 (R) (2012); J. Y. Mao et al., Appl. Phys. Lett. 106, 1311058 (2015). [2]J. Y. Mao et al., Opt. Lett. 43, 3909 (2018).

P 10.4 Di 15:00 HS 20

Absorption of Ultra-short Laser Pulses on Aluminum over a Wide Range of Intensities — •Julian Wegner, Julia Kunzelmann, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich Heine Universität Düsseldorf, Germany

The absorption of intense laser pulses at solid surfaces is described by various different mechanisms which act under specific conditions, respectively. In this talk we present measurements characterizing the absorption of sub 10 fs Ti:Sa-laser pulses and a maximum pulse energy of 0.5 mJ in a 4-orders-of-magnitude-range of intensities between 10^{14} W/cm^2 and 10^{18} W/cm^2. This huge range was made possible by using a novel fully reflective variable pulse energy attenuator which keeps all other spatial and spectral pulse parameters constant. Our results show significant variations of the relative absorption, which are discussed and explained in the talk.

P 10.5 Di 15:15 HS 20

Spectroscopy of Ions Emitted by an Ultra-Short Pulse Laser Plasma — •Jan Riedlinger, Bastian Hagmeister, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

The interaction of ultrashort high-intensity laser pulses with solids generates high temperature plasmas with extremely transient behaviour, of which many aspects are still not fully understood. An important example is the achieved ionization state which is difficult to predict due to the variety of possible processes on ultra-small temporal and spatial scales. We present here experiments aiming at the determination of the various ion species in a plasma created by focusing ultra-short laser pulses with a peak intensity close to 10^{18} W/cm^2 on a solid target. Particles emitted by this plasma propagate into the whole solid angle and reach kinetic energies of several hundred electron volts. We developed a compact and versatile Thomson parabola spectrometer for this purpose which is also presented here.

P 11: Atmospheric Pressure Plasmas III

Zeit: Dienstag 14:00–15:30 Raum: HS 21

Hauptvortrag P 11.1 Di 14:00 HS 21

Electrical and optical characterisation of pulsed, single-filament dielectric barrier discharges on a water surface — •Hans Höft, Manfred Kettlitz, and Ronny Brandenburg — Leibniz-Institut für Plasmaforschung und Technologie e.V. (INP Greifswald), Felix-Hausdorff-Straße 2, 17489 Greifswald

A dielectric barrier discharge (DBD) on purified water was investigated by means of synchronised, fast electrical and optical diagnostics. For that purpose, a single, alumina-covered electrode with 2 mm radius was placed 1.5 mm above a standing liquid surface (purified water) and a grounded tungsten electrode underwater. The gas gap was constantly flushed with 0.1 vol% O_2 in N_2 at atmospheric pressure. The applied high-voltage (HV) pulse with ≈ 15 ns rise time was supplied by a fast Behlke switch using symmetrical, unipolar positive and negative amplitudes of 15 kV at 2 kHz repetition frequency. The diagnostics consisted of fast voltage and current probes and a gated iCCD camera to record the discharge structure occurring during the rising and falling slopes of the HV pulse. The current was measured at the grounded and the HV side. A single discharge event occurs at rising and falling slopes of the HV pulse. Due to character of DBDs the discharge at the slope, which turns to zero, is induced by surface charges on the dielectric surfaces. Depending on the polarity of the HV pulse, the surface charges are either positive (negative HV pulse) or negative (positive HV pulse). Consequently, distinct discharge morphologies were observed and correlated to the discharge current and the transferred charge per discharge event.

P 11.2 Di 14:30 HS 21

Influence of Atmospheric Compounds on Dielectric Barrier Discharge Ionisation for Mass Spectrometry — •Pascal Vogel[1], Ulrich Marggraf[1], Sebastian Brandt[1], Juan F. Garcìa-Reyes[2], Constantinos Lazarou[3], and Joachim Franzke[1] — [1]ISAS, 44139 Dortmund, Germany — [2]Analytical Chemistry Research Group, University of Jaén, Campus Las Lagunillas, 23071 Jaén, Spain — [3]Department of Electrical and Computer Engineering, University of Cyprus, Nicosia, 1678, Cyprus

In the field of analytical chemistry, atmospheric pressure plasmas have gained significant interest within the scientific community, because of their advantages according to supplementary equipment: No vacuum system is needed and measurements can be performed under ambient air. This reduces significantly the costs of analytical applications. Different kinds of plasmas have been developed within this field, such as DART, LTP, ACapI, DBDI. There have been different approaches to improve the analytical performance of those discharges, most of them by changing the plasma gas using different kind of dopants such as hydrogen, oxygen or propane. Within these studies, the interaction of the plasma with the surrounding atmosphere is rarely investigated. We will present a newly designed setup to create a controlled atmosphere that directly connects a dielectric barrier discharge to a mass spectrometer. The influence of different gases in the controlled atmosphere on the ionization efficiency and chemistry in the plasma jet will be demonstrated, without changing the plasma gas itself. Analytical benefits will be evaluated.

P 11.3 Di 14:45 HS 21

Detection and quantification of arsenic in a dielectric barrier discharge with spatial and temporal resolution — •Sebastian Burhenn[1], Jan Kratzer[2], Antje Michels[1], and Joachim Franzke[1] — [1]Leibniz Institut für Analytische Wissenschaften - ISAS - e.V., Bunsen-Kirchhoff-Str. 11, 44139 Dortmund, Germany — [2]Czech Academy of Sciences, Institute of Analytical Chemistry, Veveří 97, CZ-602 00 Brno, Czech Republic

Due to their versatility, plasmas enjoy high popularity in the field of analytical chemistry. In particular, for the detection and quantification of elements, several different plasma based approaches such as inductively coupled plasma mass spectrometry (ICP-MS) became standard. Since the operation of the ICP is related to high costs, dielectric barrier discharges (DBDs) have proven to be a simple and cost effective alternative, achieving excellent detection limits. However, the mechanisms for the atomization and excitation of the analyte in the plasma are not yet fully understood. In this work the emission signal of the model analyte arsenic, which is introduced into a capillary DBD via hydride generation is tracked with spatial and temporal resolved optical emission spectrometry (OES). The plasma inside the capillary DBD is mapped through a monochromator to the CCD of an iCCD-camera serving as a detector with a temporal resolution of 5 ns. It was shown that the emission of arsenic atoms at the 234 nm line is delayed to the emission of the background signal. This enables to temporally separate the analyte signal from the background, which enhances the signal to noise ratio and results in a low detection limit of 93 ppt.

P 11.4 Di 15:00 HS 21

Cold atmospheric plasma analysis for inactivation of bacterial endospores — •Meike Müller[1], Julia Zimmermann[2], Gregor Morfill[2], Petra Rettberg[3], and Hubertus Thomas[1] — [1]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt, Weßling 82234, Deutschland — [2]terraplasma GmbH, Garching 85741, Deutschland — [3]Institut für Luft- und Raumfahrtmedizin, Deutsches Zentrum für Luft- und Raumfahrt, Köln 51147, Deutschland

In space research extra-terrestrial bodies have to be protected from possible contaminations by terrestrial microorganisms. A newly developed plasma afterglow circulation apparatus is presented as a useful sterilization method for spacecraft equipment. The apparatus uses a surface micro-discharge (SMD) to create cold atmospheric plasma (CAP) and operates with ambient air and a relative humidity up to ~ 90 %. Microbiological investigations were executed to test the inactivation efficiency of the apparatus for different treatment volumes. Contact angle and XPS measurements were performed with different materials to test the material compatibility of the plasma treatment. In addition, the composition of the afterglow was analyzed for different humidity conditions and plasma parameters using Fourier Transformation Infrared (FTIR) and UV spectroscopy. The study improves the understanding of the processes which are involved in the inactivation of microorganisms and in the composition of the afterglow plasma. We will give an overview on the status of the plasma decontamination project funded by the Bavarian Ministry of Economics.

P 11.5 Di 15:15 HS 21

Inactivation Depth of *E.coli* Biofilm in Liquids by a Surface Micro-doscharge — •chen-yon tobias tschang and markus thoma — I. Physikalisches Institut, Justus-Liebig Universität Gießen

In this study, we investigated the inactivation of *Escherichia coli* (*E. coli*) biofilm under different depths below liquid surface by two modes of a surface micro-discharge (SMD). Recently, plasma liquid sterilization had been shown to be strongly effective, yet the mechanisms are complex and not well understood. Therefore, we developed a simple method to evaluate the inactivation depth of bacteria biofilm. As *E. coli* are motile bacteria, the tendency of forming biofilm on the gas-liquid interface were used to produce samples with different distance under liquid surface. The plasma source, in our study, is a SMD driven by 5 kHz sinusoidal power input with peak to peak voltage of 8 kV for ozone mode and 12 kV for nitric oxide mode. Inactivation of microbes were tested by BacTiter-Glo assay. Gas phase ozone were evaluated by UV absorption of 254 nm. Radicals in liquid were examined by indigo method for ozone and nitrite/nitrate colorimetric assay. To evaluated the inactivation effect of UV, a MgF_2 plate was applied. Results indicates different inactivation mechanism by two plasma modes. For ozone mode, the inactivation was observed stronger on liquid surface which is believed to be related to the dissolved ozone, while a relatively homogeneous inactivation was observed for nitric oxide mode.

P 12: Plasma Surface Interaction II - Helmholtz Graduate School IV

Zeit: Dienstag 16:30–18:35 Raum: HS 20

Hauptvortrag P 12.1 Di 16:30 HS 20

Hydrogen permeation and retention in ITER steel — •Anne Houben, Jana Scheuer, Arkadi Kreter, Marcin Rasiński, Bernhard Unterberg, and Christian Linsmeier — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany

Fuel retention and hydrogen permeation in the first wall of future fusion devices is a crucial factor in order to estimate fuel losses and to guarantee an economical reactor operation. The main structure material of the ITER wall is 316L(N)-IG steel. Detailed permeation and thermal desorption spectroscopy (TDS) studies were performed on this steel.

The deuterium permeation through the bulk of the sample was measured on polished samples. In order to investigate the influence of technical surfaces, the sample surface was roughened or oxidized and measured. By comparing these results with the polished surface sample, the influence of technical surfaces can be estimated and evaluated.

Furthermore, the structure material will be exposed by high energetic deuterium particles in ITER. Therefore, the influence on the deuterium retention and permeation was studied by exposing 316L(N)-IG samples in the linear plasma device PSI-2 with deuterium plasma and performing permeation and TDS measurements afterwards. By comparing the results with unexposed samples, the change of the deuterium retention and permeation through the ITER wall during operation can be estimated.

P 12.2 Di 17:00 HS 20

Modelling of chemical vapor deposition (CVD) to improve tungsten fiber reinforced tungsten composites (W_f/W) — •L. Raumann[1,2], J.W. Coenen[1], J. Riesch[3], Y. Mao[1,2], D. Schwalenberg[1,2], H. Gietl[3], T. Höschen[3], Ch. Linsmeier[1], and O. Guillon[1,2] — [1]Institut für Energie und Klimaforschung, Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Rheinisch-Westfälische Technische Hochschule Aachen, 52062 Aachen — [3]Max-Planck-Institut für Plasmaphysik, 85748 Garching b. München

Due to many excellent material properties, tungsten is currently the main candidate for the first wall material in future fusion devices. However, its intrinsic brittleness and its susceptibility to operational embrittlement are still a major concern. To overcome this drawback, W_f/W composites featuring pseudo-ductility are developed. Bulk material can be successfully produced by coating tungsten fabrics via CVD. However, a fully dense composite with a high fiber volume fraction (30-40%) is still a challenge. Therefore, a Comsol model is developed including the complex coupling of transport phenomena, chemical reaction kinetics and solid domain growth. The model was successfully validated experimentally for the deposition on single tungsten fibers in heated tubes varying the temperature, partial pressures and gas flow. Currently, the model is validated against the infiltration of tungsten fabrics with varying fiber distances. As next step the process parameters and the fabric geometry will be optimized within the model to acquire the recipe for a fully dense W_f/W composite with a sufficient high fiber volume fraction.

P 12.3 Di 17:15 HS 20

Impact of fusion-relevant plasmas on WCrY Smart Alloys — •Janina Schmitz[1,2], Andrey Litnovsky[1], Felix Klein[1], Karen De Lannoye[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

Only few materials are suitable to withstand the high heat and particle loads of the first wall of future fusion devices such as DEMO. While advantageous properties like, among others, low tritium retention and low sputter yields make tungsten (W) a suitable plasma-facing material, its disadvantageous property of fast oxidation in oxygen-containing environment may disqualify it. For this reason self-passivating chromium(Cr)-containg smart alloys (WCrY) are developed aiming at suppressing W oxidation in case of accidental scenarios in DEMO. Exposure to steady-state deuterium (D) plasma at low ion energies of around 120 eV up to a fluence of $1 * 10^{26}$ ions/m^2 has proven W-like erosion yields for the smart alloys [1]. In order to estimate the lifetime of plasma-facing materials like WCrY in more fusion-relevant conditions plasma exposure to different gas mixtures and moreover higher fluences is necessary. Results of a recent D exposure with increased fluence are presented in this contribution. Further, the results of oxidation in dry atmosphere at 1000 °C of plasma-exposed WCrY samples is discussed.

[1] J. Schmitz et al., Nuclear Materials and Energy 15 (2018) 220-225

P 12.4 Di 17:30 HS 20

Development of components for fiber reinforced tungsten (Wf/W) produced by chemical vapor deposition — •Daniel Schwalenberg[1,3], Jan Willem Coenen[1], Johann Riesch[2], Leonard Raumann[1], Yiran Mao[1], Alexis Terra[1], Till Höschen[2], Rudolf Neu[2,3], and Christian Linsmeier[1] — [1]Institut für Energie und Klimaforschung, Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Max-Plank-Institut für Plasmaphysik, 85748 Garching b. München — [3]Technische Universität München, 85748 Garching b. München

The harsh conditions at the divertor in fusion reactors lead to very high demands for the first wall materials. Due excellent thermal properties, low sputter yield, hydrogen retention and low activation tungsten is the most promising candidate. The biggest issue for tungsten is the brittleness, which can lead to catastrophic failures of components. To compensate for the brittle behavior, a tungsten fiber reinforced composite material (Wf/W) is being developed. Because of the production process, the tungsten fibers are ductile. Together with a tungsten matrix they can be combined to form a pseudo-ductile material. To further characterize and improve the material, larger amounts of Wf/W have to be produced. Therefore the experimental setup was upgraded and the production speed increased. The next steps are first to establish a process to produce large amounts of Wf/W and second to determine the needed properties of the material for the application as divertor material. So that the material can be improved to meet the needed requirements for the implementation as a divertor component.

P 12.5 Di 17:45 HS 20

Ga^+ Sputtering of tungsten in regard to the Crystal Surface Orientation — •Karsten Schlüter[1,2], Martin Balden[1], Tiago Fiorini da Silva[3], and Kai Nordlund[4] — [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 — [4]Department of Physics, P.O. Box 43, FIN-00014 University of Helsinki, Finland

Properties like sputtering or oxidation are influenced by the crystal orientation. To investigate this effect, a measuring method is developed to study the dependency of W properties on its crystal orientation to benchmark sputtering theories and to predict the properties of textured materials.

A polycrystalline polished W sample was sputtered with a 30 keV Ga ion beam. Sequentially the crystal orientations were analyzed using electron backscatter diffraction and the height measurement was measured with a convocal laser scanning microscope.

The height information is visualized in an inverse pole figure, representing the sputter yield in all crystal orientation. The sputter yield changes more than one order of magnitude with the crystal orientation. Molecular dynamic simulations confirm the experimental results.

P 12.6 Di 18:10 HS 20

Induction-heating based gas loading of tungsten samples for determination of protium and deuterium diffusion parameters in tungsten — •Georg Holzner[1,2], Thomas Schwarz-Selinger[1], and Udo von Toussaint[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching — [2]Technische Universität München, Boltzmannstraße 15, 85748 Garching

For future fusion power plants, it will be important to predict fuel retention and transport, i.e. deuterium and tritium, in the first wall, which will probably be made of tungsten. Retention and transport modelling depend on a proper description of diffusion. For the most basic hydrogen isotope protium, the generally accepted experimental diffusion parameters stem from Frauenfelder from the late 60s. Since then, measured values scatter by several orders of magnitude, for which presumably trapping effects are the reason. Recent DFT-results question the Frauenfelder value. Furthermore, for deuterium in tungsten the amount of available data is even more scarce.

For this reason, the diffusion of protium and deuterium in tungsten was measured as well as their solubilities. This has been performed at temperatures between 1800 and 2600 K, because at these temperatures trapping effects can be neglected and pure diffusion is the governing transport effect. An ultra high vacuum (UHV)/gas loading experiment was designed and built. The measured diffusion equation for protium deviates considerably from Frauenfelder's value, the diffusion prefactor for deuterium does not follow classical predictions.

P 13: Mitgliederversammlung / General meeting of members

Zeit: Dienstag 18:45–20:00 Raum: HS 20

Mitgliederversammlung / General meeting of members

P 14: Complex and Dusty Plasmas II

Zeit: Mittwoch 11:00–12:40 Raum: HS 20

Hauptvortrag P 14.1 Mi 11:00 HS 20

Plasmas and the tailoring of nanomaterials — •Uros Cvelbar — Jozef Stefan Institute

In the recent direction of research, plasmas are being more and more used for tailoring nanomaterials, and to advance their properties, for example, to make them more efficient in catalysis. The aim is either to find alternative routes for the fast, large-scale synthesis of unique nanomaterials and/or their conversion. Low-temperature plasmas have proven to be a great source for the surface manipulations or supplying building blocks for nanomaterials. Furthermore, the specific plasma-surface interactions are leading to synergistic effects, where very little is understood regarding basic processes taking place. To understand these processes at the atomic scale and mechanisms taking place, we implemented different low-pressure plasma treatments of nanoscale materials such as nanowires or nanoparticles. As results of interactions of various plasma species including electrons or neutral atoms, the intrinsic properties of nanomaterials change. These observations are supported by analytical methods in order to unravel what is occurring on nanomaterial surface or bulk. Through the changes in the crystalline structure of material or reorganisation of its surfaces, the functionality of materials in applications such as gas sensing, liquid purification or similar, are significantly changed.

P 14.2 Mi 11:30 HS 20

Diagnostics and phenomena of three-dimensional dusty plasmas — •Michael Himpel and André Melzer — University Greifswald, Germany

Dusty plasmas are plasmas that contain micrometer-sized particles, which can be individually imaged by modern cameras. In the laboratory, the particles usually sediment to the bottom of the plasma due to the gravitational force where they form flat systems. Many interesting effects, e.g. self-excited waves and certain phase transitions, are only present in volumetric systems. These effects are often related to a critical dust particle number density, which can be exceeded in three-dimensional, but not in two-dimensional systems. This talk will show different possibilities to realize experiments with three-dimensional dusty plasmas and a brief overview about different phenomena is given. Additionally, imaging diagnostics are presented that are capable to retrieve three-dimensional particle trajectories in three-dimensional particle systems.

P 14.3 Mi 11:55 HS 20

Classic textbook experiment on entropy in binary complex plasmas — •Frank Wieben and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

In physics textbooks a classic example to illustrate the concept of entropy considers two systems that are brought into thermal contact. The change in entropy of the whole system is determined by the initial temperatures and heat capacities of the subsystems and the final temperature. To realize this gedankenexperiment turns out to be difficult since the entropy has to be measured and the two systems have to be brought into contact without creating entropy while removing the barrier itself. In two-dimensional complex plasmas the full phase space information is readily available and thermodynamic phenomena can be studied on the single particle level. In this contribution we reenact this textbook experiment and show that two particle species in a binary complex plasma can serve as two isolated subsystems where the isolation can be switched off instantaneously. Binary complex plasmas contain two particle species of different sizes and materials. The two subsystems are represented by the particle species which attain different temperatures in a laser heating scenario. Due to the nature of the laser forces acting on the particles the temperature ratio can be adjusted by variation of neutral gas pressure. The changes in entropy are determined from phase spaces and results of both experiment and numerical simulation are validated through the heat capacity. This work has been supported by the Deutsche Forschungsgemeinschaft (DFG) in the framework of SFB TR24, Project A3b and Research Grant BL555/3-1.

P 14.4 Mi 12:10 HS 20

Wave transmission across an interface in a complex plasma — •Mierk Schwabe[1], Cheng-Ran Du[2], Wei Sun[2], Li Yang[2], and Hubertus Thomas[1] — [1]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR), 82234 Weßling, Germany — [2]College of Science, Donghua University, 201620 Shanghai, PRC

Complex plasmas consist of low-temperature plasmas with embedded microparticles. The microparticles acquire electric charges of thousands of electrons and strongly interact with each other. Due to their relatively large size and slow speed, their movement can be recorded with digital cameras and traced from frame to frame. Here, we study the propagation of waves across an interface formed between two subclouds of microparticles of different sizes. For this, we use data recorded under microgravity using the PK-3 Plus Laboratory on board the International Space Station, as well as Langevin dynamics simulations of a complex plasma. Firstly, we study how self-excited waves are transmitted across the interface and demonstrate that a collision zone and a merger zone form. Secondly, we study the propagation of a solitary wave across an interface and demonstrate that at low pressures, reflection at the interface can be observed.

P 14.5 Mi 12:25 HS 20

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

Dusty plasmas allow to access the dynamical behavior of single dust particles, making them a suitable tool for studying phase separation processes. To prevent the particles from sedimenting in the lower discharge sheath and, hence, to be able to observe three-dimensionally extended systems, measurements are conducted under microgravity conditions on parabolic flights. Binary systems consisting of two particle species exhibit phase separation even for small relative size disparities of about 3%. Particles marked with a fluorecscent dye are used for one of the species. This makes it possible to distinguish between the species despite their small size disparity using a two-camera video microscopy setup and appropriate filters. The availability of high-resolution, high-speed cameras allows to track single particles during the separation process. As the particle number density as well as the flux is available, diffusion coefficients can be determined. In this contribution, measurements conducted on two parabolic flight campaigns are presented. This work was supported by DLR under grant no. 50WM1638.

P 15: Helmholtz Graduate School V - Magnetic Confinement II

Zeit: Mittwoch 11:00–13:05 Raum: HS 21

Hauptvortrag P 15.1 Mi 11:00 HS 21

Turbulence in the Wendelstein 7-X Stellarator — •Adrian von Stechow for the The Wendelstein 7-X Team-Collaboration — Institut für Plasmaphysik, Greifswald, Germany

A central design goal of magnetic confinement fusion devices is the minimization of heat and particle losses to their walls. The Wendelstein 7-X superconducting stellarator has a neoclassically optimized (and variable) 3D magnetic field geometry, such that turbulent transport can be a major loss channel. These losses are expected from analytical and numerical models to be highly geometry-dependent, both in terms of density and temperature profiles as well as geometrical properties of the field itself, e.g. local flux compression and symmetries such as quasi-isodynamicity. Turbulence in W7-X has therefore been experimentally investigated in the recently completed campaign that demonstrated long pulse operation at high density and triple product using a range of dedicated diagnostics which provide coverage from the plasma core to the scrape-off layer. Comparison of neoclassical transport simulations of plasma profiles with measured ones, as well as radial diffusion coefficient measurements based on particle transport studies suggest that a significant fraction of transport is indeed turbulent. Ion-scale turbulence is generally observed in the confied region, and is shown to be significantly reduced by profile shaping during pellet-fueled discharges while confinement is improved. Gyrokinetic simulations support these findings by showing that ITG and TEM growth rates are minimized when the ion temperature and density gradients are of similar magnitude and spatially overlap.

Hauptvortrag P 15.2 Mi 11:30 HS 21

Reduction of microwave beam quality due to plasma density fluctuations — •Alf Köhn[1], Pavel Aleynikov[2], Lorenzo Guidi[3], Eberhard Holzhauer[1], Omar Maj[3], Emanuele Poli[3], Michael Brookman[4], Antti Snicker[3], Thomas Matthew[5], Roddy Vann[5], and Hannes Weber[3] — [1]IGVP, Universität Stuttgart, Germany — [2]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [3]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [4]Institute for Fusion Studies, Austin, Texas — [5]York Plasma Institute, York, U.K.

Microwaves are commonly used in plasma experiments for heating and diagnostic purposes. When passing through the plasma boundary, the microwaves have to traverse an area where significant density fluctuations are known to occur. The beam is disturbed, resulting in reduced heating efficiencies or ambiguous diagnostics results. This is in particular problematic for the stabilization of MHD modes, which requires a highly localized power deposition. Concern has been raised recently if ITER might suffer from this. Here we present full-wave simulations of the interaction of microwaves with a layer of fluctuating plasma density. A novel wave-kinetic equation solver using a statistical description of the turbulence is compared to the full-wave simulations. The broadening of a microwave beam is investigated as a function of the turbulence properties. The possibility of density variations leading to mode-scattering is discussed. Finally, experimental verification of microwave beam broadening caused by edge density fluctuations is presented and compared with simulations for the DIII-D tokamak.

P 15.3 Mi 12:00 HS 21

Edge fast-ion transport study using passive FIDA spectroscopy at ASDEX-Upgrade — •A. Jansen van Vuuren, B. Geiger, P.A. Schneider, A. Jacobsen, K. Mitosinkova, and The ASDEX-Upgrade Team — Max-Planck-Institut für 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, instabilities and asymmetries in the magnetic field structure might redistribute fast-ions to unconfined orbits which is of particular importance for fast particles close to the plasma boundary.

A standard technique to obtain radial information on the fast-ion content is fast ion D-alpha (FIDA) spectroscopy, which measures the Doppler shifted Balmer alpha emission resulting from charge exchange reactions between fast ions and donor neutrals. On the one hand, donor neutrals are introduced by neutral beams causing so-called active FIDA radiation. On the other hand, thermal neutrals from the walls yield passive FIDA radiation which contains useful information on the fast-ion density close to the plasma edge.

This talk presents results based on the analysis of passive FIDA radiation. Background neutral densities are calculated with KN1D, with the passive D-alpha emission used as a constraint. Measurements from edge lines of sight show strongly reduced FIDA intensities after edge-localized modes. Forward modelling indicates a reduction in fast-ion density along the lines of sight, since the background neutral density is required to increase to match the passive D-alpha emission.

P 15.4 Mi 12:25 HS 21

Gas balance of Wendelstein 7-X — •Georg Schlisio, Uwe Wenzel, Thomas Sunn Pedersen, and W7X Team — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald

Wendelstein 7-X is the worlds most advanced stellarator fusion experiment. With its graphite island divertor and steady state magnetic field, it is designed for long pulse operation up to 30 minutes. This requires a continuous fuel cycle of particle input and exhaust. An accounting of all gas sources and sinks is done in a gas balance. A global approach to the gas balance is presented, along with results from the first divertor operation campaign OP1.2.

The effects of different fueling schemes as well as neutral beam heating is considered and evaluated with respect to the gas balance.

The particle output was diagnosed with total pressure gauges and a diagnostic RGA to provide more detailed insight into gas output.

P 15.5 Mi 12:50 HS 21

Towards efficient fuelling control in nuclear fusion devices: investigations at ASDEX Upgrade — •Peter Thomas Lang, Bernhard Ploeckl, and ASDEX Upgrade Team — Max-Planck-Insitut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

Efficient fuelling will be a critical task in a future nuclear fusion power plant. Basic requirement of any approach is to establish a plasma core density sufficiently high to harvest ample fusion power. This has to be achieved with high efficiency in order to keep the related burden on the fuel cycle and with respect to the stored reservoir of hazardous fuel low. To develop suitable strategies and useful tools for the emerging control and actuation needs, an ambitious R&D program is carried out at ASDEX Upgrade, a reactor relevant all-metal-wall mid-size tokamak. Particle fuelling in the planned EU-DEMO reactor is assigned to the injection of mm sized pellets composed from solid fuel. Investigations anticipated the multi-purpose challenges in a reactor by trying to establish, with restricted diagnostics capabilities, feedback core density control while keeping the plasma performance high. Simultaneously, the isotopic mixture for optimised burn conditions has to be kept. Pellets proved also useful as probe for physics investigations and auxiliary matter injection needs. Our investigations demonstrated pellet fuelling in the high-density high-confinement regime providing control over the relevant parameters; even synergetic effects have been found improving simultaneously both pellet and plasma performance. However, in this pellet created regime the observed plasma behaviour sometimes significantly deviates from extrapolation-based predictions.

P 16: Low Pressure Plasmas II

Zeit: Donnerstag 11:00–12:25 Raum: HS 21

P 16.1 Do 11:00 HS 21

Velocity distribution of titanium neutrals in the target region of high power impulse magnetron sputtering discharges — •Julian Held[1], Ante Hecimovic[2], Achim von Keudell[1], and Volker Schulz-von der Gathen[1] — [1]Experimental Physics II, Ruhr University Bochum, Germany — [2]Max Planck Institute for Plasma Physics, Garching, Germany

The velocity distribution function of titanium neutrals in the target region of a high power impulse magnetron sputtering discharge was investigated by optical emission spectroscopy. A high-resolution plane grating spectrograph combined with a fast, gated, intensified CCD camera was used to study the shape of selected optical emission lines. Doppler broadening and shift were analyzed to gain information about the velocity distribution of sputtered titanium neutrals. The velocity distribution function was found to depend on the discharge power for target power densities up to 0.6 $kW\,cm^{-2}$. Above that value, the velocity distribution was constant. The collision processes of sputtered neutrals close to the target were described using a modified version of the Krook collisional operator. Using this interpretation, evidence for strong scattering of the titanium neutrals in the target region was found. This scattered population is found to be created from previously scattered ions by resonant charge exchange.

P 16.2 Do 11:25 HS 21

Plasma chemical studies of nitrocarburizing plasmas with a carbon active screen in industrial and laboratory reactors — •Alexander Puth[1], Stephan Hamann[1], Lukas Kusýn[1,2], Igor Burlacov[3], Anke Dalke[3], Horst Biermann[3], Jürgen Röpcke[1], and Jean-Pierre van Helden[1] — [1]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany — [2]Masaryk University, Brno, Czech Republic — [3]Institute for Materials Engineering, TU Bergakademie Freiberg, Germany

Active screen plasma nitrocarburizing (ASPNC) is a process to enhance the tribological properties of steel components. As a possible advancement, the use of a carbon active screen as a substitute for carbon-containing feed gas admixtures is investigated. Therefore, carbon fibre composite screens have been studied in low-pressure pulsed dc N_2-H_2 plasmas on industrial- and laboratory-scale. The plasma chemical conditions were monitored in-situ by laser absorption spectroscopy (LAS) with tunable diode lasers (TDL), external-cavity quantum cascade lasers (EC-QCL), and a frequency comb.
We will present concentrations of CH_3, CH_4, C_2H_2, C_2H_4, C_2H_6, C_2N_2, CO, CO_2, HCN, H_2O, and NH_3 in dependence on plasma power, gas pressure, flow, and precursor composition. Translational and rotational temperatures of selected species were determined by line profile analysis and Boltzmann plots. Measured concentrations ranged from 10^{12} to 10^{16} molecules cm^{-3}, with temperatures reaching up to 800 K. Analysis of surface-microstructures of treated samples complements the LAS measurements for improved process understanding.

P 16.3 Do 11:40 HS 21

Study of particle transport above the target in high power impulse magnetron sputtering plasmas using a marker technique — •Sascha Thiemann-Monjé, Marc Sackers, and Achim von Keudell — Ruhr University Bochum, Germany

High power impulse magnetron sputtering (HiPIMS) has established itself as one of the premier methods for depositing high-quality hard coatings. Nevertheless, the plasma discharge itself is not fully understood yet. Especially the potential structure of the so-called spokes, which are believed to be rotating instabilities and the particle movement inside the plasma are part of current research. Both affect the redeposition of particles on the magnetron target surface during the plasma discharge.

In this work, a marker technique for the analysis of the particle transport inside the plasma is introduced. The marker targets are made of 50 mm Al magnetron targets with a different metal in form of a cylindrical insert placed in the middle of the racetrack. The distribution of redeposited marker material on the surface is analyzed by spatially resolved X-ray photoelectron spectroscopy (XPS) and combined with electrical and optical measurements of the plasma discharge.

It could be shown that the distribution of marker material contains information about the plasma discharge. Particularly correlations with the marker material as well as the discharge power were found. It was as well possible to find evidence for the assumed potential structure of the spoke phenomenon.

P 16.4 Do 11:55 HS 21

Separated effects of plasma particle species during surface activation — •Beatrix Biskup[1], Marc Böke[1], Jan Benedikt[2], and Achim von Keudell[1] — [1]Experimental Physics II - Reactive Plasmas, Ruhr-University Bochum, 44780 Bochum, Germany — [2]Experimental Plasma Physics, Christian-Albrechts-University Kiel, Germany

A short plasma pre-treatment can improve the barrier effect of a-C:H /a-Si:H multilayers on polymer substrates, while a prolonged treatment can negatively influence the properties. In this work, we are investigating the influence of different plasma particle species, namely ions, metastables and (V)UV-photons, during the surface activation in an inductively coupled plasma.

To separate the different species, we build an ion-repelling grid system (IReGS), which repels ions from the substrate. In a second approach we further separate the effect of argon metastables from the effect of (V)UV-photons.

The change in surface energy of the polymer substrate is than analyzed by contact angle measurements at different activation times and particle composition to find an optimal activation process.

P 16.5 Do 12:10 HS 21

Directionally resolved characterization of momentum transfer during sputter processes — •Mathis Klette, Thomas Trottenberg, Manuel Maas, and Holger Kersten — Institute of Experimental and Applied Physics (IEAP), Kiel University, Germany

In the past, the directional distributions of reflected and sputtered particles of a sputter plume have been investigated using various methods like mass spectrometry, optical emission spectroscopy, or quartz crystal microbalances. Some of these methods require a complex setup, while others can only detect certain species of particles or rely on secondary effects like deposition.

In this study, we present a characterization of sputter plumes using interferometric force probes [1]. In contrast to conventional diagnostics, these probes do not require a complex setup and they can measure the momentum flux of all charged and neutral species. In the experiment, an ion beam is focused on a rotatable sputter target. For different angles of incidence, a force probe rotating around the target characterizes the sputter plume. A second force probe determines the vector of the force acting on the sputter target. The angular ejection distributions are compared with simulated data based on the sputter code SRIM [2]. For the experiment, copper and silver targets and different noble gases were used. The energy of the impinging ions and the background gas pressure were varied to change the momentum transfer.

[1] Spethmann et al., **24**(2017), 093501.
[2] J. Biersack et al., Nucl. Instrum. Methods **174**, 257 (1980).

P 17: Helmholtz Graduate School VI

Zeit: Donnerstag 14:00–16:15 Raum: HS 21

Hauptvortrag P 17.1 Do 14:00 HS 21

Impurity Transport Investigations at the Wendelstein 7-X Stellarator — •Rainer Burhenn and W7-X Team — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

A critical issue for fusion devices is the plasma contamination by impurities released by interaction of the plasma with plasma-facing components. Depending on impurity concentration they can cause unacceptable dilution of the fusion fuel and substantial radiation cooling in case of highly charged species. The latter might lead to degraded plasma performance or even plasma termination either by an abrupt disruption as in tokamaks or a soft radiative collapse as in devices with small plasma currents such as stellarators. The magnetic field of the superconducting modular stellarator Wendelstein 7-X is optimized to reduce the enhanced particle transport at low collisionality, typically inferred by non-axisymmetric configurations. This allows for long-pulse operation with good energy confinement. For impurities, nevertheless, theory predicts inwards directed fluxes at high densities, potentially causing accumulation and endangering long-pulse operation. However, the latter had not been observed for microwave heated W7-X plasmas so far, indicating the existence of additional transport channels. First modelling of experiments with active impurity tracer injection reveals predominantly anomalous diffusive transport. For clearification of the relevance of turbulence for the observed impurity transport properties a comparison of impurity and bulk plasma confinement with turbulence measurements and gyrokinetic calculations is under investigation.

Hauptvortrag P 17.2 Do 14:30 HS 21

The role of the radial electric field in the edge of fusion plasmas — •Marco Cavedon[1], Gregor Birkenmeier[1], Ralph Dux[1], Tim Happel[1], Ulrike Plank[1], Thomas Pütterich[1], Francois Ryter[1], Ulrich Stroth[1], Eleonora Viezzer[2], Matthias Willensdorfer[1], Elisabeth Wolfrum[1], and The Asdex Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, Garching (Germany) — [2]Dept. of Atomic, Molecular and Nuclear Physics, Uni. Seville, Seville (Spain)

It is widely accepted that the edge radial electric field (E_r) gradient and the accompanying $E \times B$ velocity shear is responsible for the suppression of the edge turbulence, thus leading to the transition from the low (L-) to the high (H-) confinement mode in diverted tokamaks. The latter shows a factor of two higher energy confinement time making this regime the baseline for any future fusion device based on the tokamak concept. However, the origin of E_r is still debated. The $E \times B$ flow may be generated by turbulence stresses, collisional (neoclassical) processes via the main ion pressure gradient or by any non-ambipolar transport process. Several experiments were performed at the ASDEX Upgrade tokamak to clarify the dominant drive of E_r. A comparison of neoclassical $E_{\mathrm{r,neo}}$ and of measured E_r profiles close to the L-H transition and during a complete edge localized mode cycle shows the main role of the neoclassical contribution to the $E \times B$ velocity. In line with the above, across a large database of L-H transitions the same $E \times B$ shear is observed at the H-mode onset, which indicates that the key role of $E_{\mathrm{r,neo}}$ is a general property.

P 17.3 Do 15:00 HS 21

2D impurity ion flow characteristics in different Wendelstein 7-X island divertor configurations — •Valeria Perseo[1], Ralf König[1], Dorothea Gradic[1], Oliver Patrick Ford[1], Florian Effenberg[2], David Ennis[3], and Thomas Sunn Pedersen[1] for the The Wendelstein 7-X Team-Collaboration — [1]Max Planck Insitut für Plasmaphysik, Greifswald, Germany — [2]University of Wisonsin, Madison, USA — [3]Auburn University, Auburn, USA

The last campaign of Wendelstein 7-X (W7-X) was characterized by the island divertor. This concept exploits the stellarator intrinsic magnetic island topology, that is inherently 3D. In this context, a system able to measure 2D Doppler velocity patterns, such as Coherence Imaging Spectroscopy (CIS), is helpful to understand and confirm the basics of the impurity flow physics. The CIS diagnostic is a camera-based interferometer able to detect wavelength variation of the order of tens of pm (∼tens km/s) of an impurity selected by a narrow bandpass filter. A modulation pattern encoding the spectral line properties is generated by the usage of birefringent crystals. Two systems, set up in order to monitor the conditions of the same divertor module from nearly perpendicular lines of sight, have been designed for W7-X. Flows and line emissions have been recorded under different magnetic and plasma configurations, characterizing the behavior of the intrinsic carbon impurities. The measurements are compared with EMC3-EIRENE simulations, highlighting the presence of counter-streaming flows around the magnetic islands.

P 17.4 Do 15:25 HS 21

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

Simultaneous, non-invasive and continous measurement of plasma density, temperature and potential is a unique capability of langmuir probes. During the operation phase 1.2b of the stellerator Wendelstein 7-X two newly installed fast swept Langmuir systems were operated, sampling these quantities with typically 50 kHz.

The first system is a Mirror Langmuir Probe, a time domain triple probe with automatic bias adjustement based on the work of LaBombard (RSI 78, 2007). The second is a new development we call Bridge Probe, removing transmission line influences with a compensation cable.

The two systems are described and evaluation methods explained. Fluctuation results are related to local and global plasma parameter averages, and their spectra discussed in detail. This analysis will guide futher development of diagnostics for the steady state high heatflux divertor operation phase of Wendelstein 7-X.

P 17.5 Do 15:50 HS 21

Parametric Decay Instabilities in the Electron Cyclotron Resonance Heating Beams at ASDEX Upgrade — •Søren Kjer Hansen[1,2], Stefan Kragh Nielsen[2], Jörg Stober[1], Jesper Rasmussen[2], Mirko Salewski[2], Morten Stejner[2], and the ASDEX Upgrade Team[3] — [1]Max-Planck-Institut für Plasmaphysik, D-85748 Garching b. München, Germany — [2]Department of Physics, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark — [3]See Appendix in *Nucl. Fusion* **57**, 102015 (2017)

In a parametric decay instability (PDI), a large-amplitude pump wave decays to two daughter waves once its amplitude exceeds a nonlinear threshold. PDIs determine the limit of validity of linear theories in quadratically nonlinear media, such as fluids and plasmas. Here, we consider PDIs occurring in connection with injection of high-power mm-waves for electron cyclotron resonance heating (ECRH) of the fusion-relevant plasmas at the ASDEX Upgrade tokamak. We particularly investigate PDIs near the fundamental and second-harmonic upper hybrid resonance (UHR). Near the UHR strong field enhancement leads to the PDI threshold being exceeded at typical ECRH power levels. We have experimentally confirmed theoretical predictions of the PDI threshold and characterised the nonlinear response beyond the threshold for these PDIs. Near the second-harmonic UHR trapping of the daughter waves is required to reduce the PDI threshold to a level accessible with ECRH; this may occur near a local maximum of the electron density. We have investigated such PDIs near the plasma centre, in connection with edge localised modes, and in magnetic islands.

P 18: Postersitzung

Zeit: Donnerstag 16:30–18:30 Raum: Foyer Nordbau

P 18.1 Do 16:30 Foyer Nordbau

Modeling and Study of a Remote Plasma Source for High-rate Etching — •Steffen Pauly[1], Andreas Schulz[1], Matthias Walker[1], Bernhard Schmid[1], Günter Tovar[1], 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 industry for lithographic processes to produce surface structures in the sub-micrometer range. In the final step of the manufacturing process, the cured polymer layer acting as shaping die for the microstructures grown by electroplating must be removed. Etching of the cured resist pattern poses an extreme challenge, as the microstructures must not be damaged. Dry plasma chemical etching by means of radicals generated in the plasma chamber of a remote plasma source (RPS) is a suitable means avoiding damage to the microstructures made of metals like nickel, copper or gold. Using FEM, a model of the RPS has been developed to investigate the microwave distribution and the microwave coupling into the plasma chamber. The E-field distribution is experimental measured by heating up substrates and visualized by liquid-crystal sheets and thermal camera pictures. If a plasma is ignited, the electron density and thus the permittivity and the conductivity increase, which changes the electric field distribution in the plasma chamber. For this purpose, the model has been extended in a first step by a Drude model. To validate the Drude model, Langmuir- and double probe measurements were made, as well as pictures with a high-speed camera system.

P 18.2 Do 16:30 Foyer Nordbau

A Synthetic Doppler Reflectometry Diagnostic For Fusion Plasma Turbulence — •Carsten Lechte[1], Garrard Conway[2], Tobias Görler[2], Tim Happel[2], Kevin Schöbel[1], and The ASDEX Upgrade Team[2] — [1]IGVP, Stuttgart University, 70569 Stuttgart, Germany — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

Doppler reflectometry or Doppler backscattering is a localised scattering technique for plasma density fluctuations in the millimetre wave range (40–110 GHz). It is used to measure the wavenumber spectrum of the turbulent density fluctuations in fusion plasmas. Fullwave simulations of the reflectometer with the code IPF-FD3D are used to link the fluctuation spectra of plasma turbulence simulations (using the GENE code) to the experimental data that is available for the tokamak ASDEX Upgrade.

New high resolution simulations show the non-linear scattering properties of the plasma at the edge density fluctuation levels that have been observed in ASDEX Upgrade. Experimental and simulation spectra are shown to be in good agreement.

P 18.3 Do 16:30 Foyer Nordbau

Improvement of the Sauter model for the bootstrap current in tokamaks — •Andreas Redl[1,2], Clemente Angioni[1], Emily Belli[3], Olivier Sauter[4], and Hartmut Zohm[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Deutschland — [2]Fakultät für Physik, LMU, München, Deutschland — [3]General Atomics, San Diego, USA — [4]Swiss Plasma Center, EPFL, Switzerland

In tokamaks, the radial gradients of densities and temperatures produce the bootstrap current, parallel to the magnetic field. This current is an important part of the total plasma current, particularly in advanced scenarios where the Ohmic current is kept limited. A precise calculation of the bootstrap current is essential for realistic reconstructions of the current density profile, as well as for the computation of transport and MHD instabilities. A widely used model is the Sauter model[1].Due to its analytical form, it is very practical to be included in codes, without requiring additional computational time. However, comparisons with the more recently developed code NEO[2], a highly benchmarked fast drift-kinetic solver for neoclassical transport, show that the Sauter model can significantly deviate, particularly at high collisionality, which limits its applicability to the calculation of edge stability. Having realized this disagreement, we plan to improve the Sauter model by keeping the same analytical structure, but modifying the numerical coefficients in order to increase the agreement with NEO. The first results of this project will be presented. [1] O. Sauter et al Phys. Plasmas 6, 2834 (1999), ibid. 9 5140 (2002). [2] E.A. Belli and J. Candy, Plasma Phys. Control. Fusion 54, 015015 (2012).

P 18.4 Do 16:30 Foyer Nordbau

"PICLS" - Development of a Gyrokinetic Particle-in-cell code for the scrape-off layer — •Mathias Boesl, Andreas Bergmann, Alberto Bottino, David Coster, and Frank Jenko — Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany

Plasma properties (density/temperature) at the plasma edge and in particular the scrape-off layer significantly influence plasma confinement. Thus, to understand and control plasma properties of the Tokamak edge is crucial. Especially steep gradients and large amplitudes of disturbance within the scrape-off layer region increase complexity. To further examine this topic the PIC-code "PICLS" (technology heavily based on ORB5 PIC-code) is currently under development.

"PICLS" in a first step targets to study sheath boundary conditions at the plasma/wall interface. In particular, the logical sheath - which is designed to model a Debye sheath at the boundary without actually resolving it - will be researched. For a Gyro-kinetic model this approach seems advantageous, but its usability still needs to be studied further. The gained expertise will be used for further development of the already existing core code ORB5 towards the plasma edge. Also a benchmark with other codes (e.g., Gkeyll, GENE) that address scrape-off layer physics is planned.

The main novelty of this approach consists in studying scrape-off layer models with a combination of a PIC code and a Gyro-kinetic model. The high performance and validity of this approach could already be shown within the core, but the usability within the scrape-off layer still needs to be tested.

P 18.5 Do 16:30 Foyer Nordbau

Towards Gyrokinetic Turbulence in the Scrape-Off Layer with GENE — •Dominik Michels, Paul Crandall, Denis Jarema, Maurice Maurer, Alejandro Banon Navarro, and Frank Jenko — Max-Planck-Institut für Plasmaphysik, Garching, Deutschland

Studying, understanding and predicting the effects of plasma turbulence in the Scrape-Off layer of a plasma device is of highest importance for future fusion power plants. Our goal is to study the turbulence with the gyrokinetic code GENE. In order to apply GENE successfully in the Scrape-Off layer multiple adaptions to the code are necessary.

Fluctuations of the plasma in the Scrape-Off layer are known to be strong. Therefore non-linear effects, arising from couplings between fluctuations, become important and need to be included in the GENE code. As a first step we implemented and tested a non-linear Focker-Planck-Landau collision operator acting on the full phase space distribution function. The implementation is based on the work by Hager et al. [1] and E. S. Yoon et al. [2].

We demonstrate that the implementation of the collision operator in GENE preserves particles, energy and momentum. Furthermore we present results on temperature relaxation in collisions between different species with realistic mass ratios.

[1] R. Hager et al., Journal of Computational Physics 315 (2016) 644–660.

[2] E. S. Yoon et al., Physics of Plasmas 21, 032503 (2014)

P 18.6 Do 16:30 Foyer Nordbau

A new relativistic interaction model for 2D and 3D Wigner crystals in a plasma bubble — •Lars Reichwein, Johannes Thomas, and Alexander Pukhov — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Düsseldorf

The spatial structure of an ultralow-emittance electron bunch in the plasma wakefield bubble regime is studied. The full Liénard-Wiechert potentials are considered for mutual inter-particle interactions in the framework of an equilibrium model. This model uses a quasi-static theory which allows to solve the Liénard-Wiechert potentials without knowledge of the electrons' history. The 2D equilibrium structure we find is similar to already observed hexagonal lattices in [1] and shows more topological defects [2]. These defects reduce the stress onto the lattice, which is important for higher energies since a transition between the hexagonal lattice structure and the parabolic confinement of the external field needs to be made. To calculate the 3D equilibrium structure, we use a Lorentz transformation in propagation direction to model the retarded Coulomb interaction between the electrons inside the bunch. We find three-dimensional filaments in the direction of propagation, while the hexagonal structure in perpendicular direction is preserved. From a physical point of view, it is clear that the scaling originates from different competing structures that minimize the system's energy.

[1] Johannes Thomas, Marc M. Günther, and Alexander Pukhov, 24, 013101 (2017) [2] Lars Reichwein, Johannes Thomas, and Alexander Pukhov, Phys. Rev. E 98, 013201 (2018)

P 18.7 Do 16:30 Foyer Nordbau

Hydrodynamic description for the dynamic structure factor of a strongly coupled Yukawa plasma — •Hanno Kählert — ITAP, Christian-Albrechts-Universität zu Kiel

In the small wavenumber and low frequency limit, the dynamic structure factor (DSF) of a strongly coupled Yukawa plasma is well described by linearized hydrodynamics [1]. In this regime, the DSF is characterized by a diffusive thermal mode and two sound modes. The intensities and widths of the peaks are determined by the thermodynamic properties and the transport coefficients of the plasma. Here, the DSF of a strongly coupled Yukawa plasma is calculated from molecular dynamics simulations. The DSF from the simulations is compared with the hydrodynamic model, thereby yielding values for the transport coefficients. The applicability of this method to determine transport data for strongly coupled plasmas is tested by comparing the results with available data [2-4].

[1] J. Mithen, J. Daligault, and G. Gregori, Phys. Rev. E **83**,

015401(R) (2011)
[2] J. Daligault, K. O. Rasmussen, and S. D. Baalrud, Phys. Rev. E **90**, 033105 (2014)
[3] Z. Donkó and P. Hartmann, Phys. Rev. E **78**, 026408 (2008)
[4] T. Ott, M. Bonitz, and Z. Donkó, Phys. Rev. E **92**, 063105 (2015)

P 18.8 Do 16:30 Foyer Nordbau

Parallel Low-Rank Vlasov Simulations — •Florian Allmann-Rahn[1], Katharina Kormann[2], and Rainer Grauer[1] — [1]Ruhr-Universität Bochum — [2]Max-Planck-Institut für Plasmaphysik Garching

Kinetic Vlasov simulations are in many cases the most accurate and complete way to compute a plasma, but since they employ a full grid in phase space, they are expensive both computationally and memory-wise. This issue can be overcome by means of low-rank approximations (Kormann 2015; SIAM J. Sci. Computing 37,4) which can lead to massive performance gains. There, small singular values are discarded in order to obtain a compressed version of the plasma distribution function. For use on large computer clusters, we developed a parallel version of the low-rank Vlasov solver that is suitable for distributed memory. It employs a domain decomposition and boundary exchange in the hierarchical Tucker format. The parallel low-rank method is presented and the possibilities of fast high-resolution Vlasov simulations are demonstrated.

P 18.9 Do 16:30 Foyer Nordbau

Combination of retarding field analyzer and calorimetric probe for diagnostics of an ion beam source — •Felix Georg, Thomas Trottenberg, and Holger Kersten — IEAP, Christian-Albrechts-Universität zu Kiel, Germany

A recently developed plasma diagnostic, which combines a retarding field analyzer (RFA) and a passive thermal probe (PTP), has been used for the characterization of an ECR plasma ion source.

The PTP serves as the collector, in front of which three centrally aligned grids are operated as the retarding field system. In this setup the collector does not only measure the incoming ion current depending on the voltage applied to the grids of the RFA, but also the incoming energy flux density of the impinging ions or neutrals, respectively.

In this study the combined diagnostic is used in an ECR plasma ion source experiment. The ion energy distribution (IED) is determined regarding the energy exchange of the neutral background gas with the ion beam extracted from the plasma source.

P 18.10 Do 16:30 Foyer Nordbau

Measurements with optical tweezers in the sheath of a CCP discharge and the effect of UV irradiation on the charge of SiO_2 microparticles. — •Viktor Schneider and Holger Kersten — Institute of Experimental and Applied Physics (IEAP), Kiel University

We use SiO_2 microparticles in an optical trap to manipulate them in the environment of a CCP discharge. In contrast to common plasma diagnostic tools, e.g. Langmuir probes, calorimetric probes, mass spectrometers etc., the μPLASMA experiment uses microparticles as noninvasive probes [1]. From the displacement of a single probe particle in the optical trap we measure a force while it is moving relatively to the plasma, either deeper into the sheath or towards the plasma bulk. The benefit of the presented technique is the possibility to retain the particle even after the plasma is turned off. Residual charges on the sphere after switching off the plasma have been measured. Furthermore, charging of the sphere by UV radiation in an external electric field is investigated and discussed. The measurements indicate electron induced secondary electron emission from the particle and an emission yield above unity for energies about 100 eV.

[1] V. Schneider and H. Kersten, "An optical trapping system for particle probes in plasma diagnostics", Rev. Sci. Instrum. 89, (2018)

P 18.11 Do 16:30 Foyer Nordbau

Measurements of the H (n = 2) Density via Laser Absorption Spectroscopy — •Frederik Merk[1], Roland Friedl[1], Caecilia Fröhler[1], Stefan Briefi[1,2], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg, Germany — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

The $n = 2$ density of atomic hydrogen or deuterium in low pressure low temperature plasmas can be accessed by emission spectroscopy of the Lyman-α line at 122 nm. However, an absolutely intensity calibrated vacuum ultraviolet (VUV) spectrometer is required and opacity effects due to reabsorption of emitted photons affect the measurement. The latter problem can be solved by applying the escape factor method, which on the other hand raises large error bars to the $n = 2$ density. A direct way to measure the H (D) ($n = 2$) density is the use of tunable diode laser absorption spectroscopy on the Balmer-α line at 656 nm, allowing also to analyse the transition's line profile. The built up system consists of a laser which is tunable in the wavelength range between 652 nm and 660 nm. The change of the frequency of the emitted photons is monitored by an etalon. The system is installed, tested and characterized at a planar ICP discharge (RF 2 MHz, power up to 2 kW). Here, measurements of the $n = 2$ density of both hydrogen and deuterium are performed for plasmas under varying pressure and applied RF power. The obtained values are compared to escape factor corrected VUV spectroscopy measurements. Additionally, a comparison to the collisional radiative model `Yacora H` is perfomed.

P 18.12 Do 16:30 Foyer Nordbau

Control of size, crystallinity and structure of Si-nanoparticles synthesized in a capacitively coupled low-pressure plasma — •Oguz Han Asnaz[1], Gesa Wieck[2], Torben Dankwort[2], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Institute of Material Science, Kiel University, Germany

Non-thermal plasmas have proven themselves as a powerful system for the synthesis of crystalline nanoparticles. The high-energetic reactions possible in these plasmas provide the necessary heating to create nanoparticles of high purity and crystallinity. A capacitively coupled flow-through reactor is simple to set up while providing high production rates and good synthesis conditions. Using system parameters such as gas flow rate, plasma zone length, and RF power, it is a versatile system for the generation of nanocrystals with sharply defined characteristics.

This contribution explores controlling particle size, crystallinity and structure of the generated nanoparticles by modificating these system parameters and analyzing via a range of diagnostics from Raman Spectroscopy, over Fourier-transform infrared spectroscopy (FTIR), and transmission electron microscopy (TEM), to X-ray diffraction (XRD). These findings will lay the foundation for our next step, where the generated particles will be injected into a secondary plasma reactor for controlled surface treatment with continuous monitoring by means of IR absorption spectroscopy with a multi pass cell.

P 18.13 Do 16:30 Foyer Nordbau

Diagnostic of a Process Plasma used for the Production of Memristive Devices — •Julia Cipo[1], Sven Gauter[1], Felix Georg[1], Finn Zahari[2], Thomas Mussenbrock[3], Holger Kersten[1], and Hermann Kohlstedt[2] — [1]Plasma Technology Group, Institute of Experimental and Applied Physics, University of Kiel, Germany — [2]Nanoelctronics Group, Faculty of Engineering, University of Kiel, Germany — [3]Electrodynamics and Physical Electronics Group, Institute of Electrical Engineering and Information Science, BTU Cottbus-Senftenberg, Germany

The production of memristive devices received importance for nonvolatile memories, neuromorphic engineering and in image processing algorithms. The intrinsic properties of these devices are determined by I-V characteristics, which are influenced by various process parameters. Since the investigated memristive films are deposited by magnetron sputtering it is important to understand the physics of the discharge. The obtained plasma parameters can be correlated with the electrical properties of the memristive films. For the plasma diagnostic we used a passive thermal probe, which can be operated simultaneously as a thermal probe for energy flux measurement and as a planar Langmuir probe for measuring the floating and plasma potentials as well as the electron temperature. In particular, we investigated the reactive sputter deposition of NbOx- layers for a grounded and a floating substrate / probe. With our results we can explain the radial variations of the electric properties and can conclude for dominating factors which have a tremendous effect on the properties of these thin films.

P 18.14 Do 16:30 Foyer Nordbau

On the energetic electrons in the INCA discharge — Philipp Ahr, •Tsanko Vaskov Tsankov, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany

Recent theoretical [1,2] and experimental [3] investigations have revealed the great potential of an inductive type of discharge (INCA – INductively Coupled Array) based on a novel stochastic heating mechanism in periodic vortex fields. The predicted efficient operation at low pressures (below 1 Pa) has been experimentally verified and evidence for the presence of energetic electrons has been found.

Here the origin and the nature of these energetic electrons is further investigated. Using cusp magnetic field confinement and dielectric walls suggests that the production of the energetic electrons requires multiple reflections by the potential in the wall sheath.

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

P 18.15 Do 16:30 Foyer Nordbau

Phase resolved optical emission spectroscopy of a radio frequency discharge supported by Langmuir probe measurements — •Sören Wohlfahrt, Franko Greiner, Judith Golda, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Germany

Phase-resolved optical emission spectroscopy (PROES) is a non-intrusive diagnostic suitable of delivering plasma parameters in RF-discharges and the electron dynamic in both atmospheric and low-pressure plasmas. The time-resolved emission of certain energy levels is measured and described with a set of rate equations corresponding to the dominant processes in the plasma. Thus, the electron temperature and electron energy distribution function (EEDF) can be derived [1]. However, these parameters strongly depend on the underlying model.

We use PROES and Langmuir probe diagnostics to investigate a low-pressure capacitively coupled discharge and present a comparison of both measurements.

[1] Schulze et al., J. Phys. D: Appl. Phys. 43 (2010) 124016 (8pp)

P 18.16 Do 16:30 Foyer Nordbau

Simulation of particle and photon fluxes in low-pressure plasmas for sterilisation applications: scaling and spatial distribution — •Andrew R. Gibson, Marcel Fiebrandt, and Peter Awakowicz — Institute of Electrical Engineering and Plasma Technology (AEPT), Ruhr-Universität Bochum, Germany

Sterilisation of medical devices and implants is crucial before performing surgical procedures. In the context of the currently rising incidence of antibiotic-resistant infections, effective sterilisation procedures are increasingly important. Low-pressure, low-temperature plasmas have been demonstrated to be effective for sterilisation of a range of surfaces, including those that are temperature sensitive. A key mechanism behind their effects is their ability to deliver large doses of UV/VUV radiation. In this work, two-dimensional hybrid plasma simulations are used to study the scaling and spatial distribution of VUV photon, Ar metastable and ion fluxes to various test surfaces in low-pressure Ar inductively coupled plasmas. The base case simulation represents a double coil inductively coupled plasma source, with one coil at the top and another at the bottom, operated at a pressure of 5 Pa and a total power deposition of 500 W. A cylindrical substrate is held in the centre of the reactor, representing an object to be sterilised. It is found that two coils are required in order to ensure high photon fluxes to all surfaces of the substrate, and that photon fluxes are strongly power and pressure dependent. Particle and photon fluxes inside trenches of various aspect ratios introduced into the substrate will also be discussed in the context of ensuring homogenous sterilisation.

P 18.17 Do 16:30 Foyer Nordbau

Kinetics of heavy species in oxygen ICP during E-H mode transition — •Jürgen Meichsner[1] and Thomas Wegner[2] — [1]University of Greifswald, Institute of Physics, Greifswald, Germany — [2]IPP Greifswald, Germany

The kinetics of neutral and charged oxygen species are evaluated during the E-H mode transition in 13.56 MHz oxygen ICP configuration. The investigations combine experimental results with rate equation calculations of global model. In particular, the electron density, the electron temperature and the negative oxygen ion density resulted from line integrated microwave interferometry, laser photodetachment and probe measurements. The neutral density of ground state O2(X) and metastable O2(A) molcules was determined by VUV absorption. Additionally, the gas temperature resulted from optical emission spectroscopy. The steady state rate equation calculations of the global model were performed for neutral and charged oxygen species. In the calculations the rate coefficients were used from the literature. The combination of experimental results and rate equation calculations provides the density of relevant oxygen species during the E-H mode transition and gives information about the significance of involved elementary processes.

P 18.18 Do 16:30 Foyer Nordbau

First Experiments on Dusty Plasmas in the D-Mag Magnet — •Andre Melzer[1], Matthias Mulsow[2], Harald Krüger[1], Stefan Schütt[1], and Michael Himpel[1] — [1]Institute of Physics, University of Greifswald — [2]IPP Greifswald

In the past years the study of dusty plasmas under strong magnetic fields has gained increased interest. Dusty plasmas consist of nanometer to micrometer sized particles that acquire high negative charges due to the inflow of plasma electrons and ions. To reveal magnetization effects of the dust species high magnetic field strengths are required.

In Greifswald, recently, the D-Mag magnet has been installed that allows to generate homogeneous magnetic fields up to 6 T. Experiments at these field strengths have been performed using micrometer-sized dust particles. First results will be presented. Despite the strong field, magnetization of the dust species is not expected due to its large mass. However, electrons and ions will be magnetized and the influence of these magnetized plasma species on the dust will be investigated.

P 18.19 Do 16:30 Foyer Nordbau

Configurational temperatures: a novel approach to dusty plasmas — •Michael Himpel and André Melzer — University Greifswald, Germany

In dusty plasma systems, the kinetic temperature is often used to characterize dynamical processes of particle clusters. An experimental drawback of this temperature definition is, that the velocities of the particles have to be known, which implies the application of fast imaging techniques and which is often problematic.

A different definition of the temperature, called configurational temperature, can be used to determine the temperature of the particle system on basis of the particle positions and interaction forces instead of its velocities. Here, we show the application of this temperature definition to finite and large dust clusters in 2D and 3D.

P 18.20 Do 16:30 Foyer Nordbau

Measurement of photophoretic forces in binary complex plasmas — •Frank Wieben and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

Lasers are widely used in complex plasma research to manipulate micron sized dust particles embedded in a plasma without affecting the plasma itself. The particles experience a significant force when irradiated with laser light that is used to excite single or collective particle motion. The radiation force on the particles comprises two contributions: The first contribution is a force resulting from radiation pressure, i.e. momentum transfer from collisions with photons. The second contribution is a photophoretic force which results from interaction with the surrounding gas. Depending on how the particle absorbs energy from the electromagnetic radiation the particle surface can be non-uniformly heated causing an anisotropic net-momentum-transfer from the gas atoms. This complex interplay of particle properties, Mie scattering and interaction with neutral gas usually inhibits a separate measurement of the photophoretic force component. In this contribution a method to measure both forces for melamine-formaldehyde and silica particles in a binary mixture is presented. Forces are determined from the kinetic temperatures the particles attain in a laser heating scenario and results are compared to a model. Obtained efficiency factors are compared to Lorenz-Mie theory computations. This work has been supported by the Deutsche Forschungsgemeinschaft (DFG) in the framework of SFB TR24, Project A3b and Research Grant BL555/3-1.

P 18.21 Do 16:30 Foyer Nordbau

Setup and Calibration of a Rotating Compensator Polarimeter for the Particle Size Diagnostic of Nanodusty Plasmas — •Tabea Gleiter, Andreas Petersen, and Franko Greiner — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel

Polarimetry of nanoparticles is commonly known as Mie ellipsometry. In nanodusty plasmas Mie ellipsometers can be used for the in-situ diagnostic of the refractive index and the radius of the nanoparticles. The basic setup of an ellipsometer is quite simple, it uses the combination of a rotating quarter wave plate, a linear analyzer and a detector. However, the calibration and data analysis of the polarimeter is challenging. We present the design, calibration and data analysis of a simple system consisting of a hollow shaft stepper motor and a photomultiplier and discuss its advantages and limitations.

P 18.22 Do 16:30 Foyer Nordbau

Ekoplasma - Complex Plasma Research in Space — •C. A. Knapek[1], P. Huber[1], D. P. Mohr[1], E. Zähringer[1], V. I. Molotkov[3], A. M. Lipaev[3], U. Konopka[2], V. Naumkin[3], and H. M. Thomas[1] — [1]Deutsches Zentrum für Luft- und Raumfahrt, Institut für Materialphysik im Weltraum, Wessling, Germany — [2]Auburn University, Auburn, AL, USA — [3]Joint Institute for High Temperatures of the Russian Academy of Sciences, Moscow, Russia

Complex plasmas consist of highly charged micrometer-sized grains injected into a low temperature noble gas discharge. 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). For this project, a plasma chamber with an adaptive internal geometry was designed, which extends the accessible experimental parameter range. The chamber was used for complex plasma experiments in parabolic flights and on ground. Further, plasma simulations were performed with a PIC (particle-in-cell) code to get an idea of the available plasma parameter range regarding electron temperature and plasma density. Here, experimental results from parabolic flights, the laboratory, and results of the plasma simulations will be presented, as well as the current project status. This work is funded by DLR/BMWi (FKZ 50WM1441).

P 18.23 Do 16:30 Foyer Nordbau

Temporal evolution of the electron density of a nanosecond discharge in destilled water — •Katharina Grosse, Julian Held, and Achim von Keudell — Ruhr-Universität Bochum

Plasmas inside liquids allow a high mass transfer of reactive species from the gas phase into the liquid. Fast and efficient reaction rates for surface reactions can be realised when a surface is in direct contact with the plasma treated liquid. These plasma-liquid systems are relevant for surface modifications as for example plasma enhanced anodisation of metal surfaces inside an electrolyte. The physics of these plasmas and the interaction of the generated species with different surfaces need to be investigated to gain a full understanding of the chemical reactions occuring at the plasma-liquid-surface interface. A 10 ns pulsed plasma with a voltage amplitude of 20 kV at a repetition frequency of 15 Hz is ignited inside destilled water. The temporal evolution of the electron density and temperature is determined from the line broadening of the Hα-line (656 nm) and one OI-line (777 nm), measured with time-resolved optical emission spectroscopy (OES) with a temporal resolution of 15 ns. The electron densities are in the order of 10^{25} m^{-3} and electron temperatures between 0.1-20 eV are determined.

P 18.24 Do 16:30 Foyer Nordbau

Properties of Nanodust Clouds in Reactive Argon Acetylene Plasmas for Open and Closed Electrode Geometries — •Alexander Schmitz, Oguz Han Asnaz, and Franko Greiner — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel

The properties of a nanoparticle cloud created in a reactive argon acetylene plasma strongly depend on argon pressure and rf power as well as on the electrode geometry. Using a capacitively coupled parallel plate reactor with two circular electrodes where the radius of the electrode is equal to the electrode distance, creates a "closed system" with high nanoparticle density. In contrast, a single electrode design, where the electrode is rf driven with reference to the vacuum chamber, is a "open system" with low nanoparticle density. We present a systematic study of the shape and dynamics of the nanodust cloud for different open and closed electrode designs.

P 18.25 Do 16:30 Foyer Nordbau

Characterization of filamentary instabilities in a magnetized RF discharge — •Tim Donders[1], Hendrik Jung[2], and Franko Greiner[2] — [1]Elementary Processes in Gas Discharges, Faculty of Applied Physics, Technische Universiteit Eindhoven, The Netherlands — [2]Institute of Experimental and Applied Physics, Kiel University, Germany

Magnetized plasmas in a planar radio frequency capacitively coupled discharge system show filaments, tube-like regions of hotter and/or denser plasma along the magnetic field. The diameter of the filaments depends strongly on the absolute value of the magnetic induction. We investigate the interplay of filaments with a nanodust cloud for different magnetic inductions. This provides information on the dust confinement in a magnetized plasma and the nanoparticles can be used as tracers for the visualization and analysis of the filamentary instabilities. Given that the filaments preferably occur at facing electrode surface, switching towards a hollow electrode design helps to prevent the formation of filaments. In this configuration, stable nanodusty clouds can be grown in a magnetic field with a strength of up to 4 T

P 18.26 Do 16:30 Foyer Nordbau

Mie ellipsometry of optically thick nanodust clouds — •Nils Rehbehn[1,2], Sebastian Wolf[2], and Franko Greiner[1] — [1]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel — [2]Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel

Mie ellipsometry, i.e., the analysis of light scattered by nanoparticles, is a standard technique for the in-situ size diagnostic of nanoparticles. It can be utilized to obtain information about these particles, like refractive index and grain size. However, its use is limited to optically thin clouds, as it is based on the assumption of single scattering. With increasing optical depth, thus increasing chance for multiple scattering, resulting in further modification of the polarization state, this method fails. Consequently, the analysis of optically thick systems is difficult or even impossible. To overcome this problem we performed radiative transfer simulations, taking the polarization state of the radiation as well as multiple scattering events into account.Our goal is to develop a new diagnostic method for systems of arbitrary optical depth, based on the analysis of the polarized state of the scattered radiation.

P 18.27 Do 16:30 Foyer Nordbau

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 Vladmir E. Fortov[2] — [1]Deutsches Zentrum für Luft- und Raumfahrt, Institut für Materialphysik im Weltraum, Wessling, Germany — [2]Joint Institute for High Temperatures of the Russian Academy of Sciences, Moscow, Russia

Interrupting rf-discharge is a well known method to control processes in plasmas. It can not only be used to control particle growth in semiconductor processing, but it is also a good method to change discharge properties like electron temperature more independently. So one could tune interactions in complex plasma systems in a more flexible way. Ekoplasma will provide the future lab for complex plasma research on the international space station ISS. Its discharge chamber Zyflex with its segmented movable electrodes gives many opportunities to modify and shape very specific discharge geometries. The four electrode channels are driven with a multifunctional rf-generator, which is capable of pulsing all channels individually with on/off times even below 50 μs. Microgravity will give us in addition the possibility to extend the switching times further into the range of long off-times without loosing particles due to gravitation. In this contribution, we will show new results of particles levitated in a pulsed gas discharge in the current laboratory setup of Ekoplasma. This work and some of the authors are funded by DLR/BMWi (FKZ 50WM1441).

P 18.28 Do 16:30 Foyer Nordbau

Acoustical interactions of gas discharges — •Daniel Kotschate[1], Mate Gaal[1], Luka Hansen[2], 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 surface or material modification, light sources and electric propulsion. Since atmosphere pressure plasma generate a huge 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). The plasma-chemical interaction provides the most significant impact to the generated heat and electro-hydrodynamic force, detectable by acoustic sensors. This contribution gives an overview of experimental acoustic analysis of diffuse coplanar surface dielectric barrier discharges and provides a basic physical straight-forward model. In addition to

the characterization, possible applications (e.g. plasma acoustic loudspeaker or transducer for air-coupled ultrasonic testing) concerning these discharge types are presented.

P 18.29 Do 16:30 Foyer Nordbau

Plasma arcing during contact separation of HVDC relays — •Crispin Masahudu Ewuntomah and Jens Oberrath — Institute of Product and Process Innovation, Leuphana University Lüneburg, Germany

Plasma arcing is a common phenomenon during contact separation of high voltage direct current (HVDC) relays. In short circuit situations, a rapid increase of direct current initiates the separation of relay contacts, and hence arc formation at the contacts. To this day, the presence of these arcs poses a great challenge to relay manufacturers. Mainly because the arcs excessively heat, melt, boil, and vaporize the contact spots, and as such the relays are mostly damaged afterwards. A detailed understanding of the exact processes within the relays under such high currents during contact separation is therefore required to prevent complete damage of the relays. In this work, the contact separation of a Panasonic AEV14012 relay is being investigated using simulations. A time dependent current, ranging from 0.2 to 2.5 kA is applied to a gradually opening relay. The initial results demonstrate the plasma arc formation and time dependent arc growth at both contact spots of the relay. It is established from the results that; the temperatures of the arcs are higher than the melting temperature of the contact materials of the relay. It is therefore expected that; long arc dwell times will lead to permanent damage of the relay contacts.

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P 18.30 Do 16:30 Foyer Nordbau

Investigation of a microwave plasma torch for CO2 gas conversion — •Irina Kistner[1], Andreas Schulz[1], Matthias Walker[1], Günter Tovar[1], Frederic Buck[2], and Thomas Schiestel[2] — [1]Institute of Interfacial Process Engineering and Plasma Technology IGVP, University of Stuttgart, Stuttgart, Germany — [2]Institute for Interfacial Engineering and Biotechnology IGB, 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 particular 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, which enables a "self-ignition" and stable operation of an air and CO2 plasma over a wide range of parameters, has been constructed. The CO2 plasma has been investigated via optical emission spectroscopy, mass spectrometry and IR spectroscopy in order to determine the plasma parameters as well as the energy and conversion efficiency. While improving the energy and conversion efficiency, it is also important to remove the oxygen contained in a CO2 plasma in order to produce syngas. For this purpose a ceramic hollow fiber has been integrated into the system, which separates the oxygen.

P 18.31 Do 16:30 Foyer Nordbau

Characterization of charge distributions on dielectrics due to atmospheric-pressure plasma discharges — •Eric Andersen[1], Sven Kraft[1], Regina Lange[1], Ingo Barke[1], Sylvia Speller[1], and Ronny Brandenburg[1,2] — [1]Institute of Physics, University of Rostock, 18051 Rostock — [2]Leibniz Institute for Plasma Science and Technology (INP), 17489 Greifswald

The interaction of nonthermal plasma with dielectric boundaries leads to a deposition of surface charges, which determine the discharge development and dynamics as well as the effects of plasma surface treatment. The amount and behavior of surface charges are fundamentally important in dielectric barrier discharges [1,2] and plasma jets. Our aim is to study charge distributions on dielectric surfaces such as glass, polymers, and ceramics due to exposure to nonthermal atmospheric-pressure plasma. We explore how these charges are distributed in the outer regions of the discharge footprints. Apart from the distributions, residence times are of interest. Charges can be deposited by means of a helium plasma jet or via corona discharge in air. To study the feature sizes, scanning probe microscopy approaches are employed, i.e. electrostatic and Kelvin probe force microscopy (EFM and KPFM). Sensitivity of both methods needs to be assessed on ordinary reference samples such as interdigitated electrode systems and oxides.

[1] L Stollenwerk *et al* 2007 *Phys Rev Lett.* **98** 255001,
[2] M Bogaczyk *et al* 2012 *J. Phys. D: Appl. Phys.* **45** 465202

P 18.32 Do 16:30 Foyer Nordbau

Studies of an atmospheric-pressure dielectric barrier discharge in Ar-HMDSO mixtures — •D. Loffhagen[1], M. M. Becker[1], D. Hegemann[2], B. Nisol[3], S. Watson[3], M. R. Wertheimer[3], and C.-P. Klages[4] — [1]Leibniz Institute for Plasma Science and Technology, 17489 Greifswald, Germany — [2]Empa, Swiss Federal Laboratories for Materials Science and Technology, Plasma & Coating Group, 9014 St. Gallen, Switzerland — [3]Groupe des Couches Minces and Department of Engineering Physics, Polytechnique Montréal, Montreal QC, Canada H3C 3A7 — [4]TU Braunschweig, Institute for Surface Technology, 38108 Braunschweig, Germany

Dielectric barrier discharges (DBDs) have been widely applied as a source for the deposition of organosilicon films by means of plasma-enhanced chemical vapour deposition (PECVD) processes, where hexamethyldisiloxane (HMDSO) is often used as monomer. As a result of Penning ionization processes, already small amounts of this monomer in the argon carrier gas lead to drastic changes of the discharge characteristics. In the present contribution, a large reactor for performing DBD experiments at atmospheric pressure is investigated by means of a time-dependent, spatially one-dimensional fluid model and measurements. The focus is on the electrical characteristics of discharges in argon with HMDSO admixtures in the range from 0 to 600 ppm. Results for a.c. voltage with an amplitude of about 4 kV and a frequency of 20 kHz are presented and discussed. In general, quite good agreement between modelling and measured data for the gap voltage and discharge current is found.

P 18.33 Do 16:30 Foyer Nordbau

How the description of electron transport affects the results of microplasma modelling — •Margarita Baeva, Detlef Loffhagen, Markus M. Becker, and Dirk Uhrlandt — Leibniz Institute for Plasma Science and Technology, 17489 Greifswald, Germany

This contribution is concerned with the impact of the description of the transport parameters for electrons and their energy (mobility and diffusivity) in the framework of numerical modelling of dc microdischarges in atmopsheric pressure argon. Three modelling approaches are considered in relationship to the drift-diffusion approximation (DDA): 1) the common DDA and a Maxwellian electron velocity distribution function (EVDF); 2) the common DDA combined with EVDF as a solution of the Boltzmann equation providing the rate coefficients and electron mobility and diffusivity, and a simplified transport of electron energy; 3) an improved DDA. These three approaches are implemented in a spatially one-dimensional model. A comparison of various plasma parameters is given for a wide range of discharge currents in a parallel-plate arrangement with an inter-electrode gap of 0.4 mm. The behaviour of the plasma parameters corresponding to various discharge regimes (glow, arc and the transition region) and the model's capability of a unified description of microarcs are discussed.

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P 18.34 Do 16:30 Foyer Nordbau

Experimental and modelling studies of the temperature distribution in a microwave plasma torch and on a deposition target — •Margarita Baeva[1], Frank Hempel[1], Ralf Methling[1], Detlef Loffhagen[1], Tom Trautvetter[2], Hardy Baierl[2], and Rüdiger Foest[1] — [1]Leibniz Institute for Plasma Science and Technology, 17489 Greifswald, Germany — [2]Leibniz Institute of Photonic Technology, 07745 Jena, Germany

The applicability of an atmospheric-pressure microwave (MW, 2.45 GHz) plasma torch on multi-component doping of silica preforms has been studied. The determination of the plasma parameters in the plasma source and in the plume, where the interaction between the plasma and the precursor occurs, is of central importance. The plasma source includes a standard waveguide R26 and a quartz tube traversing at the position of maximum electric field of the fundamental mode TE_{10}. The plasma jet is directed towards a rotating substrate. Precursors are fed through an additional tube placed outside the plasma source. Pure argon and argon/oxygen mixtures are used in the modelling and experimental studies. A self-consistent model of the plasma source is employed to describe plasma, the electromagnetic and the hydrodynamic processes. Optical emission spectroscopy and thermography deliver the temperature in the region of plasma-precursor interaction and on the substrate, respectively. Experimentally determined temperatures are compared with the model predictions and discussed. This work was supported by the Leibniz-Gemeinschaft under the grant SAW-2017-IPHT-1.

P 18.35 Do 16:30 Foyer Nordbau

Investigation of Surface Modifications Caused by Plasma Treatment — •Sandra Moritz[1], Janosch J. Perlbach[1], Joachim Sann[2], Markus Göttlicher[2], and Markus H. Thoma[1] — [1]I. Physikalisches Institut, Justus-Liebig University Gießen — [2]Physikalisch-Chemisches Institut, Justus-Liebig University Gießen

Inactivation of microorganism by cold atmospheric plasma is one major application in the field of plasma medicine. Therefore, one has to know whether the plasma treatment affects the treated surfaces or not. In this contribution, the effect of cold atmospheric SMD plasma treatment on different surfaces was investigated.
Therefore, the experimental setup was driven for 16 hours with 10 minutes-breaks every 30 minutes. Within the plasma chamber, different material samples (Stainless Steel, UPVC, PP, FEP, glass) were placed. The room temperature was between 18 and 26°C, the air humidity between 68 and 96% during the treatments.
Afterwards, 3 samples of every material and configuration were analyzed, using 4 different methods. Firstly, a macroscopic analysis was made which was secondly compared with laser microscopic scans. Thirdly, the contact angles between the samples and reference liquids (water, ethanol, diiodmethane and ethylenglycol) were measured and furthermore, the free surface energy of the samples was determined. Lastly, an XPS-analysis was applied, to investigate the molecular composition of treated and untreated samples.

P 18.36 Do 16:30 Foyer Nordbau

The Influence of Electrical Properties of Wood on Dielectric Barrier Discharge plasma treatments at atmospheric conditions — •Bahram Mahdavipour[1], Sebastian Dahle[2,3], and Jens Oberrath[1] — [1]Institute of Product and Process Innovation, Leuphana University Lüneburg, Germany — [2]Clausthal Center for Material Technology, Clausthal University of Technology, Leibnizstr. 9, 38678 Clausthal-Zellerfeld, Germany — [3]Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, 1000 Ljubljana, Slovenia

The plasma treatment of wood surfaces in atmospheric conditions is a well-known and researched processing technique. For all types of materials, the properties of their surfaces change with time. Thus, due to wood surface exposure to weather, wood color and other properties change. Plasma treatments improve the wettability and compatibility for both fresh wood surfaces and wood surfaces after exposure to weathering. Most DBD plasma treatment of wood-based materials are conducted as direct cold atmospheric plasma (diCAP) treatment rather than using remote plasmas or jets. However, many internal properties of wooden materials have an impact on the plasma parameters and thus on the results of the surface treatments. This study focuses on the electrical conductivity and dielectric constant of wood as well as the electrical field penetration in fresh wood and dried wood texture. These provide good conclusions on the behavior of wooden substrates during plasma treatment in floating electrode and gliding discharge-type DBD configurations.

P 18.37 Do 16:30 Foyer Nordbau

Numerical study of the transport phenomena for an atmospheric-pressure plasma jet in contact with liquid — •I. L. Semenov, K.-D. Weltmann, and D. Loffhagen — Leibniz Institute for Plasma Science and Technology (INP), 17489 Greifswald, Germany

The interaction of cold atmospheric-pressure plasmas with liquids has become the subject of intense research due to its importance for biomedical applications. At present, plasma jets are the most common plasma sources applied in experimental studies. The reactive oxygen and nitrogen species generated by the jet are responsible for the plasma-induced changes in chemical properties of liquids. The transport of plasma-generated species from the gas into the liquid phase is determined by the convection flow in the considered system. In this work we present results of a modelling study on the transport processes for an atmospheric-pressure argon plasma jet in contact with liquid under typical experimental conditions. The flow field is studied by solving the Navier-Stokes equations and the transport of species is given by the solution of the convection-diffusion equation on the example of hydrogen peroxide. The basic equations are solved numerically using the finite-element method. The modelling results are in good agreement with available experimental data. It is shown that the convective flow in the liquid exhibits a complicated three-dimensional structure. In addition, the model is found to provide a reliable estimate for the hydrogen peroxide diffusion flux from the gas into the liquid phase.

P 18.38 Do 16:30 Foyer Nordbau

Phase-resolved study of plasma filaments occurring in an RF plasma jet — •Florian Sigeneger, Jan Schäfer, Rüdiger Foest, and Detelf Loffhagen — Leibniz Institute for Plasma Science and Technology, Felix-Hausdorff-Straße 2, 17489 Greifswald

The filamentary plasma generated in a plasma jet is investigated by means of a spatially two-dimensional fluid model. The coaxial jet is driven by an RF voltage at a frequency of 27.12 MHz supplied to the upper of both ring-shaped electrodes attached to the capillary. The lower electrode is grounded. The combination of a phase-resolved description of the RF plasma with a hydrodynamic model of gas flow and gas heating allows to study the influence of the gas flow on the plasma generation. A curved trajectory representing the filament is obtained which guides the current between the powered and grounded electrode. Along this path, the electron density reaches values of about $10^{20}\,\mathrm{m}^{-3}$. The gas flow causes density profiles of all species which are shifted in downstream direction. The asymmetry also concerns the generation of striations which arise predominantly from the upstream side. These striations are induced by the nonlinear dependence of the ionization rate on the electron density as well as by the dominant volume recombination in the wings of the filament and in the minima of the spatial structures. Despite the pronounced alterations of the electric field in the striations, only weak modulations of the mean electron density are found there compared to the remarkable amplitudes of the mean energy in the sheath regions in front of the electrodes.

P 18.39 Do 16:30 Foyer Nordbau

Characterisation of a 2.45 GHz microwave atmospheric pressure plasma torch in N_2 and CO_2 — •Federico Antonio D'Isa[1], Ante Hecimovic[1], Emile Carbone[1], Ursel Fantz[1], Irina Kistner[2], Andreas Schulz[2], and Matthias Walker[2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]Institute of Interfacial Process Engineering and Plasma Technology, Pfaffenwaldring 31, 70569 Stuttgart, Germany

Plasma technology can be used for conversion of (renewable) energy into value added chemicals through activation of chemical processes or direct conversion of raw carbon materials (e.g. CO_2, CH_4, biogas, biomass). Microwave plasmas combine the advantage of fast response to the grid power oscillation with a relatively high energy (up to 80 %) and conversion (up to 80 %) efficiencies, albeit at reduced pressure. In this work we present results obtained in a microwave plasma torch at atmospheric pressure (2.45 GHz, up to 3 kW). The plasma torch is a custom made microwave resonator consisting of a coaxial and cylindrical resonator. The plasma is confined in a quartz tube (inner diameter of 26 mm) placed in the centre of the resonator with a tangential gas inlets generating a vortex flow. The N_2 and CO_2 plasmas have been investigated by OES (rotational and vibrational temperatures), mass spectrometry (conversion and energy efficiency), ICCD imaging (plasma size and dynamics). ICCD images are compared to gas flow simulations to understand the gas dynamic in a vortex configuration. The focus of the work is on characterisation of the plasma in an effort towards higher conversion and energy efficient source.

P 18.40 Do 16:30 Foyer Nordbau

Comparison of the OH A-X emission spectra for several different plasma sources — •Roland Friedl[1], Caecilia Fröhler[1], David Rauner[1,2], Nicole Baar[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 resonant transition A→X of the hydroxyl molecule OH is studied in detail for several different discharges. Emission from an atmospheric glow discharge, an RF micro jet plasma, a microwave torch as well as a plasmoid are considered. For each discharge the OH molecule is generated from water vapor, which in turn is an impurity to the discharge, an intentional admixture to the discharge gas or even the main gaseous constituent. For comparison the spectrum of a low pressure ICP dis-

charge in a gas mixture of 85 % H_2 and 15 % O_2 is studied. Analysis of the spectra is performed by using the LIFBASE Spectroscopy Tool (J. Luque and D. R. Crosley, SRI International, 1999). Depending on the specific discharge under observation, the spectral composition thus varies from nearly thermal equilibrium between vibrational and rotational states, via two-temperature rotational populations, through to spectra which are strongly affected by quenching processes. Furthermore, the influence of the spectral resolution on the accuracy of determined population temperatures and a comparison of the obtained rotational temperature to the gas temperature at the ICP is shown.
Acknowledgment: We thank RUB, CAU and IPP for providing spectra.

P 18.41 Do 16:30 Foyer Nordbau

Windowless VUV spectroscopy of an RF-driven atmospheric pressure helium plasma jet with admixtures of oxygen or nitrogen — •Fenja Severing, Judith Golda, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Germany

Cold atmospheric pressure plasmas have a wide field of applications. Their low temperature, high density of reactive particles and emission of energetic photons can be used e.g. for activation of surfaces, disinfection of gas and water or for medical treatment. VUV radiation plays an important role in these applications but the generation mechanisms are still unknown. In this work, further insights into the mechanisms occurring in an atmospheric pressure plasma are gained by optical emission spectroscopy. To provide accurate spectral observations in the VUV region, the experimental setup must be free of VUV radiation absorbing material. This is realized by a continuous helium flow into the VUV spectrometer as well as a windowless beam path.

Here, we present optical emission measurements of high energetic photons between 50 nm and 200 nm in an atmospheric pressure plasma jet with molecular oxygen and nitrogen admixtures. The intensity characteristics of the observed spectral lines are discussed for different admixture concentrations. Interpretation based on the Corona-Model indicates changes of the electron energy distribution function (EEDF).

P 18.42 Do 16:30 Foyer Nordbau

Sub-ns electric field measurements in atmospheric plasma jet — •Nikita Lepikhin, Dirk Luggenhölscher, and Uwe Czarnetzki — Ruhr University Bochum, Faculty of Physics and Astronomy, Experimental Physics V, Germany

This work is dedicated to electric field measurements in a nanosecond pulsed atmospheric plasmas. The discharge is generated by high-voltage (HV) pulses with 6 kV amplitude at a repetition rate of 1 kHz between two electrodes with a length of 20 mm and an inter electrode distance of d=1 mm. The electric field induced Second Harmonic Generation (SHG) is chosen as measurement technique [1]. A Nd-YAG laser with pulse duration of 100 ps is used as a source of radiation at 1064 nm. In the presence of an electric field, second harmonic at 532 nm is generated proportionally to the square of field strength and detected by a PMT. The method works with arbitrary gases, for example, CO_2, N_2, CH_4, Ar and air [1]. Due to the properties of the laser, high temporal (100 ps) and spatial (100 μm) resolution can be achieved. In order to obtain absolute values, calibration with a known field value is necessary. The calibration is made by measuring the second harmonic signal at known DC voltages applied to the electrodes. Test measurements with nanosecond pulses with sub-breakdown voltage amplitude, U, have been performed in ambient air. Good agreement between sub-breakdown electric field values measured by the SHG technique and the field, calculated as U/d, has been obtained. Measurements of the value and the direction of electric field in the discharge are under development. [1] A. Dogariu et. al., Physical Review Applied 7 (2017)

P 18.43 Do 16:30 Foyer Nordbau

Ro-vibrational distribution measurements in transient atmospheric pressure plasmas by coherent anti-Stokes Raman scattering — •Jan Kuhfeld, Dirk Luggenhölscher, and Uwe Czarnetzki — Ruhr University Bochum, Faculty of Physics and Astronomy, Experimental Physics V, Germany

Ro-vibrational excited molecules govern the plasma wall interaction and the chemical reactions in atmospheric pressure plasmas. Excitation of a molecule can occur by an energetic electron or by collisional transfer from an already excited molecule. One of the key goals in discharge design is optimizing these excitation processes in order to achieve maximum energy efficiency in chemical conversion, e.g. CO_2 into CO. The experimental approach for investigating these processes introduced here is based on a particular coherent anti-Stokes Raman scattering (CARS) scheme. This single shot dual pump CARS scheme provides in parallel information on the ro-vibrational population of two molecular species, here N_2 and CO_2. Excited molecules are created by two separated ns-pulsed APPJ with effluents intercepting. Space and time resolutions are determined by the interaction volume of the lasers and the pulse length respectively. Those are in the order of 10 μm and 10 ns.

P 18.44 Do 16:30 Foyer Nordbau

Pulsed operation of large scale dielectric barrier discharge reactors — •Jan Carstensen, Frank Kassubek, Torsten Votteler, Enea Bianda, Vincent Dousset, Emmanouil Panousis, Seila Rodriguez-Vilches, and Simon Gautschi — ABB Corporate Research, Segelhofstr. 1K, 5405 Baden-Daettwil

Dielectric barrier discharges (DBD) have been studied extensivly over the last decades and are used in a wide variety of applications (generation of UV radiation, surface treatment, pollution control, aerodynamic flow control, ...). Commercial, large-scale DBD reactors, e.g. as used for the generation of ozone, are usually operated with a slow sinusoidal voltage waveform with frequencies in the range of 50 Hz to 10 kHz. It is know that the conversion of electrical energy into active species can be more efficicent for a pulsed train shaped waveform with fast rise-times ($<$ 100 ns). In this contribution we discuss options to apply pulsed voltage waveforms to large-scale DBD reactors that are characterized by a large electrical capacitance and represent a high electrical load to the power supply.

P 18.45 Do 16:30 Foyer Nordbau

Investigation of the interplay between electric fields in plasma and phospholipid membranes via molecular dynamics simulations — •Torge Appel and Michael Bonitz — Institute of Theoretical Physics and Astrophysics, University of Kiel, Germany

Cold atmospheric pressure plasmas (CAPP) are a common plasma source. Different investigations showed a significant potency against pathogenic organisms like bacteria and viruses and offer the possibility for a new area of applications in plasma medicine[1]. Beside temperature, radicals and uv-radiation, electric fields are one of the main active ingredients in CAPPs which can induce pore formation in lipid membranes [2]. The mixture of these components is highly dependent on the plasma source. To minimize the risk of medical applications on humans and to optimize the therapeutical efficacy, the knowledge of microscopical processes is important and a thorough understanding of the interplay between the biological cell and the ingredients of a plasma source is needed.
Here we investigate the effect of electric fields on model cell membranes, consisting of different single types of phoshpolipids (DPPC, DLPC, DMPC), which are common lipid types in eukaryotic cell membranes, via molecular dynamics simulations. To estimate the angular dependence and distribution of electric field induced pore formation both all-atom (CHARMM) and coarse-grained (MARTINI) force fields are used and all simulations are performed with GROMACS version 5.1.2.
[1] Woedtke *et al.*, Physics Reports **530**, 291 (2013)
[2] Levine *et al.*, Membrane Biol **236**, 27 (2010)

P 18.46 Do 16:30 Foyer Nordbau

Emission spectroscopy of the effluent of a helium-nitrogen atmospheric pressure plasma — •Carmelo Setaro, Judith Golda, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Germany

Atmospheric pressure plasma applications are established in the industrial and medical field and the number of applications are increasing. Most of these applications are based on the interaction between reactive species as well as radiation generated in the plasma source and the treated surface. Previous studies have shown that long-living nitrogen species in an afterglow can travel considerable distances along the plasma effluent [1]. However, the transport of energy responsible for emission in the effluent region is not fully understood, yet.

We used a helium atmospheric pressure plasma with an admixture of molecular nitrogen to create an afterglow in the effluent. An Echelle spectrometer was used to measure high-resolution spectra along the plasma source, both of the plasma and of the afterglow. The emitting species were identified and reaction kinetics were deduced from spatial emission profiles.

[1] S. Spiekermeier, Doctoral thesis, Ruhr-Universität Bochum, Universitätsbibliothek, 2017

P 18.47 Do 16:30 Foyer Nordbau

Assessment of the impact of Penning dissociation of CO_2 in a non-equilibrium atmospheric pressure plasma jet — •Christoph Stewig, Theresa Urbanietz, Steffen Schüttler, Volker Schulz-von der Gathen, Marc Böke, and Achim von Keudell — Research Department Plasmas with Complex Interactions, Experimental Physics II - Reactive Plasmas, Ruhr-Universität Bochum, D-44780 Bochum, Germany

The storage of renewable energies into chemical fuels due to the dissociation of CO_2 has been an inspiring idea for years. The utilization of a non-equilibrium plasma allows a degradation of the activation barrier of the required chemical reactions, thus potentially yielding to more energy efficient processes.

The observed conversion rates of up to 57% in an atmospheric helium RF plasma jet cannot be solely explained by the electron induced excitation transfer within the plasma. Therefore, other processes like the Penning dissociation, due to metastable noble gas molecules, must be considered.

The utilization of different helium-argon plasma compositions and its impact on the CO_2 excitation and dissociation is analysed with Fourier transform infrared spectroscopy and compared to the estimates based on simple global models.

P 18.48 Do 16:30 Foyer Nordbau

Initial ignition phase of a micro cavity plasma array — •Sebastian Dzikowski, Marc Böke, and Volker Schulz-von der Gathen — Experimentalphysik II, Ruhr-Universität Bochum, Bochum, Germany

Micro cavity plasma array devices have gained increased attention over the last years for large scale applications such as surface treatment and catalysis. A representative is a MCPA formed by two electrodes and a dielectric foil in between. The grounded electrode realized by a magnet is covered with a 40 microns thick dielectric of zirconium oxide. A 50 microns thick nickel grid containing hundreds to thousands symmetrically arranged holes is magnetically fixed on the dielectric and works as the powered electrode. The formed cavities have a diameter of about 200 microns and due to the magnetic holding all components can be exchanged easily. Here, this device operates with bursts consisting of about 20 bipolar triangular voltage pulses in a range between 800 and 1400 V (peak-to-peak) at 15 kHz close to atmospheric pressure. Just few hundred microseconds after the initial ignition this device already shows a time stable character. We investigate how this steady state is reached and which mechanisms are responsible for that. For an estimation of the internal electric field and rotational temperatures depending on the excitation cycles optical emission spectroscopy (OES) is used. This project is supported in frame of the SFB CRC 1316 "Transient Atmospheric Pressure Plasmas - From plasma to liquids to solids".

P 18.49 Do 16:30 Foyer Nordbau

Reproducibility of core-discharge parameters in the 'COST Reference Microplasma Jet' — •Patrick Preissing, David Steuer, Volker Schulz-von der Gathen, and Marc Böke — Experimental Physics II, Ruhr-University Bochum

Cold atmospheric pressure plasmas (CAPs) have gained intense attraction over the last few years. CAPs provide great properties for applications such as for activation of surfaces, etching, coating and many more. It has been shown that atomic oxygen plays a major role for interaction. However, the sources, especially parameter correlations of CAPs were poorly characterized and results from different devices were only hardly comparable. In this context a robust stable micro RF reference atmospheric pressure plasma jet (mAPPJ) was developed with a high degree of reproducibility. This device is referred to as the COST-Jet. Here, the reproducibility concerning current voltage characteristics is evaluated with an integrated current voltage probe in the jet, constantly recording these key quantities. The 1d spatial distribution of atomic oxygen along the discharge core, as well as a power and O2 admixture variation is then measured via passive optical emission spectroscopy, namely actinometry. The results are compared to absolute densities measured earlier by active Two Photon Absorption Laser Induced Fluorescence spectroscopy (TALIF). The measurements are performed within the framework of the B2 project of the SFB1316 'Transient Atmospheric Pressure Plasmas: from plasmas to liquids to solids'.

P 18.50 Do 16:30 Foyer Nordbau

Impurity injection beyond the tracer-limit by means of laser blow-off in W7-X. — •Th. Wegner and The W7-X Team — Max-Planck-Institute for Plasma Physics, Greifswald, Germany

The investigation of impurity transport properties is a demanding task for fusion devices with the potential of steady-state operation since central accumulation of those highly charged ions could yield too strong radiative cooling. One prominent method to study the impurity confinement is based on the injection of impurity ions via the laser blow-off technique. Basically, the impurity transport analysis relies on an impurity injection within the tracer- limit to exclude collisions between impurities and their influence on the background plasma. Hence, each ionization stage can be treated separately and the coupling to neighboring states is only determined by ionization and recombination. To estimate the trace approximation limit and to study the disturbing impact of massively impurity injection on the plasma parameters, the amount of particles injected by means of laser blow-off was increased during an experimental program. Thus, the ablation spot size as well as the laser energy density on the coated target were changed. As a result, the injected impurity amount was increased until the perturbation by the injection itself led to radiative collapse and hence to an early pulse termination. Additionally, the composition of the particle beam changed with respect to the amount of clusters and macro particles as a consequence of the reduced laser energy density.

P 18.51 Do 16:30 Foyer Nordbau

An optimized geometry for high speed pellet guiding tube on ASDEX Upgrade — •Bernhard Ploeckl, Albrecht Herrmann, Holger Köhnlein, and Peter T. Lang — Max Planck Institute for Plasma Physics, 85748 Garching, Germany

Cryogenic pellet injection from the magnetic high field side will be the prime candidate to fuel future fusion power plants. The launching system on ASDEX Upgrade injects cryogenic hydrogen pellets with a speed up to 1000 m/s from the magnetic high field side of the tokamak using guiding tubes. Pellets passing the guiding tube are sliding on a gas cushion, generated by the Leidenfrost effect. The amount of the ablated gas depends on centrifugal forces, hence from curvature and speed. The actual trajectory has a rectangular cross section and is composed of a series of ellipses in order to generate the required 270° turn; the length is 17m. The last part of this track is marked by strong geometrical constraints from vacuum vessel port. The design presently in operation is composed by a sequence of three sections of ellipses, tangentially constant but discontinuous with regard to the curvature. These steps in curvature are supposed to limit the system performance. A new geometry has been designed using clothoids, a well-known method from civil engineering (e.g. railroad track design). Clothoids provide a smooth transition between the geometrical elements, keeping the curvatures continuously differentiable. The presented measure will help to improve pellet system performance on ASDEX Upgrade and provide knowledge for the design of pellet guiding tubes in future fusion devices.

P 18.52 Do 16:30 Foyer Nordbau

Plasma Terminating Events in Large Stellarators — •Daniel Maier[1], Andreas Dinklage[1,2], Jürgen Baldzuhn[2], Rainer Burhenn[2], Rene Bussiahn[2], Birger Buttenschön[2], Phillip Hacker[2], Matthias Hirsch[2], Udo Höfel[2], Thomas Wegner[2], and Daihong Zhang[2] for the The Wendelstein 7-X Team-Collaboration — [1]Universität Greifswald, 17489 Greifswald, Germany — [2]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

The sudden termination of fusion plasmas may result in high power loads on plasma facing components. In terms of operational limits, we investigate the amount of fuelling pellets or impurities that a plasma can sustain without termination. Here, also the possibility of plasma recovery for close to marginal termination is an object of investigation.

For a quantitative assessment of mechanisms and timescales of termination, this study focuses on experiments with substantial release of plasma energy due to fuelling pellets or injected impurities. Depending on the material and its amount, plasma termination or recovery is observed. Time scales for the rate of plasma cooling were calculated from waveforms of electron cyclotron emission. The times are found to be in general around 15 to 30 percent of the characteristic energy confinement times. A stronger rate of cooling is typically found in the plasma centre.

The observed time scales and the potential of plasma recovery at marginal limits of injected impurities indicate the beneficial impact of vacuum confinement of stellarator magnetic configuration.

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Impact of edge plasma phenomena on the scintillator pat-

tern of the i-HIBP diagnostic — •Viktoriia Olevskaia[1,2], Gregor Birkenmeier[1,2], Joaquin Galdon-Quiroga[1], Elisabeth Wolfrum[1], Ulrich Stroth[1,2], and the ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, Garching 85748, Germany — [2]Physik-Department E28, Technical University Munich, 85748 Garching, Germany

The imaging Heavy Ion Beam Probe (i-HIBP) is a new powerful diagnostic based on a neutral heavy ion beam and a scintillator detector, which is currently under construction for the ASDEX Upgrade tokamak. This diagnostic has the potential to detect perturbations of density, poloidal magnetic field, and plasma potential. Potential and magnetic field perturbations cause spatial shifts of the ion trajectories and thus change the shape of the pattern on the scintillator detector, while density perturbations modify the intensity of the scintillator signal. This knowledge allows us to investigate edge instabilities and turbulent flows in magnetically confined plasmas. Simulations using a full-orbit calculating code including beam attenuation effects were conducted to predict the scintillator pattern generated by different physical phenomena like instabilities or a transport barrier which are know to influence plasma edge confinement. To distinguish the different phenomena, their temporal and spatial scales are taken into account. In the presented work, results of perturbation amplitude estimations as well as simulations of the expected scintillator patterns for different phenomena are presented.

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Influence of the optical thickness on the evaluation of the He beam diagnostics at ASDEX Upgrade — •Daniel Wendler[1,2], Michael Griener[1], Ralph Dux[1], Elisabeth Wolfrum[1], Ulrich Stroth[1,2], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Physik Department E28, TUM, Garching, Germany

For magnetically confined fusion plasmas, the behaviour of the plasma edge layer is crucial to achieve a sufficient confinement. To measure the electron density and temperature at the plasma edge of ASDEX Upgrade, helium is injected by a fast valve. The helium cloud is observed on 20 radial positions with a temporal resolution of 1μs. The injected helium is excited mainly by electron collisions. Four transitions in the visible light range are evaluated. The ratio between a singlet and triplet transition is sensitive to the temperature, whereas a ratio of transitions from different angular momentum states is sensitive to the density. These ratios are then compared with results from a collisional radiative model, which relates the state changing processes in the plasma to the measured emission in order to calculate the underlying electron temperature and density.
First results from this diagnostic show implausible temperatures near the injection valve. This is assumed to be caused by the absorption of ultraviolet resonance lines which causes a change of the population density, leading to a modification of the observed line ratios. The progress in the numerical work to simulate the opacity effects on the evaluation of temperature and density measurements is presented.

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First operation of the NBI system at Wendelstein 7-X — •Annabelle Spanier[1,2], Dirk Hartmann[2], Paul McNeely[2], Norbert Rust[2], and Robert Wolf[1,2] for the The Wendelstein 7-X Team-Collaboration — [1]Technische Universität Berlin, Berlin, Germany — [2]Max Planck Institute for Plasma Physics, Greifswald, Germany

Neutral beam injection (NBI) heating was used at the superconducting optimized stellarator Wendelstein 7-X for the first time during the experimental campaign OP1.2b in 2018. The injector is equipped with two inductively coupled ion sources that can accelerate positively charged hydrogen ions up to 55 keV. The maximum combined heating power is 3.4 MW. A second injector is planned to be operational in summer 2019.
In comparison to other heating methods, NBI is not only a source of energy but also of fast particles. Therefore, one can modify the density and temperature profiles of a plasma. For example, at high density further density peaking was observed.
The energy flow in the NBI system is being investigated in detail. The focus is on the energy distribution of the accelerated ions, the dependence of the extracted current on the ambient magnetic field of W7-X and the dependence of the perveance on the beam parameters.

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The ASDEX Upgrade room-temperature solid-state pellet injector adapted for COMPASS — •N. Hoepfl[1,2], P. T. Lang[1], B. Ploeckl[1], D. Wu[2], J. Cerovsky[3,4], O. Ficker[3,4], J. Mlynar[3,4], V. Weinzettl[3], and ASDEX Upgrade Team[1] — [1]MPI für Plasmaphysik, Boltzmannstr. 2, 85748 Garching — [2]Munich University of Applied Sciences, Lothstr. 34, 80335 München — [3]IPP Prague, Czech Republic — [4]Faculty of Nuclear Sciences and Physical Engineering, Technical University, Prague, Czech Republic

The room-temperature solid-state pellet (RTSP) injector, used at ASDEX Upgrade, was revised and characterized for the COMPASS tokamak. The system operates with a gas gun accelerator providing a repetition rate of up to 2 Hz and is capable to launch spherical and cylindrical pellets. We tested a variety of pellet materials and different propellant gases. In its application at AUG cylindrical Li pellets of 1.5 mm diameter and 2 mm length were injected using Deuterium as propellant gas to study the impact of Li on the plasma performance. For COMPASS, where it is foreseen to be applied in runaway electron studies, the injector has been optimized and characterized in a test bed. Therefore, tests with cylindrical boron nitride (BN) pellets employing Argon and Helium propellant gas were performed. Pellets with a diameter of 1.5 mm and a length of 1 mm and 2 mm, respectively, have been tested. The pellet speed ranges from 130 m/s up to 700 m/s, depending on pellet size, propellant kind and pressure, the latter varying from 5 to 100 bars. Delivery efficiencies above 91% were achieved within a 1° maximum pellet trajectory scattering cone.

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Runaway electron experiments with solid state pellet injector at COMPASS tokamak — •Jaroslav Cerovsky[1,2], Ondrej Ficker[1,2], Eva Macusova[2], Jan Mlynar[1,2], Vladimir Weinzettl[1], Michal Farnik[1,2], Jozo Varju[1], Martin Jerab[1], Petr Barton[1,3], Niklas Hoepfl[4,5], Peter Thomas Lang[4], and Bernard Ploeckl[4] — [1]Institute of Plasma Physics of the CAS, Prague, Czech Republic — [2]Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Prague, Czech Republic — [3]Faculty of Mathematics and Physics, Charles University, Prague — [4]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [5]Munich University of Applied Sciences, Lothstr. 34, 80335 München, Germany

In the recent years the runaway electrons have been intensively investigated at the COMPASS tokamak. It has proved to be a suitable experimental device for runaway electrons studies due to its safe operation concerning the presence of runaway electron beams and a set of diagnostics, which is useful for runaway investigation. The future runaway experimental campaigns at the COMPASS tokamak will be dedicated to investigation of interaction of runaway electrons with solid state pellets. In order to achieve this goal the solid state pellet injector will be moved from ASDEX Upgrade tokamak and implemented into tokamak COMPASS environment. This contribution reports on future experimental plans and discusses physics goals, which could be accomplished. The experiments will be mainly focused on generation and also on the possible mitigation of runaway electrons beams.

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First results of the confinement properties in configuration scans during the recent experimental campaign of Wendelstein 7-X — •Tamara Andreeva for the The Wendelstein 7-X Team-Collaboration — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

Wendelstein 7-X is a modular advanced stellarator, combining the modular coil concept with the optimized properties of the plasma. The machine went into operation in December 2015 at the Max-Planck-Institut für Plasmaphysik in Greifswald, Germany, and recently successfully finished its second divertor phase experimental campaign OP1.2b, devoted to the exploration of the Test Divertor Unit, high performance hydrogen discharges and verification of the W7-X optimization principles.

The predecessor experiment Wendelstein 7-AS revealed that in low to medium density plasmas small configuration changes in the rotational transform (iota) near rational iota values could lead to a significant variation of confinement. Configuration scans conducted in the recent W7-X experimental phase OP1.2b aimed to investigate similar effects by varying gradually the rotational transform with help of the planar coil currents for otherwise same discharge conditions. The configurational space between high iota and standard reference magnetic configurations was chosen, since the high iota magnetic configuration has an almost negligible value of the bootstrap current at low densities. This contribution presents the observed results of the configuration scans.

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Dynamics of TESPEL injections in the W7-X stellarator observed with SXR tomography — •Christian Brandt[1], Jonathan Schilling[1], Henning Thomsen[1], René Bussiahn[1], Naoki Tamura[2], Rainer Burhenn[1], and and the W7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald, Germany — [2]National Institute for Fusion Science, 322-6 Oroshi-cho, Toki City, 509-5292 Japan

At the stellarator experiment Wendelstein 7-X (W7-X) a tracer-encapsulated solid pellet injection (TESPEL) system has been commissioned during the recent plasma operation phase OP1.2b (Jul-Oct 2018). The TESPELs represent well-known and well-localized sources of impurity atoms, starting effective X-ray emission after the thin shell of the pellet is ablated and the impurity atoms enter the hot plasma core ($T > 1\,\mathrm{keV}$). The soft X-ray tomography system (XMCTS) – commissioned in OP1.2b – is capable to measure such dynamics by two-dimensional X-ray emissivity profiles in the up-down symmetric triangular plane with both high time resolution (sampling rate 2 MHz) and high spatial resolution ($\Delta x \approx \Delta y \approx 4\,\mathrm{cm}$). After injection of the tracer impurity pellets into the plasma volume radially localized perturbations of the equilibrium are observed in the 2D X-ray emissivity profiles. Investigations of the poloidal propagation and the spatiotemporal evolution of the perturbations created by the tracer impurity injections are presented.

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Partial Mutual Information analysis of spatio-temporal ECE data in W7-X — •Juan Fernando Guerrero Arnaiz[2], Andreas Dinklage[1,2], Bernd Pompe[2], Matthias Hirsch[1], Udo Hoefel[1], Robert Wolf[1], and The W7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, 17491 Greifswald, Germany — [2]University of Greifswald, 17489 Greifswald, Germany

Quantifying the spatio-temporal behavior of fluctuating quantities may reveal transport characteristics in high temperature plasmas. Traditional techniques employ cross correlations or higher-order statistics to determine relevant space and time scales as well as propagation velocities of the perturbations displayed by the diagnostic signals. Here we implement partial mutual information analysis on plasma data, which gives additional insight on the spatio-temporal coupling of observations at different locations. Specifically, time series from electron cyclotron emission (ECE) at different cyclotron frequencies, representing different locations along the diagnostic sightline in Wendelstein 7-X are analyzed. The technique allowed for the characterization of coupling of different observations on the same flux surface and thereby the identification of measurements supposed to originate from symmetric plasma profiles. Differently to other methods, partial mutual information analysis allows one to study the effect of spurious signal contributions, like common drivers of the signals under comparison. This capability may finally serve for causality detection.

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Simulations of 3D SOL filaments in detached conditions — •David Schwörer[1,2], Nick Walkden[2], Huw Leggate[1], Ben Dudson[3], Fulvio Militello[2], and Miles M. Turner[1] — [1]Dublin City University, Dublin, Ireland — [2]Culham Centre for Fusion Energy, Culham, UK — [3]University of York, York, UK

Filaments are field aligned density and temperature perturbations, which provide a significant flux of particles and heat from the last closed flux surface to the far scrape-off layer (SOL). In order to design next generation tokamaks, it is beneficial to make robust predictions of wall fluxes, which requires understanding of these non-diffusive transport mechanisms.

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 detached divertor conditions. Filaments were seeded on the backgrounds, and the resulting filament motion was studied. In attached conditions we found a strong target temperature dependence, while in detached conditions we found the filament to be electrically insulated from the sheath, caused by a high resistivity in the cold area adjacent to divertor target. In general a decreasing trend of the radial filament velocity with increasing density is observed, however on the onset of divertor detachment this trend is temporarily broken as the filament becomes electrically isolated from the divertor target.

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MHD activity and bootstrap current evolution during the first divertor campaign at the Wendelstein 7-X stellarator — •K Rahbarnia[1], T Andreeva[1], CD Beidler[1], T Bluhm[1], BB Carvalho[2], J Geiger[1], U Neuner[1], J Schilling[1], A v Stechow[1], H Thomsen[1], Y Turkin[1], M Zanini[1], M Zilker[1], and W7X 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

During the past operational phase OP1.2b at Wendelstein 7-X (W7-X), wall conditioning via repeated boronization led to enhanced plasma performance. A plasma heating interlock signal, based on the measured diamagnetic energy (W_{dia}), supported safe W7-X operation. The pulse duration was significantly extended (up to 100s@2MW heating power) while keeping stable plasma conditions, which allows the study of bootstrap current evolution for several characteristic time scales. Previous results indicating current minimization in W7-X are further supported by a large number of dedicated experiments and comparisons to 1-D neoclassical transport simulations. Based on measurements from a total of 125 Mirnov probes, the underlying MHD activity during transient high plasma energy phases ($W_{dia} \sim 1.2$MJ) is investigated. Sudden energy crashes, induced by external current drive, as well as fast ion triggered plasma instabilities also provoke pronounced MHD activity. Preliminary mode number analysis results are discussed, complemented by Soft X-Ray, electron cyclotron emission and phase contrast imaging diagnostic measurements.

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Impact of Tracer-Encapsulated Solid Pellets (TESPEL) on Wendelstein 7-X plasmas — •René Bussiahn[1], Naoki Tamura[2], Kieran Joseph McCarthy[3], LHD experiment group[2], and W7-X team[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald, Germany — [2]National Institute for Fusion Science(NIFS), Toki, Japan — [3]Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Madrid, Spain

A Tracer-Encapsulated Solid Pellet (TESPEL) injection system, developed by the National Institute for Fusion Science(NIFS), Japan was installed before, and commissioned during, the OP1.2b operation phase of the stellarator Wendelstein 7-X. The method allows depositing impurity tracers within a well localized region of the W7-X core plasma for impurity transport studies. A short-term perturbation of the plasma due to the ablation of the polystyrene shell and the actual tracer particles of the TESPEL is seen in time-resolved n_e and T_e -profiles (Thomson scattering) while a simultaneous reduction of plasma turbulence is also observed in phase contrast imaging (PCI) data. The formation of an ablation cloud and its spread along the magnetic field lines has been observed by means of a fast frame camera. A soft X-ray tomography system (XMCTS) was used to observe temporal changes in the 2D X-ray emissivity profiles. Vacuum ultraviolet spectroscopy (HEXOS) as well as the X-ray Imaging Crystal Spectrometer (XICS) have been employed to observe the temporal radiation evolution for impurity transport studies.

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Selected MHD phenomena observed in the first divertor campaign of Wendelstein 7-X — •Henning Thomsen for the The Wendelstein 7-X Team-Collaboration — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

The first divertor campaign in Wendelstein 7-X stellarator (W7-X) successfully finished in October 2018. The plasma duration could be extended to up to 100s in Hydrogen for an ECRH heating power of 2 MW. The plasma performance in Hydrogen could be enhanced with respect to previous campaigns by improving the wall conditioning. The peak heating power was 7 MW (ECRH / NBI).

Transiently, high performance plasmas with stored energies of up to $W_{dia} = 1MJ$ ($\langle\beta\rangle > 1$ %) could be created by means of ECRH and pellet fueling for a quick ramp-up of the plasma density. During one experimental program a sudden decrease of the stored energy by 100 kJ has been observed. We present data analysis from the soft-X-ray tomography system, which enables the estimation of the location of the crash and compare the findings with data from crashes observed in plasmas with actively driven toroidal currents.

Another focus of the ongoing investigations covers the detection and identification of MHD mode activity and their dependency on the magnetic configuration as well as the heating scenario.

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Formation of turbulent transport in 3D stellarator geometry — •Mirko Ramisch, Stephen Garland, Bernhard Schmid, and Til Ullmann — Institute for Interfacial Process Engineering and Plasmatechnology - University of Stuttgart, Germany

At the stellarator TJ-K, investigations have been carried out into the spatial dependencies of different types of turbulent transport: particle and momentum cross-field transport in the confined edge region as well as intermittent blob transport in the scrape-off layer (SOL). Multi-probe measurements were conducted for correlation of fluctuation data with local characteristics of the magnetic field, in particular field-line curvature. As a result, the transport phenomena share striking features in spatial locality: particle and momentum transport as well as density intermittency levels show peak values, where regions of negative normal curvature fall together with regions of positive geodesic curvature. This allows to understand particle transport in terms of linear instability of drift waves, and to view observed spatial Reynolds stress concentration in correlation with instability regions. Moreover, intermittency in density fluctuations turns out to result from density-potential decoupling taking place in the same region. Extended Hasegawa-Wakatani simulations point to the specific structure of curvature being responsible for the decoupling process under conditions of low magnetic shear. Geodesic curvature is also demonstrated to determine the poloidal propagation of blobs in the SOL. This contribution illustrates magnetic field curvature as an element bridging between dynamics of the drift-wave/zonal-flow system and blob filaments across the separatrix.

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Three-mode coupling under imposed $E \times B$ shear — •Til Ullmann[1], Bernhard Schmid[1], Peter Manz[2], and Mirko Ramisch[1] — [1]Institute of Interfacial Process Engineering and Plasma Technology, University of Stuttgart — [2]IPP, Max-Planck Institut, Garching

In toroidal fusion plasmas, shear flows are considered to be involved in the reduction of turbulent transport. Background shear flows can tilt the vortex structure of the perturbed plasma, which leads to a higher Reynolds stress. A stronger tilt of the eddies enhances a straining out process, which favours the creation of large scale zonal flows. Therefore, zonal flows act as an energy sink for turbulence. At the stellarator TJ-K the influence of the equilibrium shear flow on turbulence is investigated experimentally. The equilibrium shear is changed with plasma biasing and diagnosed with an emissive probe. In TJ-K, turbulence is dominated by drift-wave dynamics. Their nonlinear behavior can be described by three wave coupling: $k_1 + k_2 = k_3$, $\omega_1 + \omega_2 = \omega_3$. In order to account for both resonance conditions, a wavenumber-frequency bicoherence spectrum is calculated from potential fluctuations measured with a 128 pin poloidal probe array. Increased non-linear mode coupling is observed for (k_3, ω_3) following the drift-waves' dispersion relation. The influence of background shear flows on these three-wave interactions is studied and possible consequences for zonal-flow generation are discussed.

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The development of an Intense Pulsed Positron Source (IPPS) — Martin Singer[2], •Stephan König[1], Uwe Hergenhahn[2], Gerrit Marx[1], Thomas Sunn Pedersen[2], and Lutz Schweikhard[1] — [1]Institut für Physik, Universität Greifswald, Felix-Hausdorff-Str.6, 17489 Greifswald — [2]Max-Planck-Institut für Plasmaphysik,Wendelsteinstr. 1, 17491 Greifswald

The IPPS (Intense Pulsed Positron Source) project is part of the APEX (A Positron Electron eXperiment) collaboration [1] with the aim to produce a positron-electron pair-plasma. The worlds brightest positron source located at NEPOMUC (NEutron inducted Positron source MUniCh) at FRM2 in Garching produces a continuous beam. However, for the positron pulses needed for our purpose it is necessary to accumulate and confine the positrons for long times (in the order of hours). To reach this goal it is planned to build a multi cell trap consisting of a Penning-Malmberg trap as a master cell located on axis of the magnetic field of a superconducting magnet and several further Penning-Malmberg traps located on and off axis behind the master cell [2]. The master cell will confine an initial bunch of positrons and fill the other traps by excitation of the radial motion of the positron plasma. When the necessary number of positrons is reached they are quickly released.

In this contribution we present the general setup and preparatory measurements with one Penning-Malmberg trap serving as master cell.

[1] T. Sunn Pedersen et al., New J. Phys. 14, 035010 (2011)
[2] J. R. Danielson et al., Phys. Plasmas 13, 123502 (2006)

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Positrons polarization by nonlinear Compton scattering in strong laser field — •Yue-Yue Chen[1], Pei-Len He[2], Karen Z. Hatsagortsyan[1], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Key Laboratory for Laser Plasmas (Ministry of Education) and Department of Physics and Astronomy, Collaborative Innovation Center of IFSA (CICIFSA), Shanghai Jiao Tong University, Shanghai 200240, China

Accelerated beams of polarized positrons have important applications in high-energy and solid-state physics. Positrons produced in nonlinear Compton scattering of an ultra-relativistic electron beam and a focused PW laser pulse are polarized due to the asymmetry of spin-flip transitions and asymmetric dynamics of particles in laser fields. Both electrons and produced pairs can be polarized to a high degree in femtosecond time scale. A semi-classical model is developed to describe the classical spin procession, radiative polarization and spin resolved pair production simultaneously, which is appropriate for any field configuration and realistic trajectories of ultra-relativistic electrons.

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X-Ray Phase-Contrast Imaging of Simulated Laser-Induced Plasma Shocks — •Julian Saffer[1], Andreas Wolf[1], Veronika Ludwig[1], Max Schuster[1], Maria Seifert[1], Mareike Weule[1], Thilo Michel[1], Paul Neumayer[2], Gisela Anton[1], and Stefan Funk[1] — [1]ECAP - Erlangen Centre for Astroparticle Physics, Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany

A detailed investigation of the astrophysical processes in, e.g. supernova remnants, requires the production of plasma shocks in a laboratory setting. For this purpose, laser-induced shocks in a plasma have been simulated with a laser-plasma code. Subsequent simulations of the imaging process with an X-ray phase-contrast setup have been run and the detector images have been used for phase retrieval which eventually yields the electron density distribution of the plasma. This contribution discusses the feasibility of this concept prior to a potential realization in the laboratory.

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X-ray phase-contrast imaging as a plasma diagnostics technique — •Max Schuster[1], Veronika Ludwig[1], Maria Seifert[1], Mareike Weule[1], Andreas Wolf[1], Thilo Michel[1], Paul Neumayer[2], Gisela Anton[1], and Stefan Funk[1] — [1]ECAP - Erlangen Centre for Astroparticle Physics, Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany

X-ray phase-contrast imaging enables the retrieval of the electron-density distribution in a sample probed by X-rays. Propagation-based and grating-based X-ray phase-contrast imaging are full-field imaging techniques by which the electron-density distribution can be retrieved with a single acquisition. This, i.e. single-shot imaging, is essential for the acquisition of the processes and dynamics of laser-shocked plasmas. In this contribution both approaches are introduced and their application as a diagnostics tool for electron-density distributions of laser-induced plasmas is addressed. In particular, their implementation and resolving power at pump-probe experiments with an X-ray backlighter are presented.

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Robustness of an X-ray phase-contrast imaging setup for plasma diagnostics at an X-ray backlighter — •Veronika Ludwig[1], Max Schuster[1], Paul Neumayer[2], Maria Seifert[1], Andreas Wolf[1], Stefan Funk[1], and Gisela Anton[1] — [1]ECAP - Erlangen Centre for Astroparticle Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg — [2]GSI Helmholtzzentrum für Schwerionenforschung

Grating-based X-ray phase-contrast imaging demonstrated great potential in medical imaging and materials testing in the last decades. In addition to the conventional attenuation image, a dark-field and a differential phase image are obtained. The differential phase-image enables an enhanced sensitivity to local variations in the electron density distribution. Hence, a further upcoming field of application lies in high-energy-density (HED) physics. Imaging small variations in shocked matter at short length scales and rapid temporal dynamics are very challenging. Here, single-shot imaging with a Talbot interferometer could gain a higher contrast compared to mere attenuation imaging. Experiments regarding the applicability of Talbot imaging were performed with X-rays emitted by a laser-driven backlighter at PHELIX, GSI. Due to the long time between single laser shots on the backlighter wire, no in situ adjustment of the grating interferometer is possible. Thus, a transportable and stable setup, which preserves the exact alignment of the gratings to each other, is necessary. The results obtained with such a setup and the principle of using a moiré map for a beforehand fine adjustment in the home laboratory are presented.

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High-resolution Reflective Interferometry Experiments at a sub-10-fs Laser-produced Plasma — •Maximilian Münzberg, Michael Stumpf, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

We present results from an experiment in which ultrashort laser pulses (8 fs) were focused with maximum intensities of $2 \cdot 10^{17}$ W/cm^2 onto flat metallic surfaces. We measured the time evolution of the electron distribution by investigating the wave front deformation in the probe pulse with a Mach-Zehnder-Interferometer. Under some conditions we find two expansion phases - a fast one with a time scale of tens of femtoseconds and strong spatial variations and a ps-scale expansion which is almost isotropic. The experiments were performed with varied laser intensities and different target geometries. The experimental results are compared with PIC-simulations which verify a strong dependence of early expansion on the surface structure of the targets.

P 18.73 Do 16:30 Foyer Nordbau

Reflection Phase Shift Measurements at Developing Plasma Layers — •Nico Potzkai, Michael Stumpf, Julian Wegner, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

The reflection phase change of light depends on the optical parameters of the reflecting material and can be calculated using Fresnel's equations with complex refractive indices. We measured this phase jump for the reflection at thin plasma layers at a solid surface. The plasma was generated by ultrashort laser pulses, and the measurement was performed with an extreme time resolution in the range of 10 fs, which allows conclusions on the freshly generated and evolving plasma. The experiments were done with different materials for plasma generation and also for the reflection at thin metal layers for comparison. We discuss first experimental results together with simulations showing dependences on the layer thickness and on the plasma parameters.

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Bright terahertz-radiation source from two-color mid-infrared laser pulse interacting with a microplasma target — •Tatyana Liseykina[1] and Sergey Popruzhenko[2] — [1]Universität Rostock, Institut für Physik, Germany — [2]National Research Nuclear University, MEPhI, Moscow, Russia

A way to a considerable enhancement of the terahertz radiation from atomic gases, irradiated by intense mid-infrared laser light has been recently suggested (V. A. Tulsky, M. Baghery, U. Saalmann, S. V. Popruzhenko, Phys. Rev. A 98, 053415 (2018)). In particular, theoretical analysis of both the single-atom-ionization dynamics and the collective motion of the laser-generated plasma (restricted to the 1D model) confirmed that the application of the circularly polarized laser light with 2-4 micrometer wavelength may result in considerable increase of the conversion efficiency of the infrared radiation into the emitted terahertz waves. In this work we present the results of the 2D particle-in-cell modeling of the terahertz response in the case of a two-color mid-infrared laser pulse propagating in argon.

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Intensity Dependence of the Laser Ionization of Noble Gases — •Matthias Melchger, Dirk Hemmers, Michael Stumpf, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Describing the ionization of atoms by intense ultra-short laser pulses requires different theoretical models, depending on the intensity regime. We investigated the intermediate region between the multi-photon and the tunnelling ionization regimes and determined absolute ionization rates for Helium, Neon and Argon over a broad range of laser intensities around 10^{15} W/cm^2. Experiments were conducted using a carefully characterized large capacitor device and yielded the total number of generated free charges. The data evaluation takes into account the intensity variations over the full focal region. The measured numbers are compared to temporally and spatially resolved simulations using the relevant ionization models. Our results allow the prediction of absolute ionization rates in a large range of Keldysh parameters around one.

P 18.76 Do 16:30 Foyer Nordbau

Hybrid formulation of fully- and gyrokinetic Hamiltonian field theory for astrophysical plasmas — •Felipe Nathan deOliveira, Daniel Told, Natalia Tronko, and Karen Pommois — Max Planck Institute for Plasma Physics

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

This study aims to develop a field theoretical hybrid model where the dynamics of ions is described within a fully kinetic framework and the dynamic of electrons is described using a gyrokinetic coordinate system. From the Lagrangian 2-form one performs [5] a series of gauge transformations in order to eliminate the theta dependence up to a predefined ordering. A Lie transformation is performed to ensure theta independence in the Hamiltonian part of the Lagrangian. The dynamics of the system is derived using the variational principle in the action, which also includes the electromagnetic fields. With this work, we wish to develop a computational framework to investigate in detail the kinetic and turbulent effects present in astrophysical[6] and laboratory plasmas.

P 18.77 Do 16:30 Foyer Nordbau

Hybrid drift kinetic electron - kinetic ion computations for electrostatic fluctuations in astrophysical plasmas — •Karen Pommois[1], Simon Lautenbach[2], Florian Allman-Rahn[2], Felipe Nathan De Oliveira[1], Rainer Grauer[2], and Daniel Told[1] — [1]Max Planck Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching bei München — [2]Ruhr Universität Bochum, Universitätsstraße 150, 44801 Bochum

Kinetic numerical simulations, applied to study local heating in the solar wind, are computationally expensive due to the different evolution scales involved in the dynamics. Therefore, simplified models, such as hybrid fluid-kinetic and gyrokinetic, are widely employed. However, gyrokinetics is missing waves with frequencies above the cyclotron frequencies of the species involved and the hybrid-fluid model is missing electron kinetic effects even at ion scales [1]. Therefore, a more suitable and computationally lighter model to investi- gate kinetic effects in astrophysical plasma simulations could employ a hybrid description, composed of kinetic ions and gyrokinetic electrons. In this poster we will show our first numerical steps, where we implemented this hybrid model in the case of electrostatic dynamics and drift-kinetic electrons. This hybrid model will be included in MuPhy [2], a framework designed to couple different numerical codes for solving plasma problems.

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P 18.78 Do 16:30 Foyer Nordbau

Electron-Ion Temperature Ratio in Collisionless Shocks — •Adrian Hanusch[1], Tatyana Liseykina[1], and Mikhail Malkov[2] — [1]Institut für Physik, Universität Rostock, 18051 Rostock, Germany — [2]CASS and Department of Physics, University of California, San Diego, La Jolla, California 92093, USA

Collisionless shocks are ubiquitous in astrophysical environments and are proven to be efficient particle accelerators. Since the shock transition occurs on a length scale much smaller than the particle collisional mean free path, an equilibration between ion and electron temperatures might not occur immediately. Observations of Balmer dominated shocks have shown a trend of smaller electron temperatures with a dependence of the electron-ion temperature ratio on the shock velocity [1]. We use hybrid modeling of collisionless shocks to investigate the thermalization of test-particle electron population in the proton driven turbulence. The results of our simulations compare well with the observational data and earlier theoretical predictions [2].

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P 18.79 Do 16:30 Foyer Nordbau

Investigation of deuterium retention and permeation in ITER 316L(N)-IG stainless steel — •Jana Scheuer, Anne Houben, Arkadi Kreter, Marcin Rasinski, Yulia Martynova, Bernhard Unterberg, and Christian Linsmeier — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany

Austenitic steel type 316L(N) is installed in ITER. In terms of safety and to avoid fuel losses, it is important to study deuterium retention and permeation in 316L(N)-IG steel. The samples are polished and annealed to eliminate surface effects and influences of natural hydrogen inventory. Subsequently, a deuterium plasma exposure takes place in the linear plasma device PSI-2. In order to determine the influence of deuterium exposure on the permeation of deuterium through the material the samples are investigated in a permeation measurement system. The retained deuterium inventory can be observed by thermal desorption spectroscopy (TDS). To examine the influence of deuterium exposure, the samples are loaded with plasma or unloaded. The surface structure is determined before and after plasma loading by a Scanning Electron Microscope (SEM). Furthermore, SEM measurements on cross sections prepared by an focused ion beam (FIB) are performed to investigate the influence of the change of the surface and microstructure by deuterium exposure. The deuterium inventory and the change of deuterium permeation through the material during ITER operation can be estimated.

P 18.80 Do 16:30 Foyer Nordbau

Assesment of plasma edge transport in double null configurations in the EAST tokamak — •Dieter Boeyaert[1,2], Sven Wiesen[1], Wouter Dekeyser[2], Stefano Carli[2], and Liang Wang[3] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany — [2]KU Leuven, Department of Mechanical Engineering, Celestijnenlaan 300, 3001 Leuven, Belgium — [3]Institute of Plasma Physics, Hefei 230031, China

Optimal design of power and particle exhaust is key for future fusion reactors [1]. As the targets only resist a limited heat load, the high particle and power fluxes are a challenge for a single null (SN) divertor. A redistribution of these heat loads could be obtained using other magnetic configurations. Based on [2] it is expected that the fluxes decrease using a double null (DN) configuration.

In this contribution, we study a DN configuration at EAST. The distribution of power between the inner and outer divertor is influenced by the transport of the plasma particles. Therefore the difference in particle (cross-field) flows between SN and DN configuration is studied. For this study SOLPS-ITER simulations [3] are used as it includes drifts and flows self-consistently. Based on the first modeling results the transport in EAST SN and DN cases are compared. In [4] it is shown that drifts are important in the transport for SN discharges. For the EAST DN discharges this is studied in this contribution.

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P 18.81 Do 16:30 Foyer Nordbau

Interaction of plasma-generated reactive species with methylene blue — •Kerstin Sgonina, Nils Dose, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

The generation of highly reactive species in cold atmospheric pressure plasma jets is used for many different applications. One of them is the treatment of aqueous solutions to produce so-called Plasma Treated Water, which shows a high reactivity with biological substrates caused by the reactive species. Anyhow, the transport of these from gas-phase into liquid-phase and further reaction pathways still need to be studied in more detail. For atomic oxygen, the effective transport into aqueous solutions [1] and the importance for further reactions in water [2] were already proven.

In this contribution, our latest progress in studying the plasma-liquid interaction will be presented. Here, an aqueous methylene blue solution was treated by the effluent of an atmospheric pressure plasma jet, the COST-jet [3], with He/O2 gas mixture. By observing the degradation of methylene blue molecules, the reaction rate was calculated. These results might give an insight whether the reactions in the solution are surface or volume dominated, thus into the reaction mechanism.

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P 18.82 Do 16:30 Foyer Nordbau

Spectroscopic observation of oxygen, carbon and boron before and after boronization in W7-X — •Stepan Sereda[1], Sebastijan Brezinsek[1], Erhui Wang[1], Maciej Krychowiak[2], Marcin Jakubowski[2], Ralf König[2], Yunfeng Liang[1], Tullio Barbui[3], Bernd Schweer[1], Guruparan Satheeswaran[1], Horst Lambertz[1], Rahim Allahyari[1], Victoria Winters[3], Mathias Schülke[2], Yanling Wei[4], and Olaf Neubauer[1] for the The Wendelstein 7-X Team-Collaboration — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung, Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), Jülich, Germany — [2]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [3]University of Wisconsin-Madison, Madison, USA — [4]Southwestern Institute of Physics, Chengdu, China

The low-z elements oxygen and carbon were the main impurities in W7-X plasma. After boronization a significant decrease of oxygen and carbon reduced the radiative-induced density limit. Line emission of these two elements together with a newly arisen boron were studied with a help of spectroscopy to characterize impurity flux in the divertor region before and after boronization. Particularly, an overview spectrometer with a wide wavelength range (300 nm - 1100 nm) was used to simultaneously observe all lines of interest. In addition, cameras with narrowband interference filters together with the divertor gas injection system were used to derive a 2D emission profiles of injected He to investigate Te and ne profiles.

P 18.83 Do 16:30 Foyer Nordbau

Investigating H-retention in tungsten fiber reinforced tungsten composites by using single-layered model systems — •Annemarie Kärcher[1,2], Johann Riesch[2], Armin Manhard[2], Pirmin Almanstötter[2,3], and Rudolf Neu[1,2] — [1]Technische Universität München, München, Deutschland — [2]Max-Planck-Institut für Plasmaphysik, Garching, Deutschland — [3]Universität Augsburg, Augsburg, Deutschland

Tungsten fiber reinforced tungsten (Wf/W) composites are pseudo-ductile materials, that use extrinsic toughening mechanisms to mitigate the brittleness of W. Due to their composite structure, many new aspects of hydrogen isotope (e.g. deuterium (D)) retention may arise. For a better understanding of hydrogen retention in Wf/W composites, single-layered model systems consisting of one layer of long parallel W fibers with a diameter of 150μm are studied. The fibers are coated by an Er2O3-interface and embedded in a thick CVD-W matrix. To investigate the influence of the matrix, fiber and the interface in between, the samples are prepared in a way that the fiber layer is located at various distances to the surface. In order to load the samples with D, they are exposed to a D plasma for 72 hours. The microstructure is characterized by means of electron microscopy before and after this exposure. The D concentration is measured first by nuclear reaction analysis, giving a depth profile of up to 8μm below surface, followed by thermal desorption spectroscopy, which yields the total retention. The results will be used to understand determining mechanism and define the next steps of retention studies of bulk Wf/W composites.

P 18.84 Do 16:30 Foyer Nordbau

Preparation for high accuracy deuterium retention measurements in tungsten with μNRA — •Robert Krug, Sören Möller, Arkadi Kreter, and Bernhard Unterberg — Forschungszentrum Jülich, Institut für Energie- und Klimaforschung, 52425 Jülich, Germany

The influence of the microstructure on the deuterium retention in tungsten is not fully investigated. In this contribution, we report on the progress of developing a new testing scheme for high resolution and accuracy μNRA, which enables the correlation of the microstructure with retention.
The retention is greatly temperature and flux dependent. As such, these parameters have to be accurately measured. To achieve this, the accuracy and reproducibility of the plasma shape and measured surface temperature in the linear plasma device PSI-2 is investigated and optimized.
The sample preparation routine is refined as well and the effect of electropolishing before plasma exposure is examined. Additionally, investigations into the influence of the storage conditions between plasma exposure and μNRA on retention are done.

P 18.85 Do 16:30 Foyer Nordbau

Temperature depence of the erosion of tungsten based smart alloys for the first wall of fusion power plants — •Karen De Lannoye[1,2], Janina Schmitz[1,3], Andrey Litnovsky[1], Felix Klein[1], Arkadi Kreter[1], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich, IEK-4, 52425 Jülich, Germany — [2]Vrije Universiteit Brussel, 1000 Brussels, Belgium — [3]Department of Applied Physics, Ghent University, 9000 Ghent, Belgium

The first wall of future fusion power plants, like DEMO, will be exposed to high heat and high particle loads. Few materials can withstand these conditions. Tungsten (W) is a good candidate as a first wall material, as one of the main advantages is its low erosion rate. Fast oxidation of W at high temperatures when coming in contact with air might disqualify W in the course of an accident. Self-passivating tungsten-chromium-yttrium (WCrY) smart alloys (SA) are designed to prevent this oxidation. SA and reference W samples were exposed to steady-state D plasma to determine the erosion rate. The first experiment at around 650 ^{o}C with an ion energy of 220 eV and fluence of 1 . 10^{26} ions/m^2 revealed the necessity of considering diffusion of alloying elements in order to evaluate the sputtering rates. In order to determine the impact of diffusion on erosion of smart alloys, three experiments were done at the different temperatures of about 300 ^{o}C, 650 ^{o}C and 800 ^{o}C. The ion energy and fluence were kept at 60 eV and 1 . 10^{26} ions/m^2, respectively, for all three experiments. Analysed results of the experiments, with special regard to the temperature effects, will be presented in this contribution.

P 18.86 Do 16:30 Foyer Nordbau

Towards Applications of Deep Learning Techniques to Establish Surrogate Models for the Power Exhaust in Tokamaks — •Martin Brenzke[1], Sven Wiesen[1], Matthias Bernert[2], and The ASDEX Upgrade Team[2] — [1]Forschungszentrum Jülich, Institut für Energie- und Klimaforschung, 52425 Jülich, Germany — [2]Max Planck Institute for Plasma Physics, 85748 Garching, Germany

One of the main challenges in the design of an economically viable fusion reactor are the thermal loads experienced by the plasma facing components, especially the targets in a divertor-based design, on which this work and current developments focus. These thermal loads cause degradation of the target material and might severely damage the machine, resulting in longer downtime for maintenance. Modeling these thermal loads is one of the most important points in determining the operating scenarios for future fusion devices. Under attached conditions, simplified analytical models, such as the two-point model, are sufficient to determine the thermal load experienced by the divertor targets for given conditions of the main plasma. However, modeling and predicting thermal loads is a challenging yet crucial task for future devices. In light of current developments and successes in the field of machine learning techniques, data-driven modeling is an interesting option for this problem. We present first steps towards modeling the power exhaust of tokamaks using deep learning methods (neural networks) and experimental data from the ASDEX Upgrade experiment. The work focuses on data selection and initial approaches to the problem of modeling the power exhaust from experimental data.

P 18.87 Do 16:30 Foyer Nordbau

Towards nonlinear MHD simulations of quasi-axisymmetric stellarators — •Nikita Nikulsin and Matthias Hoelzl — Max Planck Institute for Plasma Physics, Garching, Germany

Quasi-axisymmetric (QA) stellarators present a major improvement in neoclassical confinement over unoptimized stellarators. By imposing the constraint that the magnetic field strength does not depend on the Boozer toroidal angle, particle orbits can be made tokamak-like, significantly improving confinement. In addition to particle orbits, QA stellarators share many other similarities with tokamaks. In particular, the bootstrap current contributes significantly to the rotational transform in a QA device. This raises the question of whether QA stellarators will be prone to disruptions like tokamaks, how these disruptions would compare to tokamak disruptions and whether they can be avoided more easily than in a tokamak. In order to investigate this, nonlinear MHD simulations of QA stellarators will be conducted. Currently, work is underway to derive reduced MHD equations suitable for a QA stellarator and implement them in the JOREK code, which will then be used to simulate various QA configurations.

P 18.88 Do 16:30 Foyer Nordbau

Integrated modelling of tokamak plasma confinement — •Teobaldo Luda di Cortemiglia, Clemente Angioni, Mike Dunne, Emiliano Fable, Arne Kallenbach, Philip Schneider, Giovanni Tardini, the ASDEX Upgrade Team, and and the EUROfusion MST1 Team — Max-Planck-Institut für Plasmaphysik, Garching, Germany

The design of future fusion reactors and their operational scenarios require an accurate estimate of the plasma confinement, which is a key parameter for the evaluation of the fusion performance, and the production of electricity. We are developing a new model that integrates different elements describing the main physics phenomena which determine plasma confinement. In particular, we are coupling a new pedestal transport model, based on empirical observations, to the ASTRA transport code. We also coupled a simple scrape-off-layer model to ASTRA, which provides the boundary conditions at the separatrix, which are a function of the main engineering parameters. By this way no experimental data is needed, and the only inputs of the model are the magnetic field, the plasma current, the heating power, the fueling rate, the size of the device, and the plasma geometry. In the modelling workflow, first a scan in pedestal pressure is performed, by changing the pedestal width, then the MISHKA MHD stability code is run to determine the pedestal top pressure. The long term goal is to obtain a robust model which can be used to identify important hidden dependencies affecting global plasma confinement, which are difficult to capture by statistical regressions on global parameters.

P 18.89 Do 16:30 Foyer Nordbau

A Heuristic Dimits Shift Prediction using Reduced Tertiary Instability Analysis — •Axel Hallenbert and Gabriel Plunk — Max-Planck-Institut for Plasma Physics, Greifswald, Germany

Following the recent development of a heuristic Dimits shift prediction method by St-Onge yielding accurate results in a simple modified Terry-Horton system, the feasibility of further extending this method to more physically complete systems is investigated. The ultimate aim being a Dimits shift prediction in general gyrokinetic systems and magnetic field geometries, investigations into an intermediary, local, strongly driven gyrokinetic limit, retaining both linear drive and nonlinear zonal-drift wave interactions, is presented. By the ad-hoc inclusion of damping into this system a Dimits shift can be made to arise, and through slight modifications to the original method, the revised prediction method continues to yield consistently acceptably accurate results for a broad array of different parameter realisations, hinting at its further viability for next describing full gyrokinetics in simple magnetic geometries.

P 18.90 Do 16:30 Foyer Nordbau

Correlation between source parameter and beam properties at the large negative ion source ELISE — •Isabella Mario, Federica Bonomo, Ursel Fantz, and Dirk Wünderlich — Max-Planck-Institut für Plasmaphysik, Garching, Germany

The neutral beam injection (NBI) system for ITER is based on RF sources for production of negative ions (H^-/D^-). In the European R&D roadmap towards the full size ITER NBI source, the ELISE test facility with half the size of the ITER NBI source aims 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. The ITER beam requirement in term of beam uniformity ($>$ 90%) ensures good beam line transmission. The large (1 m^2) beam produced at the ELISE test facility can be vertically asymmetric and inhomogeneous due to the interplay of plasma drifts and non-uniform negative ion production and extraction. Aim of this work is to correlate the plasma properties in the region close to the extraction system with the beam in order to improve the insight into physical effects affecting the beam properties. Particular emphasis is laid on vertical profiles both in the source and on the beam side. The main plasma parameters such as positive ion density, plasma potential, negative ion density and caesium density are monitored at 2 cm distance from the extraction apertures. The beam losses into the grid system and the global extracted current are electrically measured while several beam diagnostic tools provide local accelerated beam currents and local beam divergences.

P 18.91 Do 16:30 Foyer Nordbau

Self-consistent modelling of runaway electron generation in massive material injection scenarios in current-carrying fusion devices — •Oliver Linder, Emiliano Fable, Frank Jenko, Gergely Papp, and Gabriella Pautasso — Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany

Relativistic electrons (RE) generated during sudden loss of both thermal energy and plasma current in current-carrying fusion devices may severely damage the first wall of these machines. As the presence of a significant RE population consequently has to be avoided in future, large reactors, suppression of REs is currently being studied through massive material injection (MMI) in present-day tokamaks, such as ASDEX Upgrade. To complement experimental studies through numerical simulations, a reduced kinetic description of RE generation is introduced in the tokamak transport code package ASTRA-STRAHL, used already successfully to simulate the pre-thermal quench phase. Plasma energy and particles are evolved self-consistently in a realistic magnetic geometry within this took-kit, allowing for systematic studies of RE generation following the injection of varying amounts and types of material. This contribution presents the tools necessary for modelling MMI scenarios and first results obtained.

P 18.92 Do 16:30 Foyer Nordbau

Numerical investigation of the power transfer efficiency of inductively coupled plasmas in hydrogen and deuterium — •Dominikus Zielke[1], Stefan Briefi[1], David Rauner[1], and Ursel Fantz[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching — [2]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg

In ion sources for neutral beam heating systems for fusion, inductively coupled hydrogen and deuterium plasmas (ICPs) are used. To increase the reliability of these systems, it is desirable to reduce the power that has to be delivered by an RF generator being currently in the 100 kW range. This can be done by maximizing the power transfer efficiency η, i.e. the ratio of power absorbed by the plasma to the power that is delivered by the generator.

Experimental results at low RF powers in the 1 kW range show that besides parameters such as plasma and antenna geometries, RF frequency and power, also the used gas type (hydrogen or deuterium) has an influence on η.

While in the experiment specific effects such as the influence of the masses, collisional cross-sections and atom to molecular ratios cannot be decoupled, this is possible with numeric simulations. For this reason a dedicated time-dependent 1D multi-fluid model is used. The model simulates the inductive coupling between the antenna and the plasma self-consistently. The contribution covers quantitative investigations of each of the above mentioned specific effects and their respective influences on η.

P 18.93 Do 16:30 Foyer Nordbau

Analysis of disruption prediction methods on a per disruption-cause basis. — •Victor Artigues and Frank Jenko — Max Planck Institute for Plasma Physics, Boltzmannstr.2, 85748 Garching, Germany

The main approach in disruption prediction research using machine learning methods is to compile a database made of disruptive shots and safe shots, with little regard for the cause of disruption. The disruptive shots are all combined under one label. Multiple causes of disruption have been identified in a study on a large number of JET shots. On the one hand, splitting the databases with the different causes of disruption can ease the learning process and give a better understanding of the prediction and its link to physics. On the other hand, it is well known that reducing the size of the datasets will be detrimental to the prediction.

As a first step towards a cause-by-cause disruption prediction system, we analyzed the performances of state-of-the-art disruption prediction methods when trained on datasets separating the different causes. Our study is conducted on the shots from the ASDEX-Upgrade Tokamak, using a Support Vector Machine (SVM) model such as the one used at JET and a Long-Short Term Memory (LSTM) artificial neural network. We compare the ease of prediction regarding the different types and discuss future work such as data augmentation to deal with the smaller datasets.

P 18.94 Do 16:30 Foyer Nordbau

Local gyrokinetic stability theory of plasmas of arbitrary degree of neutrality — •Daniel Kennedy, Alexey Mishchenko, and Per Helander — Max-Planck-Institut fur plasmaphysik

Dipole (RT-1) and stellarator (CNT) geometries are capable of confining plasmas of arbitrary neutrality, ranging from pure electron plasmas through to quasineutral. The Diocotron mode is known to be important in non-neutral plasmas and has been widely studied. However, drift mode dynamics, dominating quasineutral plasmas, has received very little by way of attention in the non-neutral context. Here, we show that non-neutral plasmas can be unstable with respect to both density-gradient and temperature-gradient driven instabilities. A local shearless slab limit is considered for simplicity. A key feature of non-neutral plasmas is the development of strong electric fields, in this local limit, the effect of the corresponding ExB drift is limited to the Doppler shift of the complex frequency. However, the breaking of the quasineutrality condition still leads to interesting dynamics in non-neutral plasmas. In this paper we address the behaviour of a number of gyrokinetic modes in electron-ion and electron-positron plasmas with arbitrary degree of neutrality. We also examine the cross-field particle transport due to such modes.

P 18.95 Do 16:30 Foyer Nordbau

Bayesian modelling of reflectometers at Joint European Torus using the Minerva framework — •Sehyun Kwak[1,2], Jakob Svensson[2], Joe Abbate[3], Lynton Appel[3], Jon Hillesheim[3], Felix Parra Diaz[3], and Luis Meneses[3] — [1]Department of Nuclear and Quantum Engineering, KAIST, Daejeon 34141, Republic of Korea — [2]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany — [3]Culham Centre for Fusion Energy, Culham Science Centre, Abingdon OX14 3DB, UK

A Bayesian model for the JET reflectometers has been developed to infer electron density profiles using the Minerva framework. The reflectometry system consists of six channels covering four different bands between 44 and 150 GHz by the fast-sweeping frequency with ordinary and extraordinary mode wave. It measures electron density profiles from the edge to the centre, up to electron density of ~1020 m-3 with the temporal resolution about 10 microseconds. The forward model predicts optical path length that the waves travel and reflect back to the antenna, given electron density, temperature profiles, and magnetic field. The electron temperature profiles and magnetic field are taken from high resolution Thomson scattering diagnostics and equilibrium fitting (EFIT) code respectively. The electron density profiles are modelled by Gaussian processes to constraint profiles with length scale without any specific parameterisation. The posterior distribution is explored by Markov chain Monte Carlo (MCMC) sampling and the results include electron density profiles as well as their associated uncertainties.

P 18.96 Do 16:30 Foyer Nordbau

Investigation of the synergistic effects of H and radiation damage on the mechanical properties of W — •Bailey Curzadd[1,2], Johann Riesch[1], Till Höschen[1], Alexander Feichtmayer[1,2], and Rudolf Neu[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Deutschland — [2]Technische Universität München, München, Deutschland

As a common plasma-facing material in fusion reactors, tungsten (W) is exposed to high-energy neutron and hydrogen (H) fluxes. Progress in the development of a new experimental device to investigate the impact of this environment on the mechanical properties of W will be presented. The device will be used to characterize the influence of radiation damage, implanted H (as well as other impurities), and their synergistic interactions on the strength and ductility of W. Radiation damage will be produced by self-damaging with W ions at 20 MeV. Impurity atoms will be subsequently implanted in the sample, and the mechanical properties determined via in situ tensile testing. Due to the low penetration depth of W ions, thin fibers and foils ($\leq 5\ \mu$m) are foreseen as samples. Additionally, the high degree of deformation in these material forms results in fine microstructures, which reduces the influence of grain-size effects and thus enables the simulation of bulk material behavior. The influence of temperature during irradiation and mechanical loading will also be examined.

P 18.97 Do 16:30 Foyer Nordbau

Non-linear simulations of inter-ELM activity in ASDEX Upgrade — •Andrés Cathey[1], Matthias Hoelzl[1], Mike Dunne[1], Guido Huijsmans[2,3], and Sibylle Günter[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching bei München, Germany — [2]CEA, IRFM, 13108 Saint-Paul-Lez-Durance, France — [3]Eindhoven University of Technology, Eindhoven, The Netherlands

The presence of naturally-occurring Edge Localized Modes (ELMs) in tokamaks is of concern for future devices like ITER [T Eich, et al, NME 12 2017]. Large type-I ELMs lead to a crash of the edge pressure profile typically every $10-100$ milliseconds causing high heat fluxes to plasma facing components. Qualitative and some quantitative agreement between experimentally observed ELM crashes and simulations with the JOREK non-linear 3D magnetohydrodynamic (MHD) code [GTA Huysmans and O Czarny, NF 47 7 2007] have been achieved in many occasions by taking unstable plasma equilibria as a starting point [M Hoelzl, et al, CPP 58 6-8 2018][SJP Pamela, et al, PPCF 58 1 2015]. To obtain a fully realistic description of ELMs and become predictive the entire ELM cycle needs to be simulated [GTA Huijsmans, et al, PoP 22 2 2015]. The inter-ELM phase in ASDEX Upgrade type-I ELMy H-mode is often characterised by the presence of toroidal perturbations of mode number $n = [3-5]$ followed by higher frequency mode activity [AF Mink, et al, PPCF 58 12 2016]. Preliminary simulations show similar behaviour and confirm that these saturated modes cause losses affecting the build-up of the edge pressure gradient prior to the next ELM crash.

P 18.98 Do 16:30 Foyer Nordbau

Quantitative investigation of the neutron production in ASDEX Upgrade — •Monika Koleva, Giovanni Tardini, and the ASDEX Upgrade Team — Max-Planck-Institute for Plasma Physics, Garching, Germany

A different calibration procedure for the neutron counters with higher reproducibility and longer calibration time has been performed in ASDEX Upgrade. The main purpose was to check how strongly the calibration uncertainties influence the neutron rate measurement and thus add to the 'neutron deficit' in fusion plasmas.

Resolving the 'neutron deficit', i.e. the discrepancies between the experimental neutron counts and the theoretical calculations, is important for the systematic analysis of fast ion physics, as fast ions play a fundamental role in the plasma performance and pose challenges to the plasma facing components. The theoretical comparison is in progress and is performed with the Serpent code, developed at VTT Technical Research Centre of Finland.

Future goal of this work is to install a new neutron detector with higher time resolution, better statistics and less uncertainty, hence opening the space for fast ion physics investigation.

P 18.99 Do 16:30 Foyer Nordbau

First Results from a High Time-Resolution Thomson Scattering System at Wendelstein 7-X — •Hannes Damm and Ekkehard Pasch for the The Wendelstein 7-X Team-Collaboration — Max Planck Institute for Plasma Physics, Greifswald, Germany

Studies of short transient plasma events may reveal fast relaxation mechanisms of the plasma or MHD events.
The poster describes a Thomson Scattering (TS) System, simultaneously providing electron temperature and density profiles, combining high temporal resolution and adjustable measuring times. This "burst" TS mode has a typical 10kHz time resolution spread over a time window of typically 1.2ms, compared to the 30Hz standard mode. Three lasers are employed each emitting up to four laser pulses per burst, providing twelve consecutive measurement points. A burst can be either triggered at pre-defined times or by plasma events, for which a fast trigger logic circuit was developed.
Burst measurements of the following events have been successfully conducted: *i)* injection of cryogenic hydrogen pellets for plasma fuelling, *ii)* impurity injection via Tracer-Encapsulated Solid Pellets (TESPEL) and Laser Blow-Off, *iii)* heat waves driven by Electron-Cyclotron-Current-Drive (ECCD) crashes and *iv)* modulation of the Neutral Beam Injection and Electron Cyclotron Resonance Heating. Significant effects on the density and temperature profile shapes are shown for different plasma events.

P 18.100 Do 16:30 Foyer Nordbau

Theory-based modelling of advanced scenarios in ASDEX Upgrade — •Maximilian Reisner[1,2], Jörg Stober[1,2], Emiliano Fable[1], Alexander Bock[1], Benedikt Geiger[1], David Rittich[1], Alejandro Bañon Navarro[1], Rachael McDermott[1], and The ASDEX Upgrade Team[1] — [1]MPI für Plasmaphysik, Garching, Germany — [2]Ludwig-Maximilian-Universität, München, Germany

For the design of future nuclear fusion power plants, one needs to be able to extrapolate to larger scale devices. It is therefore important to have transport codes that allow the user to reproduce experiments done in current scale devices. Fully gyrokinetic codes like GENE allow for high accuracy, but are also very slow. A faster alternative is the quasilinear gyrofluid transport code TGLF, which is based on linear approximations to the gyrokinetic equations combined with so-called saturation rules. While being a well tested transport code in standard scenarios, TGLF in the past has failed to reproduce the good energy confinement observed in certain advanced scenario shots. In my poster, I will discuss some recent ASTRA/TGLF simulations of ASDEX Upgrade advanced scenario shots that manage to reproduce the good energy confinement of such discharges much better than was previously possible. This improvement was achieved by forcing ASTRA to keep the equilibrium fixed and adding fast ions as a kinetic species. Another important component in the TGLF simulations is the rule governing the suppression of turbulence via the ExB-shear, which was changed in a recent version of TGLF. The validity of this new rule was cross-checked with GENE simulations.

P 18.101 Do 16:30 Foyer Nordbau

Conceptual system design study of an NNBI beamline for DEMO — •Giuseppe Starnella, Christian Hopf, Niek den Harder, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik, Garching bei München, Germany

Neutral Beam Injection (NBI) is one of the heating and current drive (H&CD) systems considered for DEMO. The DEMO design is in a pre-conceptual phase, meaning that many options are under investigation and, therefore, the requirements for the NBI development are still not clear. In any case, the commercial viability of Fusion Power Plants (FPP) depends on maximizing the wall-plug efficiency. The NBI wall-plug efficiency is currently limited to about 27% on ITER, mostly due to the low efficiency of the gas neutralization. Hence, increasing the neutralization efficiency is compulsory.

Plasma neutralization is one of the alternatives that we take into consideration: a plasma is used in place of the neutral gas, in which the electrons more readily strip the negative ions. The plasma inside the neutralizer is created by the negative ion beam as it passes through the neutral gas. The optimum target thickness to obtain the maximum neutralization efficiency is studied for different geometries as well as the ion trajectories in presence of the magnetic cusp field that is applied to confine the plasma.

Another technological solution is the Energy Recovery (ER): after neutralization, the energy of the residual ions is recovered by separating, decelerating and collecting them on different collectors. We present a first conceptual design for the integration of an ER system.

P 18.102 Do 16:30 Foyer Nordbau

Extending the fluid turbulence code GRILLIX to study general geometries — •Thomas Body, Andreas Stegmeir, Wladimir Zholobenko, and Alexander Ross — Max-Planck-Institut für Plasmaphyik, Garching bei München, Germany

GRILLIX implements the drift-reduced Braginskii equations in a 3D toroidal geometry. Due to the fluid approximation and drift-reduction it may simulate longer time-scales than a similar kinetic or gyro-kinetic code, at the cost of a reduced physics set. In contrast to transport codes, GRILLIX is able to self-consistently develop turbulent structures in divertor geometry, and currently being extended for more realism such as through the inclusion of neutrals.

The code uses the flux-coordinate independent (FCI) approach, which can easily deal with complex magnetic geometries. However, it is currently based on axisymmetric magnetic fields. This work shall discuss the push to non-axisymmetric magnetic fields with 3D boundaries. As a first step, the application of boundary conditions was made more flexible through the use of the penalisation technique, which allows for the treatment of nonconformal boundaries. Next steps include including a 3D field-line tracing method for the parallel operators, and adapting the perpendicular operators to allow for pitched magnetic fields through the use of tilted toroidal planes. These modifications will allow for comparison to results from stellarators such as W7X and spherical tokamaks like MAST-U. These comparisons will help with interpretation of results from these experiments, and with scaling of these results to reactor-relevant conditions.

P 18.103 Do 16:30 Foyer Nordbau

Artificial Neural Networks for Plasma Edge Analysis in Wendelstein 7-X — •Marko Blatzheim[1,2], Daniel Böckenhoff[1], Roger Labahn[2], and Thomas Sunn Pedersen[1] for the The Wendelstein 7-X Team-Collaboration — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]Institute for Mathematics, University of Rostock, Rostock, Germany

Wendelstein 7-X (W-7X) is a stellarator type nuclear fusion experiment. The plasma facing components show heat load patterns detectable by infrared cameras due to the contact with hot plasma. Artificial neural networks can be trained with observations of heat load pattern based on Field Line Diffusion simulations to reconstruct plasma properties in real time. Different types of neural networks from feed-forward fully-connected and convolutional neural networks to deep residual inception networks can be assigned with that task. The advantages and disadvantages for each of these neural network architerctures are investigated with all results generally satisfactory.

P 18.104 Do 16:30 Foyer Nordbau

SOLPS simulations for alternative configurations in the future upper divertor in ASDEX Upgrade — •Ou Pan[1,2], Tilmann Lunt[1], Marco Wischmeier[1], David Coster[1], Ulrich Stroth[1,2], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, 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. ASDEX Upgrad recently decided to modify the upper divertor [1] to study alternative divertor configurations which are currently discussed as a possible solution for the power exhaust problem. In this work, we report on SOLPS simulations for a low-field side snowflake minus (LFS SF-) divertor configuration [2] where the geometrical splitting of the scrape-off layer as well as the enhanced connection length and divertor volume would help to reduce the maximum heat flux. Compared to a standard single null configuration with the same external input parameters, upstream profiles and impurity concentration at the separatrix, the LFS SF- configuration shows significantly higher impurity radiation and volumetric recombination, which lead to a divertor detachment at a lower impurity seeding rate. In addition to this, the first SOLPS-ITER simulation for such a LFS SF- configuration with fully activated drifts will also be shown and discussed. [1] T. Lunt, et al., Nucl. Mat. Energy 12 (2017) 1037 [2] D. Ryutov, et al., Plasma Phys. Control. Fusion 54 (2012) 124050

P 18.105 Do 16:30 Foyer Nordbau

Scale-Resolved Multi-Field Experimental Investigation of Turbulence for the Validation of Gyrokinetic Simulations — •Klara Höfler[1,2], Tim Happel[1], Pascale Hennequin[3], Alexander J. Creely[4], Tobias Görler[1], Elisee Trier[1,5], Ulrich Stroth[1,2], and the ASDEX Upgrade Team[1] — [1]Max Planck Institut für Plasmaphysik, Garching, Germany — [2]Physik Department TUM, E28, Garching, Germany — [3]Laboratoire de Physique des Plasmas, Ecole Polytechnique, Palaiseau, France — [4]MIT Plasma Science and Fusion Center, Cambridge, Massachusets, USA — [5]Max Planck Institut für Plasmaphysik, Greifswald, Germany

Fusion plasmas need high densities, temperatures and long energy confinement times. Turbulence is one of the key players to determine these parameters via particle and heat transport. The corresponding density and temperature fluctuations are measured on the ASDEX Upgrade tokamak via Doppler-reflectometry and electron cyclotron emission diagnostics. Past individual studies in a long history of gyrokinetic validations showed a good agreement between experiments and modelling.

Here the design of a plasma discharge is outlined which will extend these studies by simultaneously measuring as many as possible turbulence properties in order to obtain strong constraints for simulation codes, such as the gyrokinetic code GENE. Initial results of the plasma fluctuation velocity profile perpendicular to the confining magnetic field are presented for various poloidal angles. In addition preliminary studies of core zonal flows, which are low frequency shear flows are shown.

P 18.106 Do 16:30 Foyer Nordbau

Convolutional LSTMs for Plasma State Classification — •Francisco Matos[1], Vlado Menkovski[2], Federico Felici[3], Frank Jenko[1], and The TCV Team[3] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Eindhoven University of Technology, Eindhoven, Netherlands — [3]Swiss Plasma Center, Lausanne, Switzerland

During a tokamak discharge, the plasma can vary between different modes, Low and High confinement, with an additional intermediate state called Dithering. Furthermore, several events can happen during a discharge, namely ELMs when the plasma is in H mode. The state transitions and events in question are identifiable by a human expert post-shot by looking at features from several different diagnostic signals. Ideally, an approach should exist allowing to determine in real-time when these events occur. Convolutional neural networks (CNNs), typically used for image recognition, are ideal to automatically extract the data features necessary to determine when these events take place. However, CNNs do not keep track of temporal dependencies between different data points. As a result, they can make inconsistent predictions - for example, two successive transitions into the same state. Long Short-Term Memory Networks, or LSTMs, are a type of neural network designed specifically to keep track of temporal dependencies. By using convolutional layers for feature extraction and LSTM layers to keep track of temporal correlations, we train an automatic classifier to determine the plasma state. We use data from the TCV tokamak - specifically, photodiode, interferometer and diamagnetic loop signals.

P 18.107 Do 16:30 Foyer Nordbau

Experimental Study of the Influence of the Scrape-off Layer Radial Electric Field on the Transition to the High Confinement Mode — •Ulrike Plank[1,2], Thomas Pütterich[1,2], Marco Cavedon[1], Elisabeth Wolfrum[1], Ulrich Stroth[1], and The ASDEX Upgrade Team[1] — [1]MPI für Plasmaphysik, Garching, Germany — [2]Ludwig-Maximilian-Universität, München, Germany

The high confinement mode (H-mode) is a state of improved plasma confinement in diverted tokamaks. It is achieved when the input power exceeds a threshold and it exhibits a transport barrier in the edge of the confined plasma region. This transport barrier is considered to be caused by local gradients in the radial electric field (E_r) at the edge of the confined plasma region, which lead to sheared $E \times B$ flows ($v_{E\times B}$). These flows suppress turbulent transport in the edge, resulting in an improved plasma confinement. On ASDEX Upgrade (AUG) it was found that a critical value for the $v_{E\times B}$ minimum, a proxy for the $v_{E\times B}$ shear, is needed to sustain H-mode. However, the power threshold to enter H-mode changes when the conditions at the plasma boundary, i.e. in the scrape-off layer (SOL), are altered. Modeling results indicate that these effects impact the magnitude of E_r in the SOL. Therefore, E_r in the SOL could influence the gradients of E_r in the confined region and the access to H-mode. In order to experimentally access E_r in the SOL a charge exchange recombination spectroscopy diagnostics was installed in AUG. First experimental results will be presented.

P 18.108 Do 16:30 Foyer Nordbau

First results from Michelson Interferometer as a broadband ECE diagnostic in W7-X — •Neha Chaudhary, Johan W. Oosterbeek, Matthias Hirsch, Udo Höfel, Robert C. Wolf, and The W7-X Team — Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

For a magnetic field of 2.5T, the electron cyclotron harmonics are spectrally well separated in W7-X as it has a large aspect ratio. Because of this advantage, it is easier to measure these higher harmonics (70,140,210..GHz) compared to tokamaks with small aspect ratio. For confinement reasons, W7-X is planned to work at high plasma densities, applying O2 electron cyclotron resonance heating (ECRH). For such a plasma beyond the X2 cutoff which already has been demonstrated in the experimental campaign OP1.2a and OP1.2b of W7-X, the electron cyclotron emission (ECE) from the optically black second harmonic extraordinary mode X2 (120-160 GHz) is not present. As a result the standard ECE diagnostic consisting of a radiometer with 32 channels spread over 120-160 GHz, is not able to provide electron temperature in the regions where density exceeds the X2 cutoff value. In that case, optically grey higher harmonics provide the only access to ECE signal and hence electron temperature profiles. A Michelson interferometer was used in OP1.2b of W7-X for broadband ECE (50-500 GHz) scan. These results will be compared to modeling of ECE emission at different plasma parameters from radiation transport calculations (TRAVIS).

P 18.109 Do 16:30 Foyer Nordbau

Detachment with the 3D turbulent transport code GRILLIX — •Wladimir Zholobenko, Alexander Ross, Andreas Stegmeir, Thomas Body, David Coster, Omar Maj, Peter Manz, and Frank Jenko — Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany

The plasma edge of magnetic confinement devices is thought to be crucial in determining the performance and survival of the whole machine. The description of this region from first principles is highly demanding: the presence of large gradients drives large turbulent fluctuations, requiring simultaneous time evolution of the background. Further, due to the proximity of the walls, the plasma edge is highly influenced by atomic, molecular and surface processes.

To study the interaction of these processes with turbulence and their interdependency we extend GRILLIX[1,2]: a 3D global turbulence code based on drift-reduced Braginskii equations. The plasma model and its implementation are verified with a simulation of the LAPD experiment. A simple recycling model drastically alters the behaviour of the plasma: the enforced parallel gradients amplify turbulent fluctuations and filamentation, challenging numerical stability. The treatment of these phenomena in tokamak and stellarator geometries is undertaken.

[1] A. Ross. *Extention of GRILLIX: Towards a global turbulence code for realistic magnetic geometries.* Ph.D. thesis, Technical University of Munich (2018).

[2] A. Stegmeir *et al. Plasma Physics and Controlled Fusion*, **60** (3), 035005 (2018)

P 18.110 Do 16:30 Foyer Nordbau

Mass spectrometry and OES characterization of a CO2 microwave plasma at atmospheric pressure — •Federico Antonio D'Isa, Ante Hecimovic, Emile Carbone, and Ursel Fantz — Max-Planck-institut für Plasmaphysik, BoltzmannStr. 2, 85748 Garching

On demand energy storage plays a critical role for an energy grid based on renewable energies. The power to gas technology aims to store excess energy into gas by conversion of CO_2 into chemical fuels. One step of the process consists in the dissociation of CO_2 into CO. In this work a CO_2 plasma excited by microwaves in a TM_{01} cylindrical cavity has been investigated. The plasma was kept at pressure close to atmospheric, while the CO_2 gas flow was varied between 10 slm and 100 slm and microwave power was varied between 900 W and 3000 W. To optimize the CO_2 conversion, the quantification of the energy efficiency and conversion efficiency, and its changes with the plasma parameters such as flow and power, is of critical importance. The CO_2 dissociation has been quantified by sampling the plasma effluent with a capillary and analyzing the gas composition with a mass spectrometer. The necessary pressure drop has been achieved by means of a fixed and a variable orifices connected to an intermediate chamber. The correlation of the conversion and energy efficiency with the rotational and vibrational temperatures (T_{rot}, T_{vib}) determined from the emission of the C_2 ($d^3\Pi_g$ state) is discussed.

P 18.111 Do 16:30 Foyer Nordbau

3D Impurity Migration in Fusion Experiments using WallDYN and EMC3-EIRENE — •Lennart Bock[1,2], Klaus Schmid[2], and Tilmann Lunt[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 transport through the plasma. WallDYN has previously been coupled to the 2D code DIVIMP (WallDYN2D) and thus was 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 or modeling devices like Stellarators requires a full 3D impurity transport model. Therefore, WallDYN is now coupled to the 3D code EMC3-EIRENE (WallDYN3D). This contribution compares WallDYN3D in a toroidally symmetric geometry to results from WallDYN2D and demonstrates how WallDYN3D can describe impurity migration in a fully 3D geometry.

P 18.112 Do 16:30 Foyer Nordbau

ECCD-driven temperature collapses at W7-X — •Marco Zanini[1], Heinrich Laqua[1], Torsten Stange[1], Christian Brandt[1], Hannes Damm[1], Matthias Hirsch[1], Udo Höfel[1], Kian Rahbarnia[1], Erika Strumberger[2], Henning Thomsen[1], and Robert Wolf[1] for the The Wendelstein 7-X Team-Collaboration — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [2]Max-Planck-Institut für Plasmaphysik, Garching, Germany

The superconducting optimized stellarator Wendelstein 7-X is equipped with an electron cyclotron resonance heating (ECRH) system, allowing up to 7.5 MW of power injected into the plasma. The ECRH itself can also be used to drive a net toroidal current in the plasma. The small amounts of toroidal currents makes W7-X a perfect testbed for such ECCD experiments. During ECCD operations, repetitive and periodic collapses of the electron temperature have been detected and they display a similar behavior to sawtooth oscillations in tokamaks. Modelling the temporal current evolution shows local changes of the rotational transform, induced by ECCD, lead to the formation of low order rational value, thus making the plasma unstable. The application of ECCD over several seconds also can result in a global loss of confinement. In order to characterize and understand the observed effects the collapses have on the plasma, different current drive profiles have been used and an initial characterization is presented here. Effects of different configurations on the inversion radius and crash frequency are analyzed and an initial attempt of a mode analysis is presented.

P 18.113 Do 16:30 Foyer Nordbau

Feasibility Study of 14 MeV Neutron Detection During Deuterium Experiments of Wendelstein W7-X — •Jan Paul Koschinsky[1], Christoph Biedermann[1], Simppa Äkäslompolo[1], Sergey A. Bozhenkov[1], Wolfgang Schneider[1], Mitsutaka Isobe[2], Takeo Nishitani[2], Kunihiro Ogawa[2], G. A. Wurden[3], Robert C. Wolf[1], and the W7-X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, D-17491, Greifswald, Germany — [2]NIFS, JP — [3]LANL, US

A future objective of Wendelstein W7-X is the study of fast ion confinement in high performance deuterium plasmas of stellarators. In these plasmas 2.5 MeV neutrons and 1 MeV tritons are generated in the two equiprobable deuteron fusion channels. A significant amount of these tritons may fuse again, if the fast tritons are confined until they slowed down into the regime of highest fusion cross-section. In this secondary fusion process, called triton burn-up, 14 MeV neutrons are generated. Fast ion confinement can be studied by detecting these higher energetic neutrons separately with a scintillating fiber detector.

An one-dimensional simulation is presented, which estimates the rate of both 2.5 MeV and 14 MeV neutrons generated in thermal W7-X plasmas neglecting diffusion and prompt triton losses. A comparison with the neutron rates of beam-plasma interactions during neutral beam heating, calculated by the *FBURN* code (K. Ogawa et al PPCF **60** (2018) 095010), is given. It will be concluded, whether an existing scintillating fiber neutron detector, *SciFi*, is suitable for triton burn-up studies in thermal plasmas and beam-heated plasmas at W7-X.

P 18.114 Do 16:30 Foyer Nordbau

Observation of plasma profiles evolution relevant for magnetic reconnection at VINETA.II — •Tiziano Fulceri[1], Adrian von Stechow[1], and Olaf Grulke[1,2] — [1]Max-Planck Institut für Plasmaphysik, Wendelsteinstrasse 1, 17489 Greifswald, Deutschland — [2]Technical University of Denmark, Anker Engelunds Vej 1 Bygning 101A, 2800 Kgs. Lyngby, Denmark

VINETA.II is an experimental device suitable for the investigation of magnetic reconnection in laboratory plasmas. A fast-swept (100 kHz) Langmuir probe is used to reconstruct electron temperature, electron density, and plasma potential profiles with about 10 microsecond timestep. A magnetic probe is used to reconstruct the magnetic field, current density, and inductive electric field profiles with about 1 microsecond time-step. Both diagnostics have a length-resolution of 1 cm. The evolution of both a stationary ECRH background plasma and a transient electron-gun plasma can be observed within a 300 microsecond timeframe. Reconstructed profiles are interpreted within the framework of MHD. The results are discussed in relation to a future upgrade of the experiment aimed at investigating the propagation of the reconnection signal in different conditions.

P 18.115 Do 16:30 Foyer Nordbau

I-mode power exhaust at ASDEX Upgrade — •Davide Silvagni[1,2], Thomas Eich[1], Tim Happel[1], Michael Faitsch[1], Dirk Nille[1], Pierre David[1], Bernhard Sieglin[1], Ulrich Stroth[1,2], the ASDEX Upgrade team[1], and the EUROfusion MST1 team[3] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [2]Physik-Department E28, Technische Universität München, James-Franck-Str. 1, 85748 Garching, Germany — [3]see author list in H. Meyer et al. Nuclear Fusion 57 102014 (2017)

Heat loads on the divertor induced by Edge Localised Modes (ELMs) are a serious threat for large tokamaks operated in H-mode, such as ITER. For this reason natural ELM-free regimes such as the I-mode are of great interest. Although ELM heat loads are avoided in I-mode, power exhaust still remains a crucial challenge to be solved, as the heat flux profile on the divertor is very narrow. In this work, investigations on I-mode heat fluxes onto the ASDEX Upgrade (AUG) divertor are reported. It is shown that the scrape-off layer (SOL) power fall-off length during I-mode is wider than during H-mode, i.e. the power is deposited onto a larger area on the divertor target. However, some I-mode AUG discharges are characterised by intermittent strong heat fluxes reaching the divertor. Their filamentary and toroidally asymmetric nature is highlighted, along with their energy content carried to the divertor. In addition, to understand which SOL quantity is the main player in setting the power width, I-mode electron temperature, density and pressure decay lengths in the SOL are studied.

P 18.116 Do 16:30 Foyer Nordbau

Simulation of positrons in a magnetic dipole trap — •Stefan Nissl[1,2], Eve V. Stenson[2,4], Haruhiko Saitoh[3], Juliane Horn-Stanja[1], Uwe Hergenhahn[1,7], Thomas Sunn Pedersen[1,5], Matthew R. Stoneking[6], Markus Singer[2], Marcel Dickmann[2], Christoph Hugenschmidt[2], Lutz Schweikhard[5], James R. Danielson[4], and Cliff M. Surko[4] — [1]Max-Planck-Institut für Plasmaphysik — [2]Technische Universität München — [3]Universität Tokio — [4]University of California, San Diego — [5]Universität Greifswald — [6]Lawrence University, Appleton (Wisconsin) — [7]Leibniz-Institut für Oberflächenmodifizierung

APEX (A Positron Electron eXperiment) aims to create an electron-positron pair plasma in a magnetic dipole trap. To achieve this goal, a highly efficient positron injection scheme is an essential prerequisite. The large parameter space (multiple electrodes and steering coils to manipulate the beam) and the limited diagnostic capabilities (current and annihilation count measurements) of the experiment demanded a numerical counterpart to further understand the processes occurring during injection as well as confinement. Using discrete electric fields, analytic formulas to calculate the magnetic fields and a variant of the Boris integrator as particle pusher, full trajectory simulations were conducted and were able to reproduce the experimental data. Possible future applications include tests for adiabaticity and optimizations for the upcoming next stage of APEX with a levitating superconducting dipole coil.

P 18.117 Do 16:30 Foyer Nordbau

SOLPS Modeling of Impurity Seeded Plasmas in ASDEX Upgrade — •Ferdinand Hitzler[1,2], Marco Wischmeier[1], Felix Reimold[3], Matthias Bernert[1], Arne Kallenbach[1], David Coster[1], the ASDEX Upgrade Team[4], and the EUROfusion MST1 Team[5] — [1]IPP Garching, Germany — [2]TU München, Garching, Germany — [3]IPP Greifswald, Germany — [4]See author list in "A. Kallenbach et al., 2017 Nucl. Fusion 57 102015" — [5]See author list in "H. Meyer et al 2017 Nucl. Fusion 57 102014"

In future fusion devices like ITER or DEMO, parallel power fluxes in the order of several GWm^{-2} at the midplane have to be reduced to perpendicular divertor target loads below $5-10\,\mathrm{MWm}^{-2}$ to prevent severe damage of plasma facing components. To avoid sputtering of target material also the electron temperature at the target needs to be limited. This can be achieved by controlled impurity seeding which leads to radiative power dissipation. To provide a sufficient reduction of the power flux and target temperature while at the same time minimizing the impact on the confined plasma, it will be crucial to identify an “optimum” seeding recipe. SOLPS modeling of an ASDEX Upgrade H-mode discharge is used to investigate how different mixtures of argon and nitrogen seeding influence the radiation patterns, which depend on the radiation efficiencies and impurity density distributions. Following the analysis of the underlying mechanisms it is discussed which mixture of seeding species could be most promising for future experiments. Finally, a validation of the results using experimental data and an outlook on the impact of fluid drifts on the result will be given.

P 18.118 Do 16:30 Foyer Nordbau

Carbon content studies with Charge Exchange Spectroscopy on W7-X — •Lilla Vanó, Oliver P. Ford, and Robert C. Wolf for the The Wendelstein 7-X Team-Collaboration — Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

Apart from the main plasma species, impurities can 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 control impurities. The Wendelstein 7-X optimizied stellarator is equipped with a carbon divertor, making carbon the main impurity in the plasma.

The W7-X Charge Exchange Recombination Spectroscopy (CXRS) diagnostic is well-suited for investigating low-Z impurities, with the ability of giving spatially resolved information about them. Neutrals from the Neutral Beam Injection (NBI) transfer an electron to the fully-stripped ions in the plasma, the subsequent emission allows the characteristics of these ions to be examined. In this work, the first absolute impurity density measurements of the W7-X plasma core will be presented.

Various density profiles and their evolution showing different impurity confinement regimes will be presented. First comparisons with the STRAHL transport modeling code will also be included, with the future aim of constraining the v and D transport coefficients.

P 18.119 Do 16:30 Foyer Nordbau

NBI heating modulation experiments at W7-X — •Peter Zs. Poloskei and Benedikt Geiger for the The Wendelstein 7-X Team-Collaboration — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Low neoclassical transport of fast, collision-less particles is necessary for future reactor designs [1] and was one of the main optimization criteria of W7-X. With the installation of neutral beams (NBI) fast particles were generated for the first time such that their transport properties could be studied.

Fast-ion perturbative experiments [2] were conducted during which the NBI heating power was modulated. Hereby, variation of electron- and ion-temperature profiles is achieved since suprathermal ions heat the background plasma via Coulomb collisions. The modulation amplitude profile of the electron temperature was determined from electron-cyclotron emission (ECE) measurement while the ion temperature was derived from the charge exchange emission [3] of main ions. Comparisons of both profiles with theoretical expectations will be presented.

[1] H. Wobig 1993 Plasma Phys. Control. Fusion 35 903
[2] W. W. Heidbrink et al. 2016 Nucl. Fusion 56 112011
[3] R. C. Isler 1994 Plasma Phys. Control. Fusion 36 171

P 18.120 Do 16:30 Foyer Nordbau

Gaussian Process Tomography for the Soft X-Ray Diagnostic of Wendelstein 7-X — •Jonathan Schilling, Sehyun Kwak, Christian Brandt, Henning Thomsen, and Jakob Svensson — Max-Planck-Institute for Plasma Physics, Greifswald, Germany

Measurements of the soft X-ray emission from a high-temperature plasma provides data on its space-time behaviour and allows detection of magneto-hydrodynamic (MHD) instabilites, MHD mode dynamics and direct estimation of the Shafranov shift due to plasma currents. In combination with other diagnostics, transport dynamics of impurities can be determined. Gaussian Process Tomography is an inference method especially well-suited for the tomographic inversion problem of soft X-ray emission from a high-temperature plasma. It does not impose a parameterization in terms of an emission profile model on the prediction of the measured signals. Thus, no overfitting due to an overly complex model or imposition of artificial constraints due to an over-simplified model occurs. In this contribution, a newly developed Bayesian graphical model for the soft X-ray diagnostic in the Wendelstein 7-X (W7-X) stellarator is presented. It is applied to measurements from the latest operational campaign of W7-X.

P 18.121 Do 16:30 Foyer Nordbau

Atmospheric plasmas for generation of nanostructured materials — •Jan Benedikt[1], Ove Hansen[1], Oleksander Polonskyi[1], Mohamed Mokhtar Hefny[2], David Necas[3], and Judith Golda[1] — [1]Kiel University, Germany — [2]Ruhr-University Bochum, Germany — [3]CEITEC and Masaryk University, Brno, Czech Republic

Cold atmospheric plasmas can generate high densities of reactive species or dissociate effectively precursor gases. Contrary to low-pressure plasmas, the collisions prevent ion bombardment and the diffusion is slow. On the other hand, energy can be effectively stored in form of excitation energy (metastable atoms, excimers, metastable molecules) and a convection can be used as an effective transport of reactive species in atmospheric plasma jets. However, the main application of atmospheric plasmas is mainly in surface treatment applications, they are not widely used in applications for thin film generation due to the limited quality of the deposited material, missing ion bombardment and localized treatment. The material synthesis is mainly demonstrated in proof of principle experiments. Here, we will discuss the transport of reactive species to the substrate and the effect of recombination reactions on the treatment efficiency. An important effect of highly collisional conditions is that even species with low surface reaction probability contribute very effectively to the surface reactions. Finally, we will report on the use of He/oxygen plasma for the generation of nanostructured copper oxide layers.

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Complex plasma experiments with PK-4 on parabolic flight campaign DLR #31 — •Michael Kretschmer[1], Markus Thoma[1], Christopher Dietz[1], Benjamin Steinmüller[1], and Jeremiah Williams[2] — [1]Justus-Liebig-Universität, I. Physikalisches Institut, Giessen, Germany — [2]Wittenberg University, Ohio, USA

The Plasmakristall-4 (PK-4) plasma facility employs a dc discharge in a low-pressure noble gas inside a glass tube to study complex (dusty) plasmas (CP) under various gravity conditions. A flight model of PK-4 is installed inside the Columbus module of the International Space Station ISS since November 2014. Another model is situated at the University of Giessen, Germany. It is used for experiments on ground and on parabolic flights to compare with and extend the experiments performed in space.

The results of a recent parabolic flight campaign are presented: 1. Investigation of electro-rheological effects in complex plasmas. By changing the duty cycle of the alternating polarity of the dc discharge particles form chains inside the complex plasma that significantly change the properties of the CP fluid. A new algorithm using machine learning techniques for structure analysis was successfully tested. 2. A 20W laser was used to create a shearflow inside the CP fluid. By analyzing the transition region between stationary and driven particles, e.g. with a PIV method, we gained some information about the material properties of the fluid.

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Exposure of diagnostic duct system with mirrors in EAST tokamak: first results — •Tiziana von Witzleben[1,2], Andrey Litnovsky[1], Jiao Peng[1,3], Yury Krasikov[1], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich, Institut für Energie- und Klimaforschung, 52425 Jülich, Germany — [2]RWTH Aachen University, Department of Particle Physics, 52064 Aachen, Germany — [3]University of Science and Technology of China, 230026 Hefei, China

The first mirrors of future tokamaks, such as ITER, are receiving plasma radiation and guiding it to the tokamaks experimental detecting systems. They are used in all optical diagnostics in ITER and deliver important information on the physical processes and machine operations. To evaluate how the reflectivity of the mirrors changes in the tokamak and how it could be preserved, a diagnostic duct system was placed inside of the EAST tokamak from the 12.06.17 until the 23.07.17. It consists of three different pairs of tubes, that have single crystal Mo mirrors placed at their ends: two long tubes with a length of 10 cm, two medium tubes with a length of 7 cm and two short tubes, that measure 5 mm. One of the tubes of each pair is equipped with protective fins. The mirrors' total, diffuse and specular reflectivity have been characterized before and after the exposure. The results show very strong degradation of the specular reflectivity for mirrors in the short tubes, of up to 65 % at a wavelength of 1290 nm. In the case of the medium tubes a maximal loss of reflectivity of 18 % at 252 nm can be measured. Similarly, mirrors in the long tubes show a loss of up to 18 % at a wavelength of 250 nm.

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Heat Load Control for Wendelstein 7-X with Machine Learning Approaches — •Daniel Böckenhoff[1], Marko Blatzheim[1,2], Roger Labahn[2], and Thomas Sunn Pedersen[1] for the The Wendelstein 7-X Team-Collaboration — [1]Max-Planck-Institut für Plasmaphysik — [2]Institute for Mathematics, University of Rostock

Wendelstein 7-X (W7-X) is a stellarator type nuclear fusion experiment, aiming to confine fusion relevant plasmas in steady state. The plasma-wall contact is realized with plasma facing components (PFCs), which have to withstand heat loads of up to 10 MW/m^2. Various mechanisms, like the development of plasma currents, lead to a change in the magnetic topology as well as plasma parameters over time. Therefore the heat load pattern on the PFCs is dynamic. To ensure PFC integrity, mitigate impurity accumulation and more, heat load pattern control is essential for long term operation. Since the physics of the underlying processes is highly complex, we pursue heat load pattern control based on machine learning approaches. As an intermediate step towards this long term objective, we present neural networks capable of reconstructing crucial plasma properties from synthetic PFC heat load patterns.

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Sensing IEDFs and IADFs in radio-frequency discharges using a MEMS-based sensor stack — •Kerstin Roessel[1], Birk Berger[1], Thomas Mussenbrock[1], Marcel Melzer[2], Chris Stoeckel[2], and Sven Zimmermann[2] — [1]Brandenburg University of Technology Cottbus-Senftenberg, 03046 Cottbus, Germany — [2]Chemnitz University of Technology, 09111 Chemnitz, Germany

Ion energy distribution functions (IEDFs) and ion angular distribution functions (IADFs) are crucial parameters for materials processing using plasma discharges. This is particularly true when the physics of the plasma processes needs to be understood. Such a demand is important when plasma processing is intended to be knowledge-based, rather than based on trial and error. To reach this goal robust, non-perturbing, and reliable IEDF/IADF sensors are needed. In this contribution we propose a new IEDF/IADF sensor based on a MEMS (microelectromechanical systems) structure. We explain the working principle and show first experimental results. Finally, a profound analysis of the ion dynamics within the sensor based on kinetic simulation is provided.

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Consistently calculating the radiated power in near real time at the stellarator Wendelstein 7-X — •Philipp Hacker, Felix Reimold, Daihong Zhang, Maciej Krychowiak, Rainer Burhenn, and Thomas Klinger for the The Wendelstein 7-X Team-Collaboration — Max-Planck-Institute for Plasma Physics, Wendelsteinstraße 1, 17489 Greifswald, Germany

At the stellarator Wendelstein 7-X a two-camera bolometer system consisting of detectors with blackened gold foil absorbers has been used in the previous experiment campaign to implement and optimize a real time evaluation of the radiated power. The calculated line integrated radiation intensity was used for feedback control of the plasma discharge with auxiliary gas fueling as an actuator. The bolometer views the plasma at a triangular cross-section of W7-X horizontally and vertically across a poloidal position. Its fan-shaped lines of sight provide full coverage of the studied plasma at this cross-section with a spatial resolution of 5 cm on the magnetic axis. Based on the line-integrated measurements the radiated power loss of the plasma has been estimated independently for both cameras. Different methods of estimation have been used to access the radiated power in near real time. A single channel signal and weighting factor was used for edge radiating plasma. As a second estimator, a selection of sightlines were used together with their geometrical properties to extrapolate the power loss by radiation, as is done for the offline analysis of the radiated power. Feedback results will be shown, including benchmarks of the global power balance using the calculated radiated power.

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Gyrokinetic investigation of the nonlinear dynamics of Alfvénic instabilities and comparison with observations in ASDEX Upgrade — •Francesco Vannini — MPI for Plasma Physics, 85748 Garching, Germany

Shear Alfvén waves (SAW) are perpendicular incompressible waves which propagate along the magnetic field lines in magnetized plasmas. Their velocity is of the same order of magnitude of the typical velocity of energetic particles (EP), which are present in Tokamaks as product of fusion reactions or of heating mechanisms. Consequently, Alfvén modes can resonate with EP and become unstable. In the present poster, Alfvén modes are investigated with numerical simulations with the global particle-in-cell gyrokinetic code ORB5. The dependence of the dispersion relation on the finite electron mass is studied, as well as the phase mixing and the continuum damping. As a main result, the experimental magnetic equilibrium and plasma profiles are considered from a shot of ASDEX Upgrade, and the frequency of the Alfvén modes investigated with ORB5 are compared with the experimental observations.