Plasma Physics Division
Fachverband Plasmaphysik (P)

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Liebe Kolleginnen und Kollegen,

nach drei Jahren Pandemie ist es mir eine große Freude, Sie alle wieder zu einer DPG-Tagung in Präsenz zu begrüßen. Es ist das erste Mal, dass wir als Fachverband mit der gesamten Sektion SMuK tagen, von der wir so freundlich und offen aufgenommen wurden. Dank der Vorschläge aus dem Fachbeirat und der zahlreichen Beitragsanmeldungen ist wieder ein interessantes Programm entstanden. Ich hoffe, Sie können – trotz der schwierigen Zeiten in der Welt – den Austausch untereinander, aber auch das wunderschöne Dresden genießen.

Ich verabschiede mich mit dieser Tagung als Sprecher aus dem Fachbeirat und übergebe die Aufgabe an Prof. Jan Benedikt von der Universität Kiel. Ich möchte mich an dieser Stelle bei allen Mitgliedern des Fachbeirates für die stets vertrauensvolle und konstruktive Mitarbeit bedanken.

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Dear colleagues,

after three years of pandemic, it is a great pleasure for me to welcome you all again to a DPG meeting in presence. It is the first time that we meet with the entire section SMuK, from which we were received so friendly and openly. Thanks to the suggestions from the advisory board and the numerous applications for contributions, an interesting program has again been created. I hope you can enjoy – despite the difficult times in the world – the scientific exchange and meetings but also the beautiful city of Dresden.

With this conference I retire as the speaker from the advisory board and hand over to Prof. Jan Benedikt from the University of Kiel. I would like to take this opportunity to thank all members of the advisory board for their ever trusting and constructive cooperation.

Ronny Brandenburg

Overview of Invited Talks and Sessions

(Lecture halls CHE/0089 and CHE/0091; Poster HSZ EG)

Invited Talks

P 1.1	Mon	11:00–11:30	CHE/0089	**Ion Beam Sputter Deposition – Fundamentals and Applications** — •Carsten Bundesmann
P 2.1	Mon	11:00–11:30	CHE/0091	**Deuterium-Tritium Plasmas at JET with ITER-like Wall and the Role of Isotope Mass and Transport for H-mode Access** — •Gregor Birkenmeier, JET Contributors
P 5.1	Tue	11:00–11:30	CHE/0089	**Diagnostics of metal-grid micro cavity plasma arrays** — •Marc Böke, David Steuer, Sebastian Dzikowski, Henrik van Impel, Volker Schulz-von der Gathen, Judith Golda
P 6.1	Tue	11:00–11:30	CHE/0091	**The physics of ELM-free regimes** — •Michael Dunne, Michael Faitsch, Georg Harrer, Lidija Radovanovic, Wolfgang Suttrop, Eleonora Viezzer, Matthias Willensdorfer, Elisabeth Wolfrum
P 8.1	Tue	17:00–17:30	CHE/0091	**Fuel retention and removal in the JET tokamak** — •Dmitry Matveev, David Douai, Tom Wauters, Sebastijan Brezinsek, JET Contributors
P 9.1	Wed	11:00–11:30	CHE/0089	**Modelling and analysis of single-filament dielectric barrier discharges at atmospheric pressure** — •Markus M. Becker, Ronny Brandenburg, Tomáš Hoder, Hans Höft, Aleksandar P. Jovanović, Detlef Loffhagen

P 10.1	Wed	11:00–11:30	CHE/0091	**Diagnosing the plasma edge with helium beam spectroscopy** — •Michael Griener, the ASDEX Upgrade Team
P 13.1	Thu	11:00–11:30	CHE/0089	**Acceleration of spin-polarized ion beams from laser-plasma interaction** — •Lars Reichwein, Markus Büscher, Alexander Pukhov
P 14.1	Thu	11:00–11:30	CHE/0091	**Experimental validation of turbulence codes** — •Klara Höfler
P 15.1	Thu	14:00–14:30	CHE/0089	**Tumor irradiation in mice with a laser-accelerated proton beam** — •Florian Kroll, Florian-Emanuel Brack, Elke Beyreuther, Thomas Cowan, Leonhard Karsch, Josefine Metzkes-Ng, Jörg Pawelke, Marvin Reimold, Ulrich Schramm, Tim Ziegler, Karl Zeil
P 16.1	Thu	14:00–14:30	CHE/0091	**Development of a Laser-based Diagnostic for in situ Monitoring of Fuel Retention in ITER and future fusion devices** — •Alexander Huber, M. Zlobinski, G. Sergienko, J. Assmann, D. Castano, S. Friese, I. Ivashov, Y. Krasikov, H. Lambertz, Ph. Mertens, K. Mlynczak, M. Schrader, A. Terra, S. Brezinsek, Ch. Linsmeier
P 19.1	Thu	17:30–18:00	CHE/0089	**Numerical and experimental investigations of a linear microwave plasma source for metal foil pumps for DEMO** — •Stefan Merli, Andreas Schulz, Matthias Walker, Yannick Kathage, Stefan Hanke, Christian Day, Günter Tovar
P 20.1	Thu	17:30–18:00	CHE/0091	**Laser-Induced Breakdown Spectroscopy (LIBS) for the detection of hydrogen isotopes stored in high-Z metals tungsten and tantalum** — •Steffen Mittelmann, Kévin Touchet, Xianglei Mao, Minok Park, Vassilia Zorba, Sebastijan Brezinsek, Georg Pretzler

Sessions

P 1.1–1.6	Mon	11:00–12:45	CHE/0089	**Low Pressure Plasmas and their Application I**
P 2.1–2.5	Mon	11:00–13:10	CHE/0091	**Magnetic Confinement I/HEPP I**
P 3.1–3.5	Mon	16:30–17:45	CHE/0089	**Astrophysical Plasmas**
P 4.1–4.5	Mon	16:30–18:35	CHE/0091	**HEPP II**
P 5.1–5.7	Tue	11:00–13:00	CHE/0089	**Atmospheric Pressure Plasmas and their Applications I**
P 6.1–6.5	Tue	11:00–12:50	CHE/0091	**Magnetic Confinement II/HEPP III**
P 7.1–7.8	Tue	17:00–19:00	CHE/0089	**Atmospheric Pressure Plasmas and their Applications III**
P 8.1–8.7	Tue	17:00–19:10	CHE/0091	**Plasma Wall Interaction I/HEPP IV**
P 9.1–9.7	Wed	11:00–13:00	CHE/0089	**Atmospheric Pressure Plasmas and their Applications III**
P 10.1–10.5	Wed	11:00–13:10	CHE/0091	**Magnetic Confinement III/HEPP V**
P 11.1–11.48	Wed	14:00–15:30	HSZ EG	**Poster I**
P 12.1–12.45	Wed	17:30–19:00	HSZ EG	**Poster II**
P 13.1–13.7	Thu	11:00–13:00	CHE/0089	**Laser Plasmas I**
P 14.1–14.5	Thu	11:00–13:10	CHE/0091	**Magnetic Confinement IV/HEPP VI**
P 15.1–15.5	Thu	14:00–15:30	CHE/0089	**Laser Plasmas II/Low Pressure Plasmas and their Applications II**
P 16.1–16.5	Thu	14:00–15:30	CHE/0091	**Plasma Wall Interaction II/Codes and Modeling I**
P 17.1–17.6	Thu	15:45–17:15	CHE/0089	**Complex Plasmas and Dusty Plasmas/Codes and Modeling II**
P 18.1–18.3	Thu	15:45–17:00	CHE/0091	**HEPP VII**
P 19.1–19.3	Thu	17:30–18:40	CHE/0089	**Magnetic Confinement V/HEPP VIII**
P 20.1–20.4	Thu	17:30–18:45	CHE/0091	**Laser Plasmas III/Codes and Modeling III**
P 21	Thu	19:00–20:00	CHE/0089	**Members' Assembly**

Members' Assembly of the Plasma Physics Division (Mitgliederversammlung P)

Donnerstag, 23.03.23 19:00–20:00 Raum CHE/0089

- Bericht
- Wahl neuer Fachbeiratsmitglieder
- Tagung 2024, Verschiedenes

P 1: Low Pressure Plasmas and their Application I

Time: Monday 11:00–12:45 Location: CHE/0089

Invited Talk P 1.1 Mon 11:00 CHE/0089

Ion Beam Sputter Deposition – Fundamentals and Applications — •Carsten Bundesmann — Leibniz Institute of Surface Engineering (IOM), Leipzig

There is an increasing demand for thin films with tailored properties, which requires the use and control of adequate deposition techniques. Ion beam sputter deposition (IBSD) is a PVD technique that is capable of fulfilling the technological challenges. It is based on ion-solid interaction: A low-energy ion beam (Eion ~ 2000 eV) is directed onto a target and target particles get sputtered due to energy and momentum transfer [1]. These particles condense on a substrate and a film is growing (see Fig. 1). In addition, scattered primary particles and reactive background gas particles may contribute to thin film growth. In comparison to other PVD techniques, IBSD offers a unique opportunity to tailor angular-dependent energy and flux of the film-forming particles and, hence, thin film properties by changing ion beam parameters (ion species and ion energy) and geometrical parameters (ion incidence angle and emission angle).

Using selected examples, this talk describes the systematics, including pros and cons, of IBSD: The correlation between process parameters, properties of the film-forming particles, and thin film properties. The most important process parameters are the scattering geometry and the primary particle species. Depending on the material, different film properties can be influenced. Examples are adhesion, structural properties, composition, surface roughness, mass density, optical properties, stress, and electrical resistivity.

[1] C. Bundesmann, H. Neumann, J. Appl. Phys. 124 (2018) 231102.

P 1.2 Mon 11:30 CHE/0089

On the role of the Poisson-Boltzmann equation in the modeling of high-power magnetrons — Kevin Köhn, Dennis Krüger, Denis Eremin, Liang Xu, and •Ralf Peter Brinkmann — Ruhr University Bochum, Theoretical Electrical Engineering

The Poisson-Boltzmann equation is a nonlinear differential equation that describes equilibria of conducting fluids. Using a variation principle based on the balances of particle number, entropy, and electromagnetic enthalpy, it can also be justified for a wide class of unmagnetized technological plasmas [Köhn et al., PSST 30, 105014 (2021)].

This study aims to extend the variation principle to magnetized discharges as used in high-power pulsed magnetron sputtering (HiPIMS). The example in focus is that of a high power circular magnetron. The discharge chamber and the magnetic field are assumed to be axisymmetric; the plasma dynamics need not share this symmetry. The domain is divided into the region of confinement, where the electrons can escape from their magnetic field lines only by slow processes such as drift and diffusion, and the remainder where the electrons are effectively free. A distinction is made between a fast thermodynamic and a slow dissipative regime. A variational principle is established for the fast regime which is similar in logic to its counterpart for unmagnetized plasmas but accounts for magnetic confinement by treating the individual flux tubes of the confinement domain as separate thermodynamic units. The resulting solutions obey a generalized Poisson-Boltzmann relation; they are thermodynamic equilibria of the fast regime but must be interpreted as dissipative structures in the slow regime.

P 1.3 Mon 11:45 CHE/0089

Plasma-modified $NiCo_2O_4$ nanowires with abundant oxygen vacancies as electrocatalyst for the oxygen evolution reactions — •He Li[1], Sadegh Askari[2], and Jan Benedikt[1] — [1]Institute for Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Department of Fiber and Polymer Technology, KTH Royal Institute of Technology, Stockholm, Sweden

The development of highly active and stable electrocatalysts for the oxygen evolution reaction (OER) is critical for the applications such as water splitting or production of rechargeable zinc-air batteries. Oxygen vacancy engineering has demonstrated great promises to regulate the OER performances of transition metal compounds. However, the facile and effective generation of oxygen vacancies is still a challenge. Herein, we fabricated a $NiCo_2O_4$ nanowire catalyst by the hydrothermal method and generated oxygen vacancies with various concentrations by Ar or H_2/Ar plasma treatment. The reactive radicals generated by plasma reduce the valence of metal ions in the oxides and create oxygen vacancy defects with high electrocatalytic activity. The H_2/Ar plasma-treated $NiCo_2O_4$ presents more surface oxygen vacancies and thus better electrocatalytic performance for OER. Our work offers a facile and efficient route to design efficient OER electrocatalysts for zinc-air batteries.

P 1.4 Mon 12:00 CHE/0089

Experimental validation of a 0-D computational model for characterisation of double inductively coupled plasma — •J. Jenderny[1], M. Osca Engelbrecht[3], H. Hylla[1,2], I. Korolov[1], D. Filla[1], L. Schücke[1,2], C. P. Ridgers[3], P. Awakowicz[1], and A. R. Gibson[2] — [1]Chair of Applied Electrodynamics and Plasma Technology, Ruhr-University Bochum, Bochum, Germany — [2]Research Group for Biomedical Plasma Technology, Ruhr-University Bochum, Bochum, Germany — [3]York Plasma Institute, Department of Physics, University of York, York, UK

A double inductively coupled plasma is studied to be compared to 0-D plasma chemical kinetics simulations. A focus is placed on oxygen-containing gas mixtures due to their ability to produce large fluxes of reactive species such as atomic oxygen and UV photons. Various experimental diagnostic methods are applied. A multipole resonance probe is used to measure electron densities and electron temperatures radially resolved. Tuneable diode laser absorption spectroscopy is used to measure the absorption profile of the transition Ar ($1s_5 \rightarrow 2p_6$) at 772.376 nm to yield gas temperatures. Absolutely calibrated optical emission spectroscopy is used to determine the absolute intensities of different O transitions. These values are compared to those obtained from a 0-D computational model. The model includes electron densities and a collisional radiative treatment of excited states of O. It is then used to provide information on the flux of photons at 130 and 135 nm. This work was funded by DFG project “Plasma inactivation of microbial Biofilms”, project number 424927143.

P 1.5 Mon 12:15 CHE/0089

Modeling electromagnetic phenomena in CCP VHF plasmas with an electromagnetic PIC-MCC code — •Denis Eremin[1], Thomas Mussenbrock[2], and Ralf Peter Brinkmann[1] — [1]Institute of Theoretical Electrical Engineering, Ruhr University Bochum, Bochum, Germany — [2]Institute of Applied Electrodynamics and Plasma Technology, Ruhr University Bochum, Bochum, Germany

Increasing the electrode radius and the driving frequency would be beneficial for industrial applications of the capacitively coupled plasma reactors operated at low pressures. Unfortunately, this leads to the emergence of various nonuniformities having detrimental effects on the processing quality. The underlying physics is related to the excitation of two types of surface modes interacting with electrons and energizing them through different mechanisms. The present work investigates this problem numerically with a novel implicit energy- and charge-conserving electromagnetic PIC code ECCOPIC2M. It is demonstrated that due to the observed complexity of the processes taking place in such devices, the particle-in-cell method seems to be the only means potentially suitable for predictive studies of the plasma uniformity in CCPs in the considered parameter range.

P 1.6 Mon 12:30 CHE/0089

Investigation of capacitively coupled radio frequency Ar/CF_4 discharges using a hybrid PIC/MCC simulation — •Katharina Nösges, Maximilian Klich, Sebastian Wilczek, and Thomas Mussenbrock — Ruhr University Bochum, Germany

Capacitively coupled radio frequency (CCRF) discharges are used in many dry etching processes in the semiconductor industry to realize micro- and nanometer-scale electronics. Low pressures of a few Pascal and voltages of about hundreds of volts are required to ensure anisotropic ion bombardment. Especially carbon tetrafluoride (CF_4) and mixed (Ar/CF_4) discharges are particularly important for etching. These discharges are investigated using a one-dimensional hybrid particle-in-cell/Monte Carlo collisions (PIC/MCC) simulation in the low-pressure regime (p = 6.67 Pa) with the inclusion of realistic particle-surface interactions. This approach considers the electrons kinetically and simultaneously solves the continuity equation based on the drift-diffusion approximation for all ion species. The transport coefficients, as well as the rate coefficients, can be determined with the help of swarm simulations. A closed group of particles moves in a background gas influenced by an externally applied constant electric field. The collective behavior gives information about transport features and collision probabilities. A variation of the electrode gap size and the applied voltage is then presented as a control tool to alter the discharge dynamics significantly. Additionally, it is shown that surface coefficients (i. e., electron reflection, and secondary electron emission) play a significant role.

P 2: Magnetic Confinement I/HEPP I

Time: Monday 11:00–13:10 Location: CHE/0091

Invited Talk P 2.1 Mon 11:00 CHE/0091

Deuterium-Tritium Plasmas at JET with ITER-like Wall and the Role of Isotope Mass and Transport for H-mode Access — •Gregor Birkenmeier[1,2] and JET Contributors[3] for the JET L-H Transition Team-Collaboration — [1]Max Planck Institute for Plasma Physics, Garching — [2]Physik-Department, Technical University Munich, Garching — [3]See J. Mailloux et al 2022 Nucl. Fus. 62 042026

More than 20 years after the last deuterium-tritium (D-T) experiments in magnetic confinement fusion research, the largest operating tokamak in the world, the Joint European Torus (JET) in Culham, UK, was operated with the reactor relevant D-T fuel mixture during the 2020/2021 experimental campaign. The experiments demonstrated that reactor relevant plasma scenarios can be successfully operated in metallic wall conditions and the record of controlled fusion energy production of 59 MJ was achieved in a steady plasma over five seconds. The experiments confirmed simulations of reactor-relevant plasma performance building confidence, that next step devices like ITER will perform as predicted. In addition to experiments maximizing the fusion power, further experiments in tritium containing plasmas allowed to study isotope effects in unprecedented detail. As one striking example, it was found that the power threshold to access the high confinement regime, which is considered as being mandatory for a sufficient performance of a reactor plasma, shows an unexpected isotope dependence in isotope mixtures. After the presentation of the highlights of recent D-T experiments, an explanation for the observed isotope effects is given and its impact on modelling is discussed.

P 2.2 Mon 11:30 CHE/0091

Experimental and numerical investigation of helium exhaust at the ASDEX Upgrade tokamak with full-tungsten wall — •Antonello Zito[1,2], Marco Wischmeier[1], Athina Kappatou[1], Arne Kallenbach[1], Francesco Sciortino[1], Volker Rohde[1], Klaus Schmid[1], Edward Hinson[3], Oliver Schmitz[3], Marco Cavedon[4], Rachael McDermott[1], Ralph Dux[1], Michael Griener[1], and Ulrich Stroth[1,2] — [1]Max-Planck-Institut für Plasmaphysik — [2]Physik-Department E28, Technische Universität München — [3]University of Wisconsin-Madison — [4]Dipartimento di Fisica "G. Occhialini", Università di Milano-Bicocca

An efficient removal of helium ash by active pumping in future fusion devices is necessary to avoid fuel dilution and not degrade plasma confinement. Therefore, a deep understanding of the underlying physics mechanisms is mandatory. Helium recycling and pumping has been experimentally investigated at the ASDEX Upgrade tokamak. The time evolution of helium following a small injection during otherwise steady-state deuterium discharges was measured spectroscopically both in the core plasma and in the neutral exhaust gas. The exhaust efficiency was found to improve with increasing divertor neutral pressures, but to degrade with detachment. A multi-reservoir particle balance model was developed to interpret the observed exhaust dynamics. The limited performance of the pumping system and an efficient helium storage capability of the tungsten wall were identified to have a strong impact on the exhaust dynamics. The SOLPS-ITER code was used to interpret the observed He transport towards the divertor.

P 2.3 Mon 11:55 CHE/0091

Introduction and Uncertainty Quantification of Kinetic Models in the Integrated Data Analysis Framework — •Michael Bergmann[1], Kislaya Ravi[2], Rainer Fischer[1], Clemente Angioni[1], Klara Höfler[1], Pedro Molina Cabrera[3], Tobias Görler[1], Roberto Bilato[1], and Frank Jenko[1,2] — [1]Max- Planck-Institute für Plasmaphysik — [2]TUM (CIT) — [3]École Polytechnique Fédérale de Lausanne, Switzerland

Using a combined analysis of multiple diagnostics as well as Bayesian probability theory the Integrated Data Analysis (IDA) infers elec- tron density and temperature profiles of ASDEX Upgrade plasmas and is the standard against which simulations are validated. As the diagnostics do not cover the entire plasma or may be unavailable IDA considers a variety of non-physics-based priors. The resulting profiles may not be in accordance with theories best expectations e.g. may have gradients which drive too high turbulent transport. Using the transport solvers ASTRA coupled with the quasi-linear turbulence code TGLF we have created a loop in which simulated profiles are fed back into IDA as another prior thus providing constraints about the physically reasonable parameter space. For now the uncertainty of the simulation is given by the user, however we will discuss several ideas for a more complete uncertainty quantification such as input error propagation and comparison to the high-fidelity turbulence solver GENE.

P 2.4 Mon 12:20 CHE/0091

Analysis and modeling of momentum transport based on NBI modulation experiments at ASDEX Upgrade — •Benedikt Zimmermann[1,2], Rachael McDermott[1], Clemente Angioni[1], Basil Duval[4], Ralph Dux[1], Emiliano Fable[1], Antti Salmi[3], Ulrich Stroth[1,2], Tuomas Tala[3], Giovanni Tardini[1], Thomas Pütterich[1], and the ASDEX Upgrade Team[5] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Physik-Department E28, Technische Universität München, 85747 Garching, Germany — [3]VTT, P.O. Box 1000, FI-02044 VTT, Finland — [4]EPFL, Swiss Plasma Center, CH-1015 Lausanne, Switzerland — [5]see the author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

Understanding momentum transport is crucial to reliably predict the plasma rotation profiles in future fusion devices. At ASDEX Upgrade, momentum transport studies are used to validate theoretical models and transport codes. An advanced momentum transport analysis framework uses NBI modulation to extract the contribution of diffusion, convection, and intrinsic torque to momentum transport within the core plasma. Recent work focused on a possible mass dependence by comparing hydrogen and deuterium plasmas. Both momentum transport coefficients were found to be the same within error bars indicating no significant mass dependence. Gyrokinetically predicted Prandtl number and pinch number agree with the experimental results. Furthermore, a robust error analysis quantified the uncertainties of the assessed coefficients and the uniqueness of the determined solution in the scanned parameter range.

P 2.5 Mon 12:45 CHE/0091

Neutral gas pressure gauges for current and future fusion devices — •Bartholomäus Jagielski[1,2], Uwe Wenzel[1], Dirk Naujoks[1], Felix Mackel[1], Thomas Sunn Pedersen[1], and and the W7-X team[1] — [1]Max Planck Institute for Plasma Physics, Germany — [2]Universität Greifswald, Institut für Physik, Greifswald, Germany

Pressure gauges emplyoing helical tungsten-wire emitters suffer from the Lorentz force in strong magnetic fields. In consequence, for fusion devices, conventional pressure gauges do not work reliably, or at all when operated within specified duration of plasma operation. As an alternative, rod shaped emitters are more robust in strong magnetic fields and may sustain long-pulse operation.

We report on the performance of the ionization gauges, equipped with lanthanum hexaboride, zirconium carbide or tungsten emitter, tested in a purpose built laboratory and operated in the stellarators W7-X and LHD. During the second Wendelstein 7-X campaign, 18 manometers equipped with LaB6 cathodes are used to measure the neutral gas pressure at different positions. Early experiments show robust operation up to 900s. The gauges reveal a magnetic field dependence of the ion current and sudden jumps of the electron- and ion current limit the operation over the whole pressure region from 10^{-7} mbar to 10^{-2} mbar. Along with a basic characterization of the latter, measurements under new record conditions and the impact of limitation on the design of the instruments are discussed. Operation in different magnetic field strengths and working gases are examined.

P 3: Astrophysical Plasmas

Time: Monday 16:30–17:45 Location: CHE/0089

P 3.1 Mon 16:30 CHE/0089

Energy conversion by magnetic reconnection in multiple ion temperature plasmas — •Jeremy Dargent[1], Sergio Toledo-Redondo[2], Andrey Divin[3], and Maria Elena Innocenti[1] — [1]Institut für Theoretische Physik, Ruhr-Universität Bochum, Bochum, Germany — [2]Department of Electromagnetism and Electronics, University of Murcia, Murcia, Spain — [3]St. Petersburg, Russia

Magnetic reconnection is one of the most efficient plasma process to convert magnetic energy into kinetic energy. In this work, we study the impact of the microscopic distribution function on the energy budget of symmetric magnetic reconnection in collisionless plasmas. We run two two-dimensional semi-implicit PIC simulations of symmetric reconnection with the same global parameters, but with different ion distribution functions: one simulation is loaded using Maxwellian distributions, while the other is the sum of two Maxwellian distributions, a hot one and a cold one, resulting in a very peaked distribution with large tails. We measure the evolution of the bulk and thermal kinetic energies in both simulations for each population and compare it to the loss of magnetic energy through a contour surrounding the ion diffusion region. We show that the global energy budget for ions and electrons does not change depending on the distribution function of the plasma, but also that, when focusing on sub-populations, the hot ion population gains more energy than the cold ion population and that the distribution of the energy gain between kinetic and thermal energy also depends on the initial temperature.

P 3.2 Mon 16:45 CHE/0089

Ionization and transport in partially ionized multicomponent plasmas: Atmospheres of hot Jupiters — Sandeep Kumar[1,2], Anna Julia Poser[1], Manuel Schöttler[1], Uwe Kleinschmidt[1], Wieland Dietrich[3], Johannes Wicht[3], Martin French[1], and •Ronald Redmer[1] — [1]Universität Rostock, Institut für Physik, D-18051 Rostock — [2]CASUS, D-02826 Görlitz — [3]MPI for Solar System Research, D-37077 Göttingen

We study ionization and transport processes in partially ionized multicomponent plasmas [1]. The plasma composition is calculated via a system of coupled mass-action laws. The electronic transport properties are determined by the electron-ion and electron-neutral transport cross sections. The electrical and thermal conductivities as well as the Lorenz number are calculated. For the thermal conductivity, we consider also the contributions of the translational motion of neutral particles and of the dissociation, ionization, and recombination reactions. We apply our approach to plasma conditions as typical for atmospheres of hot Jupiters such as HD 209458b. The electrical conductivity profile allows revising the Ohmic heating power related to the fierce winds in the planet's atmosphere in order to explain the observed inflation of HD 209458b. The model is also applied to study possible induction processes in the atmosphere of ultra-hot Jupiters like KELT-9b [2].

[1] S. Kumar et al., Phys. Rev. E 103, 063203 (2021)

[2] W. Dietrich et al., MNRAS 517, 3113 (2022)

P 3.3 Mon 17:00 CHE/0089

M^5 - Mars Magnetospheric Multipoint Measurement Mission: A multi-spacecraft plasma physics mission to Mars — •Cormac Larkin — Max Planck Institut fuer Kernphysik, Heidelberg, Germany — Astronomisches Rechen-Institut, Heidelberg, Germany

We propose the Mars Magnetospheric Multipoint Measurement Mission (M5), a multi-spacecraft mission to study the dynamics and energy transport of the Martian magnetosphere. Particular focus lies on the largely unexplored magnetotail region, where signatures of magnetic reconnection of the Interplanetary Magnetic Field (IMF) have been found. Further, to study the dynamics of the Martian magnetosphere depending on the upstream solar wind conditions, knowledge of those is needed. Finally, to resolve the three-dimensional structure of the Martian magnetosphere and make use of multipoint data analysis techniques, multipoint measurements are required. As a result, M5 is a five spacecraft mission, with one solar wind monitor orbiting Mars in a circular orbit, and four smaller spacecraft in a tetrahedral configuration orbiting Mars in an elliptical orbit. We present a detailed assessment not only of the scientific need for such a mission but also show the resulting mission and spacecraft design taking into account all aspects of systems engineering as well as spacecraft budgets like mass and data rate. The mission outlined in this abstract was developed during the ESA Alpbach Summer School 2022 on the topic of "Comparative Plasma Physics in the Universe".

P 3.4 Mon 17:15 CHE/0089

Berechnung elektronischer Transportkoeffizienten von Wasserstoffplasma mit Dichtefunktionaltheorie — •Martin French[1], Gerd Röpke[1], Maximilian Schörner[1], Mandy Bethkenhagen[1,2], Michael Desjarlais[3] und Ronald Redmer[1] — [1]Universität Rostock, Institut für Physik, D-18051 Rostock — [2]École Normale Supérieure, Université Lyon 1, Lyon, France — [3]Sandia National Laboratories, Albuquerque, USA

Dichtefunktionaltheorie (DFT) ist eine weit verbreitete Methode, um stark gekoppelte Coulombsysteme quantenmechanisch zu beschreiben. Die Berechnung von Transporteigenschaften erfolgt dabei über den Kubo-Greenwood-Formalismus [1]. Eine bislang kontrovers diskutierte Fragestellung ist, ob die Mean-Field-Beschreibung von Elektronen mit DFT den Einfluss von Elektron-Elektron-Stößen korrekt erfassen kann [2]. Diese Frage kann durch die Berechnung elektronischer Transportkoeffizienten im schwach gekoppelten und nicht entarteten Grenzfall beantwortet werden, für den exakte Grenzwerte aus der Spitzer-Theorie bekannt sind. Wir stellen entsprechende Ergebnisse von DFT-Rechnungen zur Thermokraft und Lorenz-Zahl vor und zeigen, dass Elektron-Elektron-Streuprozesse nicht mit dem Kubo-Greenwood-Formalismus in der DFT erfassbar sind [3].

[1] B. Holst, M. French, and R. Redmer, Phys. Rev. B 83, 235120 (2011). [2] M. P. Desjarlais et al., Phys. Rev. E 95, 033203 (2017); H. Reinholz et al., Phys. Rev. E 91, 034105 (2015). [3] M. French, G. Röpke, M. Schörner, M. Bethkenhagen, M. P. Desjarlais, and R. Redmer, Phys. Rev. E 105, 065204 (2022).

P 3.5 Mon 17:30 CHE/0089

Electron polarization in ultrarelativistic plasma current filamentation instabilities — •Zheng Gong, Karen Hatsagortsyan, and Christoph Keitel — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany

By utilizing particle-in-cell simulations, we investigate the plasma current filamentation of an ultrarelativistic electron beam impinging on an overdense plasma. The effect of the radiation-induced electron polarization is self-consistently studied. Here, three different regimes of the current filaments, namely, the normal filament, abnormal filament, and quenching regimes, are identified. We show that electron radiative polarization emerges during the instability along the azimuthal direction in the momentum space, which significantly varies across the regimes. We put forward a Hamiltonian model to trace the origin of the electron polarization dynamics. In particular, we discern the role of nonlinear transverse motion of plasma filaments, which induces asymmetry in radiative spin flips, yielding an accumulation of electron polarization.

P 4: HEPP II

Time: Monday 16:30–18:35 Location: CHE/0091

P 4.1 Mon 16:30 CHE/0091

CO_2 dissociation using a microwave plasma torch - a study on industrially relevant parameters — •Christian Karl Kiefer[1], Rodrigo Antunes[1], Ante Hecimovic[1], Arne Meindl[1], and Ursel Fantz[1,2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]University of Augsburg, 86159 Augsburg, Germany

Under laboratory conditions, microwave plasma torches are known to be an energetically highly efficient CO_2 conversion technology, for pressures ranging from 100 mbar up to atmospheric pressure. However, issues relevant for industrial application such as the wall-plug energy efficiency, including the energy consumption of peripheral equipment, the performance for impure CO_2 streams directly from carbon capture facilities and the stability at long-term operation are usually not addressed. To fill that gap, the wall-plug energy efficiency of a lab-scale microwave plasma torch was determined reaching values up to 17.9%, corresponding to an electrical power consumption of 19.6 kWh per produced Nm^3 of carbon monoxide. The effect of Ar, N_2, O_2 and air admixture to the CO_2 feed gas stream was investigated. Experiments show that small amounts of nitrogen can even increase energy efficiency whereas the most detrimental effect on CO_2 dissociation was found for air admixture. Finally, a durability test over 29 h was performed, demonstrating that microwave plasma torch operation is very reproducible and stable in all figures of merit with short ramp-up times, making it a promising technology for intermittent operation.

P 4.2 Mon 16:55 CHE/0091

3D Monte Carlo PIC modeling of particle extraction from negative ion sources — •Max Lindqvist[1,2], Dirk Wünderlich[1], Serhiy Mochalskyy[1], Adrien Revel[2], Tiberiu Minea[2], and Ursel Fantz[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Université Paris-Saclay, CNRS, LPGP, Orsay, France

Negative H^- or D^- ions for the ITER NBI system are produced in RF ion sources, mainly by surface production, and accelerated through a multi-aperture grid system. One of the main limiting factors during operation of such ion sources is the amount of co-extracted e^-, in particular during operation with D. For a correct description of the particle dynamics close to the Plasma Grid (PG) where a 3D magnetic field is present, self-consistent 3D PIC-MCC modeling is needed. The 3D PIC-MCC code ONIX has been used to simulate one PG aperture in the ELISE ion source, a half-size ITER-like ion source in IPP Garching. The impact of plasma parameters on the co-extraction of e^- is presented. A higher T_e has a strong impact on the amount of co-extracted e^-. The original code was improved by adding a plasma generation module that allows modeling the biasing of the PG w.r.t. the source walls. By increasing the PG bias above the floating potential, the amount and temporal instability of co-extracted e^- are strongly decreased, in agreement with experiments. ONIX was coupled with the beam code IBSimu to allow the correlation of particle properties from the plasma to the beam, and to study the extraction probability and beam divergence of negative ions during different configurations of PG biases and geometries to give insights into grid optimization.

P 4.3 Mon 17:20 CHE/0091

Non-local neoclassical PIC simulations for the radial electric field in stellarators. — •Michał Kuczyński, Ralf Kleiber, and Håkan Smith — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Transport in fusion plasma devices can be classified as either turbulent or neoclassical. While turbulence is responsible for the majority of particle and heat losses in both, tokamaks and optimised stellarators the theory of neoclassical transport should not be disregarded. Its applications, for example the prediction of the bootstrap current, are of great importance in fusion research. This talk focuses on the neoclassical radial electric field in stellarators.

For a quasi-neutral plasma in a thermodynamic equilibrium, commonly, the electric field is negative throughout the plasma vessel. This is called an ion root. However, when electrons are much hotter than ions, the electric field takes a positive value. This electron root and can be achieved with, for example, ECRH heating. As correctly predicted by the local neoclassical transport theory, this is a consequence of the ambipolarity condition on the ion and electron fluxes. However, the theory meets its limitations when there is a transition between the two solutions. Moreover, since the electric field switches the sign during the transition, the strongly sheared ExB flow is likely to affect turbulence. To understand the physics of this phenomenon we must resort to simulations of global neoclassical transport. We present the first self-consistent global neoclassical radial electric field simulations performed using a particle-in-cell code - EUTERPE.

P 4.4 Mon 17:45 CHE/0091

Suppression of Diocotron Drift Modes and Increased Transfer in a Multicell Trap — •Martin Singer[1,3], James R. Danielson[2], and Lutz Schweikhard[3] — [1]IPP Greifswald, Germany — [2]Department of Physics, UCSD, USA — [3]Institut für Physik, Universität Greifswald, Germany

The A Positron Electron eXperiment (APEX) will accumulate large quantities of positrons for a positron-electron (pair) plasma which are an excellent candidate to test basic plasmas physics. To this end we have designed and constructed a new multicell Penning-Malmberg trap (MCT). It includes a master-cell, and three prototype storage cells (one on-axis, and two off-axis). With this device we will test and improve the plasma transfer to the off-axis cells and the stacking of multiple plasma pulses to create large space-charges. We will develop suitable protocols to achieve these key goals, for the use of a MCT at the NEPOMUC positron source in Munich.

In this contribution, we will discuss the dynamics during the transport to the off-axis cells. These are dominated by competing diocotron drift modes. We developed techniques to suppress these modes to mitigate losses and to center the plasma in the off-axis cells. Furthermore, we demonstrated an improved transfer and consecutive transfer to multiple off-axis cells. This enabled the first simultaneous confinement in two different off-axis storage cells. The work was funded by DFG (Grant Nos. SCHW 401/23-1, Hu 978/15-1 and PE 2655/1-1) and ERC (Grant No. 741322). JRD is funded by U.S. DOE (Grant No. DE-SC0019271).

P 4.5 Mon 18:10 CHE/0091

Characterization and identification of MHD-like fluctuations of core electron temperature transitions in W7-X plasmas — •Juan Fernando Guerrero Arnaiz[1,2], Andreas Dinklage[1,2], Axel Könies[2], Carolin Nührenberg[2], Alessandro Zocco[2], Matthias Borchardt[2], Christian Brandt[2], Neha Chaudhary[2], Joachim Geiger[2], Matthias Hirsch[2], Udo Höfel[2], Ralf Kleiber[2], Kian Rahbarnia[2], Sara Vaz Mendez[2], Alexei Mishchenko[2], Jonathan Schilling[2], John Schmitt[3], Henning Thomsen[2], Marco Zanini[2], and W7-X Team[2] — [1]Universität Greifswald, Greifswald, Germany — [2]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [3]Auburn University, Auburn AL, United States

Previously unexpected spontaneous transitions to higher core-electron temperatures preserving plasma pressure were detected in low-iota configuration W7-X plasmas. Transitions occurred at stationary plasma conditions at fixed heating power and line integrated density but with evolving plasma currents. Here we report on low frequency activity preceding the transitions. To gain insight on the transition mechanism, this activity is characterized. This is done through experimental and numerical modelling, shedding light on the nature of the underlying MHD instability. The rational iota-values and the impact of radial electric fields on the mode activity and the transition to enhanced core electron temperature are examined. As for now, the instability is narrowed down to GAM oscillations and zonal flow activity, both of which were found to potentially exist according to systematic simulations.

P 5: Atmospheric Pressure Plasmas and their Applications I

Time: Tuesday 11:00–13:00 Location: CHE/0089

Invited Talk P 5.1 Tue 11:00 CHE/0089

Diagnostics of metal-grid micro cavity plasma arrays — •Marc Böke[1], David Steuer[2], Sebastian Dzikowski[1], Henrik van Impel[2], Volker Schulz-von der Gathen[1], and Judith Golda[2] — [1]Physics of Reactive Plasmas, Ruhr-University Bochum, D-44801 Bochum, Germany — [2]Plasma Interface Physics, Ruhr-University Bochum, D-44801 Bochum, Germany

Micro-structured plasma discharges offer great potential for a variety of applications, such as large-area treatment, catalytic conversion, or decomposition of volatile organic compounds. Therefore, they are of high relevance from a technical and scientific point of view. To understand the processes, fundamental knowledge about the discharge mechanisms and dynamics and generation of reactive species is necessary. Here, we investigate metal-grid micro cavity plasma arrays of well-defined microdischarges. They are modular in construction and allow stable operation and the use of catalysts. The plasma arrays are operated in helium with admixtures of reactive gases, typically in the percentage range, and excited by triangular voltage amplitudes of 400-800V at kHz frequencies. Diagnostics in these cavities are challenging due to their small dimensions in the range of 100μm and the limited access because of the encapsulation of the plasma cavities. Therefore, we apply optical emission-based methods to determine electric fields (Stark shift) or 2D resolved densities of reactive species (e.g. by state enhanced actinometry). The basic discharge behavior like discharge modes and spatial distribution, electrical characteristics and dynamics will be discussed. Supported by the DFG within SFB 1316.

P 5.2 Tue 11:30 CHE/0089

Modelling and experimental analysis of DBDs in Ar-TMS and Ar-HMDS mixtures — •Marjan Stankov[1], Markus M. Becker[1], Lars Bröcker[2], Claus-Peter Klages[2], and Detlef Loffhagen[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), 17489 Greifswald — [2]Institute for Surface Technology (IOT), Technische Universität Braunschweig, 38108 Braunschweig

During the last two decades, plasma-enhanced chemical vapour deposition processes using atmospheric-pressure dielectric barrier discharges (DBDs) have become of great interest for fabricating various thin films and coatings. Here, fluid modelling and experimental analyses of such DBDs in argon with the addition of small amounts of tetramethylsilane (TMS) or hexamethyldisilane (HMDS) as precursors are reported. A plane-parallel and a single-filament discharge configuration are operated by sinusoidal voltages of few kV at frequencies of 86 and 19 kHz, respectively. A time-dependent, spatially one-dimensional fluid-Poisson model including an extensive reaction kinetic scheme for argon and the organosilicon presursors with about 90 species and 700 reactions is used for the modelling studies. Results for electrical discharge properties and relevant species in the DBD are represented and discussed. Penning ionization (PI) processes of excited argon species with the precursor gas are found to have a decisive impact on the discharge characteristics. In particular, it is found that cations generated due to PI processes are the dominant species for thin film formation.

Funded by the Deutsche Forschungsgemeinschaft (DFG) - project number 504701852.

P 5.3 Tue 11:45 CHE/0089

State enhanced actinometry in a micro cavity plasma array — •David Steuer, Henrik van Impel, Volker Schulz-von der Gathen, Marc Böke, and Judith Golda — Ruhr-University Bochum, D-44801 Bochum, Germany

In recent years, plasma catalysis as an application of atmospheric pressure plasmas has become a research. Suitable reactors for investigating the fundamental interaction between plasmas and catalytic surfaces are micro cavity plasma arrays. To understand the plasma catalytic processes, it is important to monitor the densities of reactive species. In the case of atomic oxygen, this is typically done using laser spectroscopic methods. Due to the small dimensions of micro cavities between 50-200μm this is very complex. Therefore, a new approach, helium state enhanced actinometry (SEA)[1], was used. 2D resolved measurements are performed by using an ICCD camera in combination with a tuneable bandpass filter. The discharge is operated in helium with an oxygen admixture of 0.1%. An argon admixture of 0.05% is used as actinometer gas. The triangular excitation voltage between amplitudes of 400-800V is varied at a frequency of 15 kHz. Very high dissociation degrees up to nearly complete dissociation are observed. The spatial resolution allows density distributions within individual cavities to be resolved. Time resolved measurements show significant differences in oxygen density between the increasing potential phase and the decreasing potential phase. This work is supported by the DFG via SFB 1316 (project A6). [1]Steuer et al 2022 PSST 31 10LT01

P 5.4 Tue 12:00 CHE/0089

CO_2 splitting in 3D-printed barrier discharge reactors — •Dimas Adrianto[1], Milko Schiorlin[1], Volker Brüser[1], Ronny Brandenburg[1,2], and Sven Grundmann[2] — [1]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany — [2]University of Rostock, Rostock, Germany

First attempts to use Dielectric Barrier Discharges (DBDs) for the conversion of carbon dioxide (CO_2) date back to the 1990's, and found a renewed interest in the 2010's due to the energy transition, i.e., the demand for PtX technologies for the generation of fuels or chemicals. DBDs still lack on energy efficiency, but provide a simple and robust design for plasma reactors. In contrast to the studies of microwave discharges, the impact of gas flow distribution in DBDs reactors is still a rather unexplored field. In this study, a 3D printer is used to realize DBD discharge chambers with a predefined gas flow pattern. Thus, the high flexibility of rapid prototyping enables to correlate fluid dynamic simulations with the plasmachemical performance of CO_2 splitting. DBD reactors are made of methacrylic acid polymer and have an overall dimension of 120 x 120 mm, with a powered electrode size of 55 x 55 mm, placed in the center. The influence of flow mechanics is investigated in three DBD reactors with different gas flow patterns and velocity profiles. Besides CO_2 splitting in pure CO_2, ozone generation in air is studied. It is shown that CO or O_3 yield can be influenced by the flow pattern and gas flow rate.

P 5.5 Tue 12:15 CHE/0089

Gas Separation of O_2 in a CO_2 Plasma Membrane Reactor — •Katharina Wiegers[1], Andreas Schulz[1], Matthias Walker[1], Günter Tovar[1], Frederic Buck[2], Thomas Schiestel[2], and Stefan Baumann[3] — [1]University of Stuttgart IGVP, Stuttgart, Germany — [2]Fraunhofer IGB, Stuttgart, Germany — [3]Forschungszentrum Jülich IEK-1, Jülich, Germany

Mankind nowadays is strongly affected by ongoing climate change, mainly caused by the increasing emission of CO_2. CO_2, a very stable molecule, can be activated by a plasma process. It converts CO_2 into the value-added chemical molecule CO. In order for this method to become competitive with electrolysis, the simultaneously produced O_2 must be separated from the gas mixture. In order to do so, oxygen-conducting ceramic hollow fibers can be used. The first and well-investigated ceramic is $La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-\delta}$ by Tereoka [1]. Changing the A site cations or using a dual-phase material can improve the temperature stability and chemical resistance against the CO_2 and CO atmosphere in the plasma membrane reactor.

In this work, $La_{0.6}Ca_{0.4}Co_{0.5}Fe_{0.5}O_{3-\delta}$ hollow fibers are investigated in terms of their oxygen separation ability. They are temperature stable up to 1200°C. To increase the viable region for O_2 separation in the plasma torch, new ceramic materials (e.g. 60 wt% $Ce_{0.8}Gd_{0.2}O_{1.9}$-40 wt% $Gd_{0.85}Ce_{0.15}Fe_{0.75}Co_{0.25}O_3$) with higher temperature resistance have to be developed and investigated. The idea is that different fiber materials can be used depending on the local plasma temperature.

[1] Y. Teraoka et al., Chemistry Letters, 1985, 14 (11), 1743,17-46.

P 5.6 Tue 12:30 CHE/0089

Evaluation of an electron beam sustained atmospheric pressure plasma for the conversion of carbon dioxide — •Lars Dincklage[1], Burkhard Zimmermann[1], Gösta Mattausch[1], and Ronny Brandenburg[2,3] — [1]1Fraunhofer Institute for Org. Electr., EB and Plasma Technol. FEP, Dresden, Germany — [2]Leibniz-Institute for Plasma Science and Technology, Greifswald, Germany — [3]University of Rostock, Germany

Carbon dioxide (CO_2) conversion processes will play an important role in closed carbon cycles for zero carbon emission economies in the future. Even though plasmas exhibit numerous technical advantages, they are not yet economically feasible in terms of CO_2 conversion, since they struggle to simultaneously achieve high energy efficiency and high conversion degree for the splitting of CO_2 molecules and are often bound to sub-atmospheric pressures. Therefore, a new hybrid approach for the plasma-chemical conversion of CO_2 is presented, consisting of an atmospheric pressure glow discharge sustained by an electron beam. This hybrid approach potentially allows to transfer energy from the plasma mainly into vibrational dissociation pathways by working at low reduced electric field strengths (about 20 Td), while sufficient ionization in the plasma is ensured by the electron beam. Based on this principle a reactor for gas conversion processes was developed. Furthermore, preparatory electron beam dose measurements for estimating ionization rates in the plasma were conducted and power deposition by the electric field and the electron beam into the plasma were calculated for continuous and pulsed operation modes.

P 5.7 Tue 12:45 CHE/0089

Control of the gas flow by a surface barrier discharge — •Soad Mohsenimehr, Marc Böke, and Achim Von Keudell — Experimental Physics II, Ruhr-University Bochum, Bochum, Germany

Surface Dielectric Barrier Discharges (SDBD) are well-known plasma sources for gas stream purification and gas conversion due to their easy scalability in various applications. In addition, SDBDs are used as plasma actuators to generate thrust in a gas for flow control. The aim of this project is to combine plasma chemistry and plasma-based flow control concepts. The plasma-flow interaction and its contribution to the chemistry of transported species is evaluated. In this work, a twin SDBD is employed, which consists of an aluminium oxide plate (190x88x0.63 mm) that is covered by nickel metallic grid printed on both sides. The SDBD is generated at atmospheric pressure using damped sinusoidal voltage waveforms (G2000 Redline Technologies). To investigate the flow pattern, the Schlieren technique was carried out to visualize the refractive index gradients in the medium and to compare this with a fluid dynamic simulation in two dimensions performed by COMSOL. The fluid simulation uses the 2D Navier Stokes equations for compressible Laminar flow assuming small Reynolds numbers. This simulation model is used to predict the plasma aerodynamic and how it could influence the surrounding fluidic flow. The formation of distinct vortices in the flow pattern in both simulation and experiment is observed. The electrode design of the SDBDs is optimized to maximize the plasma-induced thrust on the species conversion.

P 6: Magnetic Confinement II/HEPP III

Time: Tuesday 11:00–12:50 Location: CHE/0091

Invited Talk P 6.1 Tue 11:00 CHE/0091

The physics of ELM-free regimes — •Michael Dunne[1], Michael Faitsch[1], Georg Harrer[2], Lidija Radovanovic[2], Wolfgang Suttrop[1], Eleonora Viezzer[3], Matthias Willensdorfer[1], and Elisabeth Wolfrum[1] — [1]Max-Plank Institute for Plasma Physics, Bolzmannstr. 2, 85748 Garching-bei-München, Germany — [2]Institute of Applied Physics, TU Wien, Fusion@ÖAW, Wiedner Hauptstr. 8-10, 1040 Vienna, Austria — [3]Dept. of Atomic, Molecular and Nuclear Physics, University of Seville, Avda. Reina Mercedes, 41012 Seville, Spain

High performance tokamak scenarios rely on an edge transport barrier (ETB) to reach the pressure and confinement time necessary for high fusion gain. The ETB is characterised by a steep pressure gradient, which provide energy for edge-localised modes (ELMs), quasi-periodic explosive instabilities, which are projected to cause significant damage to the walls of a fusion reactor. Ensuring the longevity of tokamak reactors requires, therefore, alternative operational scenarios where large ELMs are avoided. We present a general framework in which the occurrence of ELMs is understood as a combination of turbulent transport and magnetohydrodynamic (MHD) stability. Predicting and controlling ELM-free regimes is then a matter of increasing transport such that the MHD instabilities are avoided. Three ELM-free regimes are highlighted; the quasi-continuous exhaust (QCE), quiescent H-mode (QH-mode), and operation with magnetic perturbations (MPs). We present the current understanding of the physical mechanisms as well as projections to future devices.

P 6.2 Tue 11:30 CHE/0091

Gyrokinetic turbulence simulations in the pedestal — •Leonhard A. Leppin[1], Tobias Görler[1], Marco Cavedon[1], Mike Dunne[1], Elisabeth Wolfrum[1], Frank Jenko[1], and ASDEX Upgrade Team[2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching b. München, Germany — [2]See author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

The theoretical investigation of relevant turbulent transport mechanisms in H-mode pedestals is a great scientific and numerical challenge. In this study we address this challenge by global, nonlinear gyrokinetic simulations of a full pedestal up to the separatrix, supported by a detailed characterization of gyrokinetic instabilities at pedestal top, center and foot. We present ASDEX- Upgrade pedestal simulations (and first comparisons to other experiments) using the gyrokinetic, Eulerian, delta-f code GENE (genecode.org). We investigate the differences in turbulence characteristics between the pedestal regions via local simulations and obtain global heat flux profiles employing a new code upgrade which enables stable simulations at experimental beta values. In agreement with experimental measurements [Viezzer, PPCF, 2020] our global GENE simulations reveal a complex structure with different radial transport regimes. The dominant drive of electron turbulent transport transitions from ion-scale TEMs at pedestal top to small-scale ETG modes in the steep gradient region. Ion turbulent transport is relevant at the pedestal top but suppressed towards the pedestal center. A combination of linear and nonlinear stabilization mechanisms is identified to contribute to this heat flux structure.

P 6.3 Tue 11:55 CHE/0091

Linear MHD stability studies of pedestals in magnetically perturbed Tokamak plasmas — •Jonas Puchmayr, Mike Dunne, Erika Strumberger, Hartmut Zohm, and Matthias Willensdorfer — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

In H-mode Tokamak plasmas, edge localized modes (ELMs) limit the achievable pressure-gradient in the edge region and may cause severe damage in future fusion devices. For this reason, it is important to understand the onset conditions of ELMs and develop methods to avoid them. The ELM onset is well-described by the theory of peeling-ballooning (PB) modes which are magnetohydrodynamic (MHD) instabilities at the edge. This provides a framework to analyze the operational space of ELMs and their mitigation/suppression.

One method to suppress/mitigate ELMs is the application of magnetic perturbation (MP) fields. However, the impact of MPs on MHD stability is not well understood. In this talk, we use the CASTOR3D code for the numerical stability analysis of a range of plasmas. Results on the toroidal localization of PB modes in magnetically perturbed Tokamak plasmas are shown and successfully compared to experimental observations. We show that PB modes are predicted to appear only at selected toroidal locations when MP fields are applied and two different kinds of localization are distinguished. Finally, results on the effect of the MP fields on the linear MHD stability limit, i.e. the marginally stable edge pressure, are presented. In general, MP fields lead to a reduction of the stability limit, as experimentally observed.

P 6.4 Tue 12:20 CHE/0091

Experimental Evidence for the Drift Wave Nature of the Weakly Coherent Mode — •Manuel Herschel[1,2], Tim Happel[1], Daniel Wendler[1,3], Michael Griener[1], Joey Kalis[1,3], Peter Manz[4], Ulrich Stroth[1,3], and The ASDEX Upgrade Team[5] — [1]MPI für Plasmaphysik, Garching — [2]Universität Ulm — [3]Physik Department E28, TUM, Garching — [4]Institut für Physik, Universität Greifswald — [5]See Author list of "Stroth, U. et al., Nuclear Fusion 62 (2022) 042006"

Improved confinement regimes will play a key role in the operation of future fusion power plants. I-mode, one of these regimes, combines good energy confinement with the absence of ELMs. It features a characteristic edge transport barrier in energy but not in density. This selective transport reduction is not understood. An edge density fluctuation called the Weakly Coherent Mode (WCM) is often brought forward as a possible explanation

Measurements obtained from Doppler reflectometry and thermal helium beam spectroscopy at ASDEX Upgrade (AUG) are combined to analyze the WCM in unprecedented detail. A phase velocity of the WCM consistent with the dispersion relation of a near ideal drift wave is found for the first time at AUG.

This marks a novel experimental verification of a specific mechanism for the WCM and sheds new light on a long-standing debate on the underlying physics.

P 6.5 Tue 12:35 CHE/0091

Numerical studies of the O-X mode conversion process in MAST Upgrade — •Alf Köhn-Seemann[1], Bengt E. Eliasson[2], Simon J. Freethy[3], Lou A. Holland[4], and Roddy G.L. Vann[4] — [1]IGVP, University of Stuttgart, Germany — [2]SUPA, Department of Physics, University of Strathclyde, Glasgow, U.K. — [3]Culham Centre for Fusion Energy, Culham, U.K. — [4]York Plasma Institute, York, U.K.

Microwaves in the GHz-range play an indispensable role for heating and current drive in plasmas. If, however, the plasma density exceeds the cut-off density of the injected microwave, it can no longer reach its electron cyclotron resonance layer. To overcome this limitation, heating at electron cyclotron harmonics is an often applied method. Another possibility is to couple to the electrostatic electron Bernstein wave which has no high-density cut-off and is very well absorbed at the electron cyclotron resonance layer. Spherical tokamaks can in particular benefit from EBWs as their current drive efficiency exceeds those of

O- or X-mode. Here, we present numerical investigations of coupling to the EBW via the O-X-B mode conversion process in the spherical tokamak MAST Upgrade. These studies are to be understood as a feasibility study of an EBW heating system in MAST Upgrade.

P 7: Atmospheric Pressure Plasmas and their Applications III

Time: Tuesday 17:00–19:00 Location: CHE/0089

P 7.1 Tue 17:00 CHE/0089

Operation modes of the COST plasma jet — •Maximilian Klich, David Schulenberg, Máté Vass, Katharina Nösges, Sebastian Wilczek, and Ralf P Brinkmann — Ruhr University Bochum, 44780 Bochum, Germany

Discharges ignited at ambient pressure drive complex chemistry. This chemical variety offers plenty of applications; for example, wound healing. A commonly used plasma source at atmospheric pressures is the COST plasma jet, a capacitively coupled radio-frequency driven plasma jet. The main goal of this study is to demonstrate three distinct operation regimes of the COST jet and to indicate their relation. The work is conducted by applying a hybrid particle-in-cell/Monte Carlo collisions (PIC/MCC) simulation code between the jet's electrodes (i.e., a one-dim. setup) for He/N2 chemistry. The framework treats electrons kinetically via PIC/MCC and solves the continuity equation based on the drift-diffusion approximation for all ion species. We vary basic input parameters (e.g., the driving frequency or voltage) to control the discharge regimes. It shows that the scaling of the Debye length, the average sheath width, and the discharge length are comparable in magnitude. Depending on their exact values, the discharge enters one of three modes: (i) A quasi-neutral regime where distinguishable bulk and sheath areas exist. (ii) A non-neutral regime where no quasi-neutral bulk region is developed. (iii) All dynamics are constricted to tiny sheath regions shielding a vast, steady bulk region in the constricted mode. Overall, this work offers parameters for distinct operation modes that allow tailoring the discharge.

P 7.2 Tue 17:15 CHE/0089

A comparison of the spatial distribution of H_2O_2 in the effluent of the kINPen-Sci and the COST Reference Microplasma Jet — •Levin Krös[1], Ben Harris[2], Andy Nave[1], Erik Wagenaars[2], and Jean-Pierre van Helden[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]York Plasma Institute, Department of Physics, University of York, UK

Cold atmospheric plasma jets (CAPJs) are utilised in biomedical applications, as they provide important reactive oxygen and nitrogen species (RONS) for the plasma cell interaction, such as H_2O_2. There are still open questions in the physical and chemical field regarding the production of the RONS. Where are they formed and how does the jet-type has an influence on their production? As a first step to resolve that question, the production of H_2O_2 in humidified helium is compared between the kINPen-Sci and the COST Reference Microplasma Jet. The small sample length (about 4 mm) combined with low number densities are a challenge for established absorption spectroscopic techniques. Continuous-wave cavity ring-down spectroscopy (cw-CRDS) is applied in order to increase the path length through the sample. The difference in the spatial distribution of H_2O_2 in the effluent between the jets will be discussed.

P 7.3 Tue 17:30 CHE/0089

Gas temperature variations along the discharge channel in an atmospheric pressure RF plasma jet and their consequences on electron dynamics — •David A. Schulenberg[1], Maximilian Klich[1], Zoltán Donkó[2], Máté Vass[1,2], Jeldrik Klotz[1], Nikita Bibinov[1], Julian Schulze[1], and Thomas Mussenbrock[1] — [1]Ruhr University Bochum, German — [2]Wigner Research Center for Physics, Budapest, Hungary

The gas temperature increase along the discharge channel of a radio frequency micro-atmospheric pressure plasma jet is investigated by a combination of spectroscopic measurements and particle in cell (PIC) simulations. The jet is operated using Helium-Nitrogen mixtures of He:N2 ratios of 1000:0.5 to 1000:2. We find that under standard operating conditions, the increase in gas temperature depends on the nitrogen content of the jet gas, the driving voltage, and the driving voltage waveform. Depending on the exact combination of these parameters, the gas temperature increases approximately 80 K between the gas inlet and the nozzle of the jet. Phase Resolved Optical Emission Spectroscopy measurements reveal a change of the time- and space-dependent dynamics of the high energy electrons in the plasma under operating conditions at which the gas temperature determined by optical emission spectroscopy also changes. This behavior is reproduced by PIC simulations, in which the gas temperature is an input parameter. The dependence of the operation mode on the gas temperature might offer an additional degree of freedom in terms of controlling the plasma properties in order to match specific application requirements.

P 7.4 Tue 17:45 CHE/0089

Modeling and simulation of transport processes in capacitively coupled radio-frequency-driven micro atmospheric pressure plasma jets — •Lukas L. Vogelhuber, Katharina Nösges, Maximilian Klich, Thomas Mussenbrock, and Ralf Peter Brinkmann — Faculty of Electrical Engineering and Information Technology, Ruhr University Bochum, Bochum, Germany

Capacitively coupled radio-frequency-driven micro atmospheric pressure plasma jets (CCRF μAPPJ) are used in biomedical science and CO_2 conversion. Numerical methods offer a range of possibilities to investigate a μAPPJ's gas and plasma dynamics. A hybrid simulation code is implemented to investigate a CCRF μAPPJ that handles electrons kinetically in a particle-in-cell/Monte Carlo collisions (PIC/MCC) scheme and ions and other heavy particles in a fluid mechanical manner. The simulation cycle of charged and neutral particles is separated, accounting for their different time scales and to spare computational resources. A one-dimensional continuity equation for the charged heavy particles is solved based on the drift-diffusion approximation. For neutral heavy particles, the gas flow is modeled by Hagen Poisseuille's law, and a two-dimensional continuity equation is solved. The main goal of this work is implementing a scheme that can solve complex chemistry and gas transport and gives two-dimensional (2D) resolved data without evoking a full 2D-PIC scheme. With the exemplary chemistry of He/N_2 this work shows that the presented scheme is suitable for the communication between separate plasma and gas dynamics simulation that creates a multi-physics framework.

P 7.5 Tue 18:00 CHE/0089

Impact of feed gas humidity on the discharge dynamics in an Ar-operating atmospheric pressure plasma jet — •Sarah-Johanna Klose, Robert Bansemer, Ronny Brandenburg, and Jean-Pierre H. van Helden — Leibniz-Institut für Plasmaforschung und Technologie e.V. (INP), Greifswald, Deutschland

Cold atmospheric pressure plasma jets are often employed for biomedical purposes as they provide a large variety of reactive species remaining around room temperature, such as atomic and molecular radicals, and key species, such as H_2O_2. In particular, hydrogen, oxygen and nitrogen containing species have been proven beneficial for wound healing and cancer treatment. The formation of these species starts in general with the dissociation of molecular gases in the plasma zone of the plasma jet. It has been shown previously that by the addition of water to the feed gas, the composition of reactive species could be changed drastically. In this presentation, we will demonstrate the impact of feed gas humidity on the discharge dynamics of the kINPen-sci plasmajet, a cold atmospheric pressure plasma jet that is operating with Ar. By means of time-resolved laser atomic absorption spectroscopy (LAAS), absolute densities of $Ar(^3P_2)$ species have been determined as a function of the feed gas humidity and of the distance to the nozzle of the plasmajet. By analysing the quenching, conclusions on the dissociation of water have been drawn, which will also be presented.

P 7.6 Tue 18:15 CHE/0089

Impact of humidity on the OH distribution in the effluent of an atmospheric pressure plasma jet measured by laser induced fluorescence — •Judith Golda[1], Sebastian Burhenn[1], Maike Kai[1], Pia-Victoria Pottkämper[1], Volker Schulz-von der Gathen[2], and Marc Böke[2] — [1]Plasma Interface Physics, 44801 Bochum, Germany — [2]Experimental Physics II, Ruhr Univer-

sity Bochum, 44801 Bochum, Germany

For plasma sources operating in ambient atmosphere, such as the COST-Jet, the environmental conditions have a sensitive impact on the reactive species leaving the discharge zone. One important parameter is humidity: Water impurities in the feed gas or diffusion of moisture from the ambient atmosphere in the gas stream can contribute to an increase of humidity in the effluent. To study these effects, OH as a side-product from the dissociation of water by the plasma can be used as a tracer molecule. Therefore, we measured the 2D-distribution of OH produced in the COST-Jet by laser induced fluorescence. To control the influence of gas composition and humidity of the ambient atmosphere, the experiments were performed inside a closed vessel. By systematically varying the water content of the gas inside the vessel by a bubbler system, the influence of humidity on the OH density profile was studied. These results were then compared to profiles, which were obtained from the variation of humidity in the feed gas providing valuable information about the production channels of OH.

Funded by the DFG in the PlasNOW project 430219886.

P 7.7 Tue 18:30 CHE/0089

Photo-chemistry of organosilicon precursors initiated by VUV/UV-radiation from an atmospheric pressure RF plasma jet — •Tristan Winzer, Natascha Blosczyk, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

Thin-film deposition using plasmas at atmospheric pressure is a topic of current research, because sources and setups are more simple and cost-effective when compared to their low-pressure counterparts. Furthermore, they enable continuous treatment of vacuum-sensitive substrates.

However, direct contact of the precursor with the plasma can lead to unwanted particle formation and ambient conditions influence the film via impurities from nitrogen, oxygen and water. To overcome these limitations, we use high purity noble gas in a setup that provides effective separation of plasma species and precursor gas and utilizes the VUV/UV-radiaton from the plasma to initiate photo-chemistry. Photo-chemistry products of different organosilicon precursors in dependence of plasma power and precursor gas flow will be analyzed using ion mass spectrometry with the goal of optimizing conditions for effective film deposition. Deposited films are analyzed using Fourier-transform infrared spectroscopy (FTIR).

P 7.8 Tue 18:45 CHE/0089

Anomalous $N_2^+(B^2\Sigma_u^+)$ population in the discharge and the afterglow of an APPJ in N_2 — •Nikita Lepikhin[1], Nikolay Popov[2], Dirk Luggenhölscher[1], Nader Sadeghi[3], and Uwe Czarnetzki[1] — [1]Institute for Plasma and Atomic Physics, Ruhr University Bochum, Bochum, Germany — [2]Moscow, Russia — [3]Laboratoire Interdisciplinaire de Physique, LIPhy, CNRS, UMR 5588, Laboratoire des Technologies de la Microélectronique, LTM, CNRS, UMR 5129, Université de Grenoble-Alpes, Grenoble, France

An anomalously high relative density of the $N_2^+(B^2\Sigma_u^+, v=0)$ state is observed in the plasma bulk of a nanosecond near-atmospheric pressure plasma jet in nitrogen during its quasi-DC phase and afterglow. Additional population of $N_2^+(B^2\Sigma_u^+, v=0)$ is confirmed by analyzing the rotational structure of the (0-0) transition of the First Negative System (FNS) of nitrogen. Numerical kinetic modeling is used to identify possible mechanisms of additional $N_2^+(B^2\Sigma_u^+, v=0)$ formation. Kinetic calculations taking into account production of $N_2^+(B^2\Sigma_u^+, v=0)$ in reaction between the $N_2(a^1\Pi_g)$ and $N_2(C^3\Pi_u)$ states as well as in reaction of the $N_2(a^1\Pi_g)$ state with the N_4^+ ion describe adequately the FNS(0-0) emission dynamics and the high relative density of the $N_2^+(B^2\Sigma_u^+, v=0)$ state observed experimentally.

P 8: Plasma Wall Interaction I/HEPP IV

Time: Tuesday 17:00–19:10 Location: CHE/0091

Invited Talk P 8.1 Tue 17:00 CHE/0091

Fuel retention and removal in the JET tokamak — •Dmitry Matveev[1], David Douai[2], Tom Wauters[3], Sebastijan Brezinsek[1], and JET Contributors[4] — [1]Forschungszentrum Juelich GmbH, EURATOM Association, 52425 Jülich, Germany — [2]CEA Cadarache, IRFM, F-13108 Saint Paul Lez Durance, France — [3]ITER Organization, Route de Vinon-sur-Verdon, CS 90 046, F-13067 St Paul Lez Durance Cedex, France — [4]See the author list of J. Mailloux et al, Nucl. Fusion 62, 042026 (2022)

The control of fuel retention remains a critical issue for future fusion reactors due to tritium fuel self-sufficiency and related radiation safety requirements. This talk will cover fuel retention studies in the JET tokamak over the past decades, from the carbon wall configuration and the first deuterium-tritium experiment (DTE1) to the beryllium-tungsten ITER-Like Wall (ILW) configuration and the recent second deuterium-tritium campaign (DTE2). Fuel retention mechanisms, the aspects of long-term and short-term fuel retention, and post-discharge outgassing of hydrogen isotopes from tokamak wall materials, as well as wall cleaning techniques and respective fuel removal experiments will be addressed.

P 8.2 Tue 17:30 CHE/0091

Early stages of He cluster formation in pristine and displacement-damaged tungsten — •Annemarie Kärcher[1,2], Vassily V. Burwitz[2], Thomas Schwarz-Selinger[1], Lucian Mathes[2], Wolfgang Jacob[1], and Christoph Hugenschmidt[2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Technische Universität München, 85748 Garching, Germany

In future fusion reactors, tungsten as plasma-facing material will be subjected to intense fluxes of helium (He). While the consequences of high He fluxes on the surface properties of tungsten have already been thoroughly studied, there are no experiments that could clarify the process of early He cluster formation. To understand the initial steps of the interaction of He with W, especially the impact of pre-existing defects, annealed, polycrystalline W samples were irradiation-damaged to various damage levels. Then, these samples were exposed to a low-temperature He plasma at fluxes between 10^{17} and 10^{19} He/m^{2}s and various fluences using implantation energies of 50 and 100 eV. The samples were measured by positron annihilation spectroscopy for defect characterization and elastic recoil detection analysis (ERDA) for quantification of the He retention. For the depth distribution of He, a novel method was applied: thin surface layers of the sample were subsequently removed followed by ERDA measurements in between the erosion steps. The removal was performed by by electrochemical oxidation and dissolution of the oxide in NaOH. The results show a higher He retention in pre-damaged samples by factors up to 10 and a deeper reaching distribution of He in undamaged samples.

P 8.3 Tue 17:55 CHE/0091

Low Energy Ion Scattering investigation of dynamic surface segregation of chromium in the WCrY SMART material — •Pawel Bittner, Hans Rudolf Koslowski, Andrey Litnovsky, and Christian Linsmeier — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung, 52425 Jülich,Germany

Self-passivating Metal Alloys with Reduced Thermo-oxidation (SMART) are promising candidates for the first wall of the DEMOnstration power plant (DEMO). These materials should feature an increased oxidation resistance during accidental conditions and tolerate plasma loading during regular operation of the power plant. In this work, the effects of segregation, diffusion and sputter erosion on the surface Cr concentration of a tungsten-chromium-yttrium SMART alloy (WCrY - 68 at% of W, 31 at% of Cr and 1 at% of Y) are studied with low energy ion scattering (LEIS) measurements at 800 K, 900 K and 1000 K and numerical simulations. The LEIS is operated with He^+, Ne^+ and Ar^+ ions at 1 keV in sputter mode. The time resolved measurements show a build-up of Cr at the surface directly after increasing the temperature, followed by a slow decrease with evolving time. A comparison to a discrete layer model, in which the segregation enthalpy, entropy and atomic mobility are taken into account, indicates that this decrease is caused by a slower bulk diffusion rate compared to the rates of sputtering and surface segregation.

P 8.4 Tue 18:10 CHE/0091

Influence of the Microstructure of Tritium Permeation Barrier Layers on Hydrogen Isotope Retention and Permeation

— •Jonah Lennart Book, Anne Houben, and Christian Linsmeier — Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

For the safe and efficient operation of fusion reactors, tritium permeation barriers, or TPBs, are required to prevent fuel loss through first wall materials. Yttrium oxide is chosen as a TPB due its favorable neutron activation behavior compared to other candidates. Different Y_2O_3 layers several hundred nanometers thick are deposited onto a steel substrate using RF magnetron sputtering and studied using scanning electron microscopy. The samples are annealed at 550°C to obtain the favorable cubic phase of Y_2O_3, which is verified by X-ray diffraction. Permeation measurements are performed by gas-driven deuterium permeation experiments from 25 mbar to 800 mbar at 300°C to 550°C. The calculation of the single layer permeability is introduced to obtain a comparable value of the permeation reduction effect for the different coatings. In addition, in lag time measurements the diffusivity of the sample is determined separately from the permeability. The permeation results and layer permeabilities are compared for the different microstructures. Furthermore, the hydrogen isotope retention of the different layers is measured using nuclear reaction analysis and evaluated with their permeation reduction performance.

P 8.5 Tue 18:25 CHE/0091

Ex-Situ Ion Beam Analysis of ^{13}C on Plasma-Facing Components of Wendelstein 7-X — •Christoph Kawan[1], Sebastijan Brezinsek[1], Timo Dittmar[1], Sören Möller[1], and the W7-X team[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]See author list of T. Klinger et al. (2019) Nucl. Fusion 59 112004

At the end of OP1.2B 4.5 * 10^{22} ^{13}C - methane molecules were injected to study carbon transport in W7-X and generate benchmark data for material migration codes. Here we present the results of a dedicated NRA analysis using the $^{13}C(d, p_0)^{14}C$ reaction on 24 divertor target elements of different toroidal positions. The majority of the deposition was on the divertor half module where the carbon was injected (60%), with layers up to 100 μm in a 5 cm radius around the injection location. The reminder of the ^{13}C was deposited on the other divertor modules close to the strike line.

P 8.6 Tue 18:40 CHE/0091

Experimental Determination of Irradiation-Induced Stress Relaxation in Thin Tungsten Wires — •Alexander Feichtmayer[1,2], Max Boleininger[3], Raphael Colson[1,2], Bailey Curzadd[1,2], Sebastian Estermann[1,2], Till Höschen[1], Johann Riesch[1], Thomas Schwarz-Selinger[1], and Rudolf Neu[1,2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]Technical University Munich, Boltzmannstr. 15, 85748 Garching, Germany — [3]Culham Centre for Fusion Energy, Abingdon, OX14 3DB, Oxfordshire, UK

The development of suitable materials for the highly loaded plasma facing components is a major challenge in the development of a future fusion power plant. The influence of neutron irradiation on the mechanical properties is particularly difficult to measure, since there is no suitable neutron source available. A widely used technique to simulate neutron irradiation is the use of high energy ions, since these can produce similar dislocation damage as neutrons. For this purpose, a dedicated device has been developed to allow simultaneous ion irradiation as well as mechanical testing. This device and the latest upgrades, as for example a laser-based strain measurement system, will be presented. The setup of a stress relaxation experiment on 16 μm tungsten wires, to study the synergistic effects between mechanical stress and irradiation damage, will also be presented. For this the wires were preloaded with up to 2 GPa and simultaneously irradiated with 20.3 MeV tungsten ions. The resulting force drop (10-30 mN) and the ion current across the sample (0.1-0.8 nA) was measured.

P 8.7 Tue 18:55 CHE/0091

First trials to regenerate the surface of plasma-facing components by wire based laser metal deposition — •Jannik Tweer[1], Robin Day[2], Thomas Derra[2], Daniel Dorow-Gerspach[1], Christian Linsmeier[1], Thorsten Loewenhoff[1], Ghaleb Natour[3,4], and Marius Wirtz[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany — [2]Fraunhofer-Institut für Produktionstechnologie IPT, 52074 Aachen, Germany — [3]Forschungszentrum Jülich GmbH, Zentralinstitut für Engineering, Elektronik und Analytik (ZEA-1), 52425 Jülich, Germany — [4]Lehrstuhl und Institut für Schweißtechnik und Fügetechnik, RWTH Aachen University, 52074 Aachen, Germany

The harsh conditions inside a nuclear fusion reactor put high demands on the plasma-facing materials and components. Tungsten is the preferred material for lining the inner walls of future fusion reactors. It is considered as such due to its exceptionally high melting point, excellent thermal conductivity, low tritium retention and high erosion resistance during plasma exposure. However, even plasma-facing components made of tungsten get damaged during reactor operation, thereby limiting the lifetime of these components. It is envisioned to counteract these erosion losses by local deposition of tungsten using the wire based laser metal deposition process (LMD-w). During this process new material gets fused to the substrate, enabling in-situ repair of damaged plasma-facing components. Several experiments were conducted to find suitable process parameters and methods to create layers of new material by placing several melt tracks next to each other.

P 9: Atmospheric Pressure Plasmas and their Applications III

Time: Wednesday 11:00–13:00 Location: CHE/0089

Invited Talk P 9.1 Wed 11:00 CHE/0089

Modelling and analysis of single-filament dielectric barrier discharges at atmospheric pressure — •Markus M. Becker[1], Ronny Brandenburg[1], Tomáš Hoder[2], Hans Höft[1], Aleksandar P. Jovanović[1], and Detlef Loffhagen[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Masaryk University, Brno, Czech Republic

This contribution gives an overview of research results of the last 10 years on the modelling of single-filament dielectric barrier discharges (DBDs). Two discharge configurations are used to highlight the possibilities and limitations of spatially one- (1D) and two-dimensional (2D) time-dependent fluid models. First, it is shown for a one-sided, sine-driven DBD in argon that 1D models are generally suitable to describe the discharge characteristics in periodic operation. Second, 1D models are found to be suitable for systematic determination of the influence of preionisation on repetitively pulsed, two-sided DBDs in nitrogen-oxygen gas mixtures up to time scales of milliseconds. However, 1D models lack the ability to correctly describe the appearance of striations (in argon) and the streamer breakdown phase (∼ 1 ns). For this purpose, 2D models are applied, which show a very good agreement with measurement results. Since processes on longer time scales (μs to ms) can only be investigated in 2D with extreme computational effort, a smart combination of 1D and 2D models is most promising for a profound understanding of filamentary DBDs.

This work was partly funded by the DFG—projects 407462159 and 408777255, and Czech Science Foundation project 21-16391S.

P 9.2 Wed 11:30 CHE/0089

Kinetic modeling of the charge transfer across a negatively biased semiconducting plasma-solid interface — Kristopher Rasek, •Franz Xaver Bronold, and Holger Fehske — Institut für Physik, Universität Greifswald, 17489 Greifswald

We discuss the selfconsistent ambipolar charge transfer across a negatively biased semiconducting plasma-solid interface using a thin germanium layer with electron-phonon scattering sandwiched between an Ohmic contact and a collisionless argon plasma as a model system. The current-voltage characteristics of the interface is obtained from the distribution functions of the charge carriers on both sides of it. Due to quantum-mechanical reflection at the interface and collisions inside the solid, the characteristics differs substantially from the one obtained for a perfectly absorbing interface. The electron microphysics inside the solid affects thus the characteristics. In addition, the spatially and energetically resolved fluxes and charge distributions inside the germanium layer visualize the behavior of the charge carriers responsible for the charge transport. Albeit not quantitative, because of the crude model for the germanium band structure and the neglect of

particle-nonconserving scattering processes, such as impact ionization and electron-hole recombination, which at the energies involved cannot be neglected, our results [1] clearly indicate (i) the current through the interface is carried by rather hot carriers and (ii) the perfect absorber model, often used for the description of charge transport across plasma-solid interfaces, cannot be maintained for semiconducting interfaces.
[1] K. Rasek *et al.*, Phys. Rev. E **105**, 045202 (2022).

P 9.3 Wed 11:45 CHE/0089

Challenges during the design of a DC microplasma cell intended for *in situ* TEM — •Luka Hansen[1], Niklas Kohlmann[2], Lorenz Kienle[2], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Institute for Material Science, Kiel University, Kiel, Germany

In situ observation of plasma surface modifications are possible if a microplasma is inserted into a TEM as shown by proof of principle experiments in 2013 [1]. Still, multiple challenges have to be overcome for the development of a microplasma cell suitable for TEM integration. The electrodes have to be electron beam transparent and are therefore restricted to tens of nanometers in thickness. The microplasma itself has to be vacuum-proof encapsulated and operated in a stable regime. A DC microplasma was designed and intensively studied to ensure its stable operation in the normal glow regime [2]. *Ex situ* performed measurements proved the possibility to setup the electrodes thin enough for TEM imaging and study the surface modifications [3]. Furthermore, the microplasma cell was successfully introduced into the TEM and first images without plasma could be taken. Electrical isolation problems prevented plasma ignition inside of the TEM, but will be solved by rebuilding the vacuum-proof encapsulation from ceramic. This contribution summarizes the already overcome challenges and updates about the recent steps towards *in situ* TEM imaging.

[1] K. Tai *et al.*, 2013 *Scientific Reports* **3** 1325
[2] L. Hansen *et al.*, 2022 *Plasma Sources Sci. Technol.* **31** 035013
[3] L. Hansen *et al.*, *Thin Solid Films* **(Accepted)**

P 9.4 Wed 12:00 CHE/0089

Characterization of Sputtered Polyethylene Naphthalate-Foil for Flexible Surface DBD Plasma Generation — •Sandra Moritz[1], Roman Bergert[2], Martin Becker[1], and Markus H. Thoma[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Deutschland — [2]II. Physikalisches Institut, Justus-Liebig-Universität Gießen, Deutschland

Plasma medicine demands for very specific plasma source configurations. Beside gasflow-driven jet-arrays, dielectrical barrier discharges (DBD) are commonly used to generate ambient air plasma at room temperature for sterilization. There, electrode and dielectric material limit its use in application. Especially, the sterilization of difficult, uneven or edged surface geometries with DBD can be rather challenging. Therefore, flexible polyethylene naphthalate-foil (PEN-foil) which was covered with electrode material by ion-beam sputtering is characterized regarding its electrical and bactericidal performance for different power and electrode thickness configurations. Operating temperature, ozone production capability and plasma parameters (electron temperature and density) were used as characterization parameters. Advantages as well as limitations of this new approach are presented.

P 9.5 Wed 12:15 CHE/0089

Study on interaction of two single-filament DBDs — •Hans Höft[1], Chiel Ton[2], Tom Huiskamp[2], and Torsten Gerling[1,3] — [1]Leibniz Institute for Plasma Science and Technology (INP), Felix-Hausdorff-Str. 2, 17489 Greifswald, Germany — [2]Department of Electrical Engineering, Electrical Energy Systems group, Eindhoven University of Technology, PO Box 513, 5600 MB Eindhoven, The Netherlands — [3]Competency centre for diabetes (KDK), Greifswalder Str. 11, 17495 Karlsburg, Germany

A dielectric barrier discharge configuration consisting of two identical single-filament arrangements with variable radial distance between them was investigated by means of synchronised, fast electrical and optical diagnostics. For that purpose, two single, alumina-covered electrode pairs featuring two 1 mm gaps were put in a stainless-steel chamber flushed with 0.1 vol% O_2 in N_2 at atmospheric pressure. A high-voltage pulse with $\approx$45 ns rise time was simultaneously applied to the electrode (10 kV amplitude and variable repetition frequencies). The diagnostics consisted of fast voltage and current probes, which were synchronised with an iCCD camera to record individual discharge structures. The current was measured at the grounded side for each single-filament to calculate the discharge power and transferred charge. The interaction between two adjacent discharges was investigated to better understand upscaling challenges and opportunities, e.g. by using an electrical circuit model and the synchronised single-shot data of the electrical measurements and the corresponding iCCD images.
Funded by the DFG – project number 466331904.

P 9.6 Wed 12:30 CHE/0089

Binary nanocrystal synthesis using atmospheric pressure plasmas — •Maren Dworschak[1], Martin Müller[2], Lorenz Kienle[3], and Jan Benedikt[1] — [1]Institue of Experimental and Applied Physics,Kiel University, Germany — [2]Institute of Physics, Czech Academy of Sciences, Czech Republic — [3]Faculty of Engineering, Kiel University, Germany

Nanocrystals of binary or multinary compounds with group IV semiconductors offer great flexibility in composition, morphology and structure. The resulting tunable band gap is associated with enhanced optical properties and tuneable luminescence ranging from the UV to the near-infrared region. The variety of possible nanocrystals offers a great selection of materials for energy conversion and storage application, yet the synthesis of such compounds on the nanometer scale is still challenging due to the complexity of the synthesis process. We report on possible methods that could facilitate the generation of metal-silicide nanocrystals while using atmospheric pressure plasmas as a tool. Silicon nanocrystals are generated in the plasma source from the reactive gas silane. An additional electrode inserted in to the plasma can be coated with the metal of choice. When the electrode is heated, the metal evaporates and gets incorporated in the produced nanoparticles downstream of the jet. A second possible method involves a post synthesis in-flight annealing stage. Particles synthesized in the plasma jet pass through a furnace at 1100°C, in which the desired metal is present in gaseous phase. Here, the high temperature has proven to facilitates the formation of crystalline polyelemental compounds.

P 9.7 Wed 12:45 CHE/0089

Modelling of self-pulsing discharges at atmospheric pressure — •Aleksandar P. Jovanović[1], Hans Höft[1], Detlef Loffhagen[1], Torsten Gerling[1,2], and Markus M. Becker[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), Felix-Hausdorff-Str. 2, 17489 Greifswald, Germany — [2]Competency centre for diabetes KDK Karlsburg, Greifswalder Str. 11, 17495 Karlsburg, Germany

Non-thermal atmospheric-pressure plasmas are of considerable interest due to their wide relevance for technical and medical applications over the past decade. Self-pulsing discharges are a common way to generate these plasmas. Here, the discharge current is limited by a suitably designed electrical circuit to prevent thermalisation. Current oscillations observed in these discharges were attributed to the existence of ion acoustic waves (IAWs) and can be used for plasma diagnostics. Therefore, a detailed understanding of the electron and ion kinetics during the discharge evolution is of great interest. For this purpose, a time-dependent, spatially one-dimensional fluid-Poisson model coupled with an equation of electrical circuit has been applied to study a self-pulsing discharge in argon at atmospheric pressure. The characteristic phases governed by different charge carrier production and loss processes as well as the dominant ions produced during the discharge have been analysed. The two-cathode effect has been identified as a potential excitation mechanism of IAWs at atmospheric pressure.

Funded by the Deutsche Forschungsgemeinschaft (DFG) – project number 466331904.

P 10: Magnetic Confinement III/HEPP V

Time: Wednesday 11:00–13:10 Location: CHE/0091

Invited Talk P 10.1 Wed 11:00 CHE/0091

Diagnosing the plasma edge with helium beam spectroscopy

— •Michael Griener and the ASDEX Upgrade Team — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

The outer 5% of the plasma radius of magnetically confined fusion plasmas – the plasma edge region – plays a key role for reactor performance. It sets the boundary for the plasma core by establishing transport barriers and it distributes the power to the plasma facing components.

The power and particle transport at the plasma edge is influenced by coherent plasma modes and turbulent structures like convective filaments. To study these important physical phenomena, diagnostics with high spatiotemporal resolution are required as typical structures with a size of around 1 cm move with velocities of several km/s.

One diagnostic dedicated to this is active spectroscopy on a locally injected neutral helium beam, which gets excited mainly by plasma electrons. Dependent on temperature T_e and density n_e of the plasma electrons, the population densities of the neutral helium energy levels vary. Subsequently, n_e and T_e can be reconstructed out of measured line intensity ratios together with a collisional radiative model.

In this talk the diagnostic principle is explained and inventive measurements of plasma modes and filaments in fusion reactor relevant plasma scenarios are discussed.

P 10.2 Wed 11:30 CHE/0091

Determination of SOL filament cooldown at ASDEX Upgrade

— •Daniel Wendler[1,2], Michael Griener[1], Gregor Birkenmeier[1,2], Elisabeth Wolfrum[1], Ulrich Stroth[1,2], and the ASDEX Upgrade team[3] — [1]Max-Planck-Institut für Plasmaphysik, Garching — [2]Physik-Department E28, Technische Universität München, 85747 Garching, Germany — [3]See author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

Filaments, alternatively called blobs, are coherent structures, appearing in the scrape-off layer (SOL) of magnetic fusion devices in all plasma scenarios. They have a higher pressure than the background plasma and a radial motion outwards, which also differs from the background. As a consequence, blobs cause convective transport, being correlated with phenomena like the density shoulder formation and in general the power deposition in the plasma vessel. To better estimate the power transported by the filaments, their temperatures, densities and velocities are measured. This is done by means of a two-dimensional grid of lines of sight at the ASDEX Upgrade thermal helium beam. Measured radiances of helium transitions are then converted into the plasma electron temperature and density by applying a collisional radiative model. Via the calculation of the temporal evolution of these quantities and the blob position, the convective power of the filament is determined. This shows a cooldown of the filament's temperature which is combined with a loss of density. These processes are compared to analytical models, allowing to determine the temporal evolution of the convective power.

P 10.3 Wed 11:55 CHE/0091

Experimental Exploration of a Two Point Model for the Island Divertor of Wendelstein 7-X via Helium Line Ratio Spectroscopy

— •Erik Flom[1,3], Tullio Barbui[2], Oliver Schmitz[1], Maciej Krychowiak[3], Ralf König[3], Marcin Jakubowski[3], Sergei Bozhenkov[3], Valeria Perso[3], Felix Reimold[3], and The Wendelstein 7-X Team[3] — [1]UW-Madison, Madison, WI, USA — [2]PPPL, Princeton, New Jersey, US — [3]Max Planck Inst. for Plasma Physics, Greifswald, Germany

Understanding the basic plasma parameters of temperature and density, as well as their gradients in the scrape-off layer (SOL), is a topic critical for providing information about the performance of a divertor concept. The stellarator Wendelstein 7-X features a novel resonant island divertor with an adjustable rotational transform of $\iota = 2\pi$ (5/6, *, 5/4). In order to study the performance of this divertor concept, an active spectroscopy system on an atomic helium beam [1] was developed and installed on the stellarator [2]. The diagnostic was successfully operated in the first two divertor campaigns of the device in two magnetically connected modules. In this work, a database analysis of experiments from the operational phase OP1.2b is performed and systematic trends in divertor performance are discussed within the framework of a two-point, single-fluid model [3]. Particular focus is applied to separatrix vs. target density scaling and evidence for a *high-recycling* conduction limited regime, as well as an exploration of the validity of the helium beam as a downstream proxy given its displacement from the strike line poloidally.

P 10.4 Wed 12:20 CHE/0091

Low-collisionality extension of the edge turbulence fluid code GRILLIX

— •Christoph Pitzal, Andreas Stegmeir, Kaiyu Zhang, Wladimir Zholobenko, and Frank Jenko — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

Fluid models are yet the workhorse for plasma edge turbulence simulations, but the fluid assumptions have certain limitations. As one leaves the realm of validity, by decreasing collisionality, the most fragile quantity is the heat flux, as it represents usually the highest order fluid moment. These conditions can already be present in the near SOL of present day experiments and the commonly used Spitzer-Härm formula vastly overestimates the parallel heat conductivity. An approach to introduce Landau damping into fluid models and therefore predict the kinetic heat flux, is given in [1]. A method to translate this approach from k-space into configuration space, where most fluid codes act is presented in [2]. In this work the Landau-fluid closure is implemented into the edge turbulence fluid code GRILLIX [3]. This requires solving a set of elliptic equations along magnetic field lines. Turbulence simulations are performed to compare the Landau-fluid closure with the Spitzer-Härm formula. The aim is to find out whether this model is capable of predicting the parallel heat conductivity self-consistently and to investigate if non-local effects of the Landau-fluid closure can be seen. Finally, the performance of the model is assessed.

[1] G. Hammett et al., Phys. Rev. Lett., vol. 64, pp. 3019, 1990.
[2] A. Dimits et al. Physics of Plasmas, vol. 21, no. 5, 2014
[3] A. Stegmeir et al., Physics of Plasmas, vol. 26, no. 5, 2019.

P 10.5 Wed 12:45 CHE/0091

Gyrokinetic investigation of linear and non-linear excitation of energetic particle driven instabilities in ASDEX Upgrade

— •Brando Rettino[1], Thomas Hayward-Schneider[1], Alessandro Biancalani[2,1], Alberto Bottino[1], Philipp Lauber[1], Ilija Chavdarovski[3], Markus Weiland[1], Francesco Vannini[1], and Frank Jenko[1] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Léonard de Vinci Pole Universitaire, Research Center, 92916 Paris la Défense, France — [3]Korea Institute of Fusion Energy, 34133 Daejeon, South Korea

Excitation of Alfvén Waves (AW) and Geodesic Acoustic Modes (GAM) by energetic particles (EPs) is an important topic of study for the physics of fusion reactors. In tokamaks, ions are injected with high energies to heat the plasma. These energetic particles are very weakly collisional and exist far from thermal equilibrium. We examine the effects of experimental-like anisotropic in velocity distribution functions of EPs on the excitation of such instabilities with the gyrokinetic particle-in-cell code ORB5. The growth rate of GAMs is found to be sensitively dependent on the phase-space shape of the distribution function as well as on the non-linear wave-wave coupling with AWs.

P 11: Poster I

Time: Wednesday 14:00–15:30 Location: HSZ EG

P 11.1 Wed 14:00 HSZ EG

Novel microwave interferometry approach for spatial plasma profile measurements — •Christos Vagkidis, Eberhard Holzhauer, Walter Kasparek, Alf Köhn-Seemann, Stefan Merli, Mirko Ramisch, and Andreas Schulz — IGVP, University of Stuttgart, Germany

Interferometry is widely used in plasma physics to obtain the line-integrated density of a plasma. Here, we present a method to obtain in addition information about the spatial profile of the plasma density from interferometry measurements with the help of accompanying full-wave simulations. For this purpose, a microwave-generated plasma torch is used, which is confined in a quartz tube. A high frequency (208 GHz) microwave beam is emitted by a horn antenna, perpendicular to the plasma, and used as a probing beam. The receiving antenna is placed behind the plasma and is aligned with the sending antenna. The reference beam is generated artificially from a network analyser, which measures the phase difference of the beams. In spite of the beam being scattered, the phase difference can still be used to calculate the line-integrated density of the plasma with reasonable accuracy. Furthermore, the intensity distribution of the probing beam, in the plane perpendicular to the plasma torch, is obtained by moving the receiving antenna with a stepping motor, which can be operated with sub-millimetre precision. Full-wave simulations (inhouse FDTD code and COMSOL Multiphysics) have been carried out with arbitrary plasma density profiles. Comparing the simulation results with experiments allows to deduce information on the actual density profile.

P 11.2 Wed 14:00 HSZ EG

Inverstigation on methanol synthesis with a microwave plasma torch — •Marc Bresser, Katharina Wiegers, Andreas Schulz, Matthias Walker, and Günter Tovar — IGVP, University of Stuttgart, Germany

Due to the increasing concentration of carbon dioxide (CO_2) in the atmosphere and the resulting impact on climate change, possibilities are being sought to remove CO_2 from air by direct air capturing and a subsequent reuse of CO_2. In addition, the chemical industry is heavily dependent on fossil fuels and is looking for new ways to generate sustainable base chemicals. A possible renewable way to form carbon-based products is to use CO_2 as a reactant for the production of the base chemical methanol. Renewable methanol synthesis could be achieved via a microwave plasma process using electricity from renewable sources and "green" hydrogen (H_2). A CO_2 plasma forms carbon monoxide (CO) and oxygen (O_2).The oxygen is extracted via ceramic hollow fibers from the plasma. The addition of H_2 to the CO_2 plasma leads to the formation of new molecules such as methanol. The methanol can be separated by condensation of the exhaust gas. In this work, the CO_2 conversion in a microwave plasma (2.45 GHz) is studied. In dependence of the gas flow and the microwave power (up to 6 kW) the exhaust gas composition is analyzed with a Fourier-transform infrared spectroscopy (FTIR). Optical emission spectroscopy (OES) in the range from UV to IR is used to investigate the influence of the added H_2 onto the plasma gas composition and the exhaust gas stream.

P 11.3 Wed 14:00 HSZ EG

Applying machine learning to the inverse scattering problem for experimental plasma profiles — •Ewout Devlaminck, Christos Vagkidis, Mirko Ramisch, and Alf Köhn-Seemann — IGVP, University of Stuttgart, Germany

This work proposes a novel method to study the spatially resolved electron density profile of experimental plasmas using machine learning. The approach, here applied to an atmospheric plasma torch, solves the so-called inverse scattering problem of recovering the plasma profile from non-invasive measurements of the scattered microwave field. The proposed multi-output neural network is trained on 1D scattered intensity profiles, obtained from full-wave FDTD simulations of a high-frequency microwave beam traversing the plasma torch setup with various plasma profile settings. As opposed to the conventional experimental diagnostic, which only provides information on the line-integrated plasma density, the neural network can use the same measurement data to predict multiple parameters describing the complete spatial density profile.

P 11.4 Wed 14:00 HSZ EG

Combining a nanosecond-pulsed DBD with an electrolytic cell to reduce CO_2 and N_2 — •Martin Leander Marxen[1], Luka Hansen[1], Gustav Sievers[2], Volker Brüser[2], and Holger Kersten[1] — [1]Plasmatechnology Group, Institute of Experimental and Applied Physics, Kiel University (CAU), Kiel, Germany — [2]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany

Plasma-catalytic approaches are promising for converting mixtures of CO_2 or N_2 with H_2 at mild conditions (ambient pressure and low temperatures) into higher-value gases or fuels such as syngas ($CO + H_2$), methanol (CH_3OH) or ammonia (NH_3)[1]. Activation of the strong chemical bonds in CO_2 and N_2 is achieved by collisions of the molecules with energetic electrons present in the discharge.

In a polymer electrolyte membrane (PEM) cell[2], oxygen ions (O^{2-}) and protons (H^+) are produced in the anode space. The protons permeate the membrane and adsorb on the cathode. By locating a custom nanosecond-pulsed DBD in the cathode space (as proposed in this contribution), the adsorbed hydrogen can directly be utilized for reducing activated CO_2 or N_2 species. This has two major advantages compared to other plama-catalytic approaches: First, hydrogen is produced in place. Second, the power supplied to the plasma is mainly used to activate the CO_2 or N_2 bonds instead of activating H_2 bonds as well.

[1] A. Bogaerts et al., J Phys D Appl Phys 53 (2020) 443001

[2] S. Shiva Kumar, V. Himabindu, Mater Sci Energy Technol 2 (2019) 442-454

P 11.5 Wed 14:00 HSZ EG

Investigation of OH and H2O2 distribution in aqueous solution treated by a humid atmospheric pressure plasma jet — •Steffen Schüttler, Emanuel Jess, Marc Böke, Volker Schulz-von der Gathen, and Judith Golda — Ruhr-University Bochum, Universitätsstraße 150, 44801 Bochum, Germany

Biological enzymes are suitable to convert a substrate into a valuable product in presence of H2O2 without producing heavy metal waste. Atmospheric pressure plasma jets can produce H2O2 under very good control so that a stable environment can be maintained. This work investigated the delivery of reactive species from an atmospheric pressure plasma jet into a liquid. The capillary plasma jet used is comparable to the COST reference jet and was operated in humid He. Spectrophotometric diagnostics by use of ammonium metavanadate and terephthalic acid were performed to measure the concentrations of H2O2 and OH in the liquid, respectively. The distribution of reactive species at the liquid surface was visualise by the chemiluminescence of luminol. Our work showed that a H2O2 concentration of up to 1 mM was achievable while the OH concentration was a factor of 40 lower. Both species could be controlled by the dissipated plasma power and by the humidity of the feed gas. The transport process could be used to achieve a higher selectivity towards H2O2. Pulsing the RF jet at low frequencies of up to 2 kHz increased the energy efficiency of H2O2 production while reducing the OH concentration in the liquid. This work is supported by the DFG within CRC1316 (Subproject B11, project number 327886311).

P 11.6 Wed 14:00 HSZ EG

Time-resolved characterization of a micro cavity plasma array using a multi-photomultiplier setup — •Henrik van Impel[1], David Steuer[1], Volker Schulz-von der Gathen[2], Marc Böke[2], and Judith Golda[1] — [1]Plasma Interface Physics, Ruhr-University Bochum, D-44801 Bochum, Germany — [2]Physics of Reactive Plasmas, Ruhr-University Bochum, D-44801 Bochum, Germany

Dielectric barrier discharges (DBDs) have many applications, such as ozone generation or treating volatile organic compounds (VOCs). To understand the underlying processes, fundamental knowledge about the generation of reactive species is necessary. Here we investigated atomic oxygen production as a model system in a micro cavity plasma array, a customized surface DBD confined to geometrically arranged cavities of micrometer size. We studied the behavior and the plasma chemical processes using optical emission spectroscopy methods. The discharge is operated in helium with a molecular oxygen admixture of about 0.1% at atmospheric pressure using a 15 kHz and about 600V triangular excitation voltage. With helium state enhanced actinometry (SEA) [1] high atomic oxygen densities could be observed. Using a multi-photomultiplier setup with synchronous narrow bandwidth detection of characteristic transitions and SEA, we measured the temporal evolution of the atomic oxygen density and the effective mean electron energy over the first ignitions, which are affected by a memory effect due to residual charges on the dielectric surface.

The project is funded within project A6 of the SFB 1316.

[1] David Steuer et al 2022 Plasma Sources Sci. Technol. 31 10LT01

P 11.7 Wed 14:00 HSZ EG

Development of plasma reactors for plasma-assisted catalysis — •Kerstin Sgonina, Alexander Quack, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

The energy efficient and decentralized performance of catalytic reactions, such as for the production of ammonia, has become even more important nowadays. Plasma-assisted catalysis can help to achieve these goals as it is available on demand and works without enormous external heating. Non-equilibrium atmospheric pressure plasmas are used to dissociate gaseous molecules, which can then react at the surface of the catalyst to form the desired products. Plasma-assisted catalysis reactors at atmospheric pressure are often realized by packed bed reactors, in which the catalyst is packed into or deposited on millimeter-sized spheres. However, these millimeter-sized spheres are not feasible for all types of possible catalysts.

Therefore, different plasma reactors for plasma-assisted catalysis were developed and tested with and without different catalysts for in-plasma catalysis, where the catalyst is in direct contact with plasma, and post-plasma catalysis, where only reactive species from the plasma are reaching the catalyst. Dielectric barrier discharges operated at kHz- or radio-frequencies are used for ammonia synthesis using N_2 and H_2 as working gas as well as for methane formation experiments using CO_2 and H_2. Depending on the reactor-type and working gas, the gas temperature during plasma operation ranges from room temperature up to 200 °C.

P 11.8 Wed 14:00 HSZ EG

Coaxial dielectric barrier discharge for plasma catalysis in N_2 and H_2 — •Roland Friedl[1], David Rauner[1], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Dielectric barrier discharges (DBDs) are frequently utilized for plasma catalytic systems, due to their advantages regarding several crucial aspects: due to the repetitive filamented discharge, gas heating is avoided and distinctive non-equilibrium conditions are maintained at atmospheric pressure. In addition, if operated in a so-called packed-bed configuration, where the catalyst is coated on or embedded in the dielectric material, a large interaction area between the plasma and the active catalyst surface can be exploited.

In this contribution, a recently commissioned coaxial DBD setup is introduced, which is targeted towards the investigation of nitrogen and hydrogen discharges together with catalytic materials in a packed-bed configuration, e. g. in view of ammonia production. First investigations in view of an electrical and spectroscopical characterization are presented.

P 11.9 Wed 14:00 HSZ EG

Active Flux for Vlasov-Maxwell I: Application of the Linear Advection scheme to the Vlasov System — Lukas Hensel, •Gudrun Grünwald, and Rainer Grauer — Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum, Germany

The Vlasov-Maxwell system for the kinetic description of collisionless plasmas is numerically challenging due to its high dimensionality (3 dimensions in position and velocity space, respectively, plus the time) as well as the coupling of the particle trajectories to the EM-fields, resulting in extreme computational expense. Thus, there is an ongoing demand for efficient low-dissipation conservative schemes suitable for this system. The Active-Flux (AF) Method is a finite-volume method for hyperbolic conservation laws with additional degrees of freedom on the cell interfaces. It hereby allows achieving 3rd order while keeping a compact stencil in space and time. This can facilitate the bulk coupling. The point values on the cell interfaces are evolved independently of the conservation update, with the former step not having to be conservative. For the Vlasov equation, being a linear transport equation, this allows for the use of semi-Lagrangian techniques. We present first results on the numerical error of the method for the cases of 1 and multidimensional linear advection and the 1D electrostatic limit, considering the case of Landau-damping. AF showed lower dissipation than other 3rd order schemes and performed better particularly at low resolution, encouraging its application to the full 3D Vlasov-Maxwell problem.

P 11.10 Wed 14:00 HSZ EG

Active Flux for Vlasov-Maxwell II: Application of the Linear Advection scheme to the Vlasov System — •Lukas Hensel, Gudrun Grünwald, and Rainer Grauer — Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum, Germany

The Vlasov-Maxwell system for the kinetic description of collisionless plasmas is numerically challenging due to its high dimensionality (3 dimensions in position and velocity space, respectively, plus the time) as well as the coupling of the particle trajectories to the EM-fields, resulting in extreme computational expense. Thus, there is an ongoing demand for efficient low-dissipation conservative schemes suitable for this system. The Active-Flux (AF) Method is a finite-volume method for hyperbolic conservation laws with additional degrees of freedom on the cell interfaces. It hereby allows achieving 3rd order while keeping a compact stencil in space and time.

The point values on the cell interfaces are evolved independently of the conservation update. For the Vlasov equation, being a linear transport equation, this allows for the use of non-conservative semi-Lagrangian techniques. We present first results on the application of AF to the full three-dimensional Vlasov-Poisson system. Different possible strategies for directional splitting that allows the solution of the six-dimensional equation with lower dimensional substeps are discussed. The multidimensionality of AF furthermore allows for the solution of the three-dimensional velocity space in a single steps, encouraging its future application to the relativistic Vlasov-Maxwell equations.

P 11.11 Wed 14:00 HSZ EG

Efficient GPU implementation of 2D Particle-in-Cell Simulations for capacitively coupled plasmas — •Christian A. Busch and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany

Particle in cell (PIC) simulations are an indispensable tool for the study of low-pressure plasmas, in which a correct description of the particle transport can only arise from kinetic theory. However, the great ability of PIC simulations to model such systems has the drawback of being extremely expensive computationally.

In recent years, the development of general purpose graphics processing units (GPGPUs), provided cards with thousands of cores for computations different from graphics processing. This highly parallel hardware allows significant speedups in PIC simulations up to around a factor of 100 compared to CPUs, enabling the simulation of large multidimensional discharges.

Presented here are details for the efficient implementation of all components of a 2d3v PIC/MCC simulation on the GPU. The focus is on data management across the different types of memory on the GPU. Since data transfer is one of the main bottlenecks for high speed computation, optimization of the data storage and processing strategy is key to a successful implementation of PIC codes on the GPU.

P 11.12 Wed 14:00 HSZ EG

Control of the angular distribution of incident ions by tailoring electromagnetic fields in the sheath region — •Elia Johannes Jüngling, Neil Unteregge, David Klute, Marc Böke, and Achim von Keudell — Experimental Physics II - Reactive Plasmas, Ruhr-University Bochum, Bochum, Germany

The angular distribution of ions impinging on a surface in contact with a plasma plays a key role in various applications like anisotropic plasma etching or glancing angle film growth for the fabrication of microstructure devices. Here, we investigate ways to influence and ultimately control the ion incident angle and the angular distribution of the impinging ions to enable a true 3d manufacturing of microstructure devices. The ion incident angle can be controlled by applying additional local electric and magnetic fields in the sheath region of a plasma. Here, the electric field is modified by including a grid system (mask) in front of the surface which can be either on the floating potential of the plasma or externally biased; a magnetic field parallel to the surface is introduced to induce an asymmetry in the angular distribution of incident ions. A combination of both methods has been tested for reactive ion etching of carbon films in an argon-oxygen plasma and for deposition of copper in a HIPIMS plasma. The resulting etching or deposition profiles have been compared with a 2d3v particle-in-cell code (PIC) to simulate the ion trajectories in the sheath region/mask region in front of the substrate surface. A very good agreement has been found.

P 11.13 Wed 14:00 HSZ EG

Studies of low temperature radio-frequency discharges using a velocity moment analysis — •Tim Bolles, Maximilian Klich, Thomas Mussenbrock, Ralf Peter Brinkmann, and Sebastian Wilczek — Ruhr University Bochum, 44780 Bochum, Germany

Plasmas are complex systems in terms of their physics and chemistry. Thus, a fundamental understanding of the underlying mechanisms is crucial. The solution of the Boltzmann equation (BE) offers insight into the full spatio-temporal dynamics of the plasma. Single particle simulations such as the kinetic particle-in-cell/Monte Carlo collisions scheme (PIC/MCC) are a feasible way to obtain this information. This work aims to generate a fundamental understanding of a low-temperature plasma by the means of an analysis of velocity moments of the electron energy distribution function. By doing so, the particle generation can, for example, be related to plasma heating. Since the PIC/MCC scheme gives a stochastic solution to BE, arbitrary moments can be calculated and interpreted without approximations and truncation. Many considerations stop the analysis after the first moment, known as momentum balance. We, however, include the energy balance equation (i.e., the second moment) in our evaluation. For our work, we run simulations at varied parameters for pressure, background gas and driving frequency. The conservation equations, especially the energy balance equation, then provides insight into energy dissipation mechanisms. Overall, this work establishes the second moment of the BE as valuable diagnostics and contributes to a fundamental understanding.

P 11.14 Wed 14:00 HSZ EG

High-efficiency machine learning approach for nanoparticle 2D size characterization via kinetic Mie polarimetry — •Alexander Schmitz, Andreas Petersen, and Franko Greiner — IEAP, Kiel University, 24118 Kiel, Germany

In a nanodusty plasma, the determination of the size of the nanoparticles is crucial to their diagnostics. In the Mie regime, in situ polarization measurements of light scattered by the particles (polarimetry), have proven to be an effective, non-invasive technique.

This method holds a number of challenges. The polarization state depends not only on the particle size, but also on its complex refractive index. Furthermore, the inverse mapping from the measured polarization state to the time dependent particle size and refractive index in a reactive plasma exhibits a strongly non-linear relationship. To resolve this, a customized kinetic fitting algorithm has been introduced in the past [1]. However, that method, based on Least-Square Fits, is highly sensitive to the time series length and requires considerable computing time.

We present a new deep-learning approach to the mapping problem via our High-Efficiency Refractive index MappIng NEural network (HERMINE). With this, the error rate of automated data evaluation, as well as computing time was significantly reduced. This paves the path for future data-intensive, real-time imaging of the particle's growth dynamics in nanodusty plasmas [2].

[1] S Groth et al, J. Phys. D: Appl. Phys., 2015.
[2] S Groth et al, Plasma Sources Sci Technol, 28 (11), 2019.

P 11.15 Wed 14:00 HSZ EG

3D machine-learning reconstruction techniques for particles in dusty plasmas — •Andre Melzer, Michael Himpel, Christina Knapek, Daniel Maier, Daniel Mohr, and Stefan Schütt — Institute of Physics, University Greifswald

Dusty plasmas provide an interesting system to study fundamental processes in many-particle systems since the particles can be imaged and followed on the kinetic individual-particle level.

We have performed experiments with dusty plasmas on parabolic flights using a stereoscopic camera system with four cameras. Under microgravity conditions the dust particles form a dense dust cloud, and a small fraction of the dust cloud is imaged by the four cameras.

In this contribution, techniques to reconstruct the three-dimensional position of the dust particles from the stereoscopic images with the help of machine-learning methods are reviewed and tested. This is important for a future application in the Compact facility planned for the ISS [1].

The work is supported by DLR under 50WM2161/50WM1962.

[1] C. Knapek et al., "COMPACT - A new complex plasma facility for the ISS", Plasma Phys. Control. Fusion 64 (2022) 12400

P 11.16 Wed 14:00 HSZ EG

What's the rheology of electro-rheological plasmas? — •Michael Kretschmer[1,2], Markus Thoma[1], Andreas Schmitz[1], Lukas Wimmer[1], Thomas Nimmerfroh[1], and Christian Schinz[1] — [1]Justus Liebig University, 1st Institute for Physics, Giessen — [2]Technische Hochschule Mittelhessen, Abt. EI, Giessen, Germany

Negatively charged micron-sized particles inside a low-temperature plasma interact with each other and form strongly coupled Coulomb systems. In such so-called complex plasmas structure formation can be observed, from crystalline states ('plasma crystal') to dynamical fluids, depending on the plasma parameters. Since gravity is a disturbing factor many experiments with complex plasmas are performed in microgravity, e.g. on parabolic flights or aboard the International Space Station ISS.

We report here on experiments on so-called electro-rheological (ER) plasmas done on parabolic flights. ER plasmas are a model system of well-known and technically used ER fluids where immersed particles form strings when an electric field is applied. This drastically changes rheological properties, such as viscosity and elasticity of the fluid.

In a setup similar to PK-4 on the ISS we use a laser to manipulate strings of microparticles inside a polarity-switched DC discharge by applying a force (light pressure) in longitudinal as well as transversal direction. The behaviour between particles in strings and unbound particles is investigated to compare their rheology and to decide whether the labeling of a complex plasma as 'ER' is justified.

P 11.17 Wed 14:00 HSZ EG

Dust acoustic wave properties in varying discharge volumes — •Christina A. Knapek[1,4], Mierk Schwabe[2,4], Victoriya Yaroshenko[3,4], Peter Huber[4], Daniel P. Mohr[1,2,4], and Uwe Konopka[5] — [1]Institute of Physics, University of Greifswald, Greifswald, Germany — [2]Institut für Physik der Atmosphäre, DLR, Oberpfaffenhofen, Germany — [3]Institut für Solar-Terrestrische Physik, DLR, Neustrelitz, Germany — [4]Institut für Materialphysik im Weltraum, DLR, Köln, Germany — [5]Physics Department, Auburn University, Auburn, Alabama, USA

An ion flow through a cloud of microparticles suspended in a low-temperature plasma can induce an ion streaming instability and lead to the formation of dust acoustic waves. The properties of such self-excited dust acoustic waves under the influence of active compression of the dust particle system were experimentally studied. Ground based laboratory experiments show clearly that wave properties can be manipulated by changing the discharge volume and thus the dust particle density. Complementary experiments under microgravity conditions (parabolic flights) were less conclusive due to residual fluctuations in the planes acceleration indicating the need for a better microgravity environment. A theoretical model, using plasma parameters obtained from PIC (particle-in-cell) simulations as input, supports the experimental findings. It shows that the waves can be described as a new observation of the dust acoustic mode which demonstrates their generic character. This work is funded by DLR/BMWi (FKZ 50WP0700, FKZ 50WM1441).

P 11.18 Wed 14:00 HSZ EG

Dichromatic Mie scattering approach for particle size measurements — •Franziska Reiser, Sören Wohlfahrt, and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Microparticles are an essential component in complex (dusty) plasmas. These microparticles are negatively charged in the plasma and levitate in the plasma sheath due to the sheath electric field. To understand structure as well as dynamical processes in dust clouds, a precise knowledge of the particle size is indispensable, as it determines charge as well as all forces acting on a particle. Recently, a suitable diagnostic based on Mie scattering was introduced [1]. It compares measured angular and polarization resolved intensity patterns of scattered light with predictions of Mie theory. However, Mie scattering is based on interference, the intensity patterns of particles which slightly differ in size and refractive index are selfsimilar and thus an ambiguity in the resulting particle size can occur. As this ambiguity is dependent on the wavelength it can be removed using two lasers with different wavelength. This contribution presents an enhanced setup using two lasers with different wavelength and discusses evaluation concepts.

[1] S. Wohlfahrt, D. Block, 2021 Phys. Plasmas 28

P 11.19 Wed 14:00 HSZ EG

COMPACT – the future complex plasma facility for the ISS — •Daniel P. Mohr and Christina A. Knapek for the COMPACT-Collaboration — University of Greifswald, Institute of Physics, Greifswald, Germany

Complex, or dusty, plasmas consist of micrometer-sized grains injected into a low temperature noble gas discharge. The grains become charged and interact with each other via a screened Coulomb potential. On ground, gravity compresses the system and prevents the generation of larger, three-dimensional particle clouds.

The future complex plasma facility COMPACT will allow the investigation of large three-dimensional complex plasmas under microgravity conditions on the International Space Station (ISS). Its technology is mainly based on pre-studies (Ekoplasma, PlasmaLab), including a novel plasma chamber with adaptive internal geometry, a four-electrode radio-frequency system for plasma generation, and a stereoscopic particle diagnostic that allows to record 3D particle dynamics in real-time.

We will present the scientific goals of COMPACT, scientific and technology results from the pre-studies, technologies currently under discussion, and the project status.

This work is funded by DLR/BMWi (FKZ 50WM2161).

P 11.20 Wed 14:00 HSZ EG

Comparison of HERMES-2 and EMC3 for the SOL transport of Wendelstein 7-X — •David Bold[1], Brendan Shanahan[1], Felix Reimold[1], and Benjamin Dudson[2] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [2]Lawrence Livermore National Laboratory, Livermore, California, USA

The EMC3-EIRENE code is a well established tool for modelling of the scrape-off layer (SOL) of stellerator devices like Wendelstein 7-X. However EMC3 does not include drifts, which are expected to play a significant contribution to the transport in the SOL.

HERMES-2 is a hot-ion drift reduced SOL-model using the BOUT++ framework. A recent addition to BOUT++ is the inclusion of the flux coordinate independent (FCI) scheme for fully 3D geometries. The HERMES-2 model is currently modified to be able to handle the geometry of a stellerator using the FCI method. As a first step the results of the two codes are compared when solving the geometry of Wendelstein 7-X. For a direct comparison, only the terms in Hermes-2 which are similar to those found in EMC3 are used.

P 11.21 Wed 14:00 HSZ EG

Overview of MHD mode observations during the recent operational phase at the Wendelstein 7-X stellarator — •Kian Rahbarnia, Sara Vaz Mendes, Charlotte Bueschel, Christian Brandt, Henning Thomsen, Adrian von Stechow, Jan-Peter Baehner, Ralf Kleiber, Christoph Slaby, Axel Koenies, and Wendelstein 7-X Team — Max-Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

In November 2022 the second operational phase (OP2) at Wendelstein 7-X (W7-X) started. Amongst many technical and diagnostic upgrades W7-X has been equipped with a fully water cooled high heat flux divertor, which in principle allows to operate high energy regimes for several minutes up to the envisaged half hour pulse. During the first part of the recent phase, OP2.1, a number of experiments have been conducted, specifically to investigate the role of magnetohydrodynamic (MHD) mode activity in high power heating scenarios involving neutral beam injection and electron cyclotron resonance heating. The obervation of various fluctuation diagnostics (Mirnov coils, soft X-ray tomography, phase contrast imaging, electron cyclotron emmission) are investigated and closely compared to findings of past operational campaigns. This contribution will mainly focus on Alfvén eigenmode activity, new insight concerning their driving mechanism and impact on high performance experiments.

P 11.22 Wed 14:00 HSZ EG

Neural Networks for the analysis of Langmuir probe characteristics — •Jasmin Joshi-Thompson and Mirko Ramisch — IGVP, University of Stuttgart, Germany

Developed in the early 1920s, Langmuir probes continue to be one of the most widely used plasma diagnostic tools. Theoretical curves are fitted to measured current-voltage (I-V) characteristics in order to obtain parameters such as electron density (n_e) and temperature (T_e). For extensive discharge conditions and comprehensive spatial profiles, measuring plasma parameters becomes more challenging and would best be addressed via automation, with manual checks for specific samples. In this work, deep neural networks are used for associating I-V characteristics to plasma parameters and are tested for robustness. Data is collected from the stellarator TJ-K for training and testing the networks, covering magnetized low-temperature plasmas in a broad parameter space. These networks are assessed as an adaptable, automated plasma characterisation method without the need for further control processes.

P 11.23 Wed 14:00 HSZ EG

Mode analysis of high performance discharges at Wendelstein 7-X during OP 1.2 — •Charlotte Büschel, Kian Rahbarnia, Sara Vaz Mendes, Henning Thomsen, Christian Brandt, Ralf Kleiber, Axel Könies, and Wendelstein 7-X Team — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

During the last operational phase, the optimized stellarator Wendelstein 7-X achieved so-called high performance up to 1.1 MJ of diamagnetic energy. In most experiments the high energy phase only lasted for about 200 ms following a series of pellet injections. During the discharges Alfvén Eigenmodes (AEs) were recognized which show dynamic behaviour throughout the pulse. The AE activity is investigated in detail to determine the type of the AEs and their possible impact on the often abrupt ending of the high energy phase. To identify relevant frequencies with high precision the parametric model stochastic system identification is used. Additionally poloidal mode number spectra are calculated with the use of a nonuniform Fourier Transformation. Experimental findings are compared to theoretical predictions of Alfvén continua calculated by the 3D ideal MHD code CONTI.

P 11.24 Wed 14:00 HSZ EG

ITG simulations with a fully-kinetic Semi-Lagrangian code — •Aleksandr Mustonen[1], Felipe Nathan de Oliveira[2], Ken Hagiwara[2], Sreenivasa Thatikonda[2], Daniel Told[2], and Rainer Grauer[1] — [1]The Ruhr Univeristy Bochum — [2]Max Planck Institute for Plasma Physics

Gyrokinetic framewrok has become a standart tool to research the phenomena occuring in the nuclear fusion devices. However, steep gradients in the edge region of tokamaks violate the the assumptions used to derive the gyrokinetic theory. Thus, we want to investigate the practical limits of the gyrokinetic theory with a model containing complete physics of the system. We develop a fully kinetic code employing semi-Lagrangian schemes to simulate the slab ion temperature gradient (ITG) mode with various setups, in order to learn the new physical effects that could be present only in the 6D model. Adiabatic electron approximation used to both verify the results with the analytical linear solution and to perform simulations. However, due to the smalness of the electron Larmor radius with comparison to the ion one, we can employ driftkinetic model for electrons to obtain a hybrid electrostatic description for the ITG simulations.

P 11.25 Wed 14:00 HSZ EG

Investigation of the influence of nanosecond pulsed plasmas in water on surfaces and on nanoparticle formation — •Pia-Victoria Pottkämper, Katharina Laake, Elia Jüngling, Oliver Krettek, and Achim von Keudell — Ruhr-Universität Bochum

One application of in-liquid plasmas is the formation of nanoparticles both in the treated liquid and on a surface in contact with the liquid. Plasmas in liquids ignited by voltage pulses with fast rise times and nanosecond pulse lengths applied to an electrode cause a dissociation of the molecules in the liquid. The reactive species created by the in-liquid plasma can propagate through the liquid and are able to modify surfaces in direkt contact with it. For instance it is possible to initiate surface growth of nanoparticles. In this project the modification of copper surfaces by in-liquid plasma treatment is investigated. On copper surfaces nanoparticles can be found in the shape of CuxO nanocubes which can act as catalysts e.g. in the reduction of CO2. The activity of these catalysts decreases over time. The plasma in water causes the formation of reactive oxygen species from the water molecules which can react with the surface to re-oxidize the material, leading to the formation of new CuxO nanocubes. It is postulated that by an in-situ in-liquid plasma treatment a re-activation of the surface could be achieved, thereby extending the lifetime of the catalytic surface. Furthermore the in-liquid plasmas can also yield particles through erosion of the electrode material itself. These particles dissolved in the liquid and their production is also investigated in this project.

P 11.26 Wed 14:00 HSZ EG

Influence of atmospheric microplasma jet treatment on self-organised sub-micrometer surface structures generated by short pulsed laser irradiation — •S. Chur[1], L. Kulik[1], R. Labenski[1], V. Schulz-von der Gathen[2], M. Böke[2], and J. Golda[1] — [1]Plasma Interface Physics, Ruhr-University Bochum, D-44801 Bochum, Germany — [2]Physics of Reactive Plasmas, Ruhr-University Bochum, D-44801 Bochum, Germany

Catalyst efficiency is strongly dependent on catalytic surface characteristics. Key features are the morphology and chemical composition. The combination of reactive species provided by an atmospheric pressure microplasma jet and energy input by laser irradiation can lead to very effective functionalisation of surfaces.
Self-organising surface structures were generated on copper (Cu) layers deposited through High Power Impuls Magnetron Sputtering (HiPIMS) on silicon wafers via the Pulsed Laser-Induced Dewetting (PLID) effect. The nanoparticles were investigated using a Scanning Electron microscope (SEM). Cu samples were treated simultaneously with the effluent of a micro atmospheric plasma jet (He/O2 admixture) and laser irradiation in a controlled atmosphere. Treated surfaces were investigated using Xray Photon Emission Spectroscopy (XPS).
A trade-off between high atomic oxygen fluxes and nanoparticle formation was found. Preliminary XPS measurements showed that plasma treatment can influence the oxidation state of copper, namely increase the percentage of CuO compared to an untreated surface.
Supported by the SFB 1316 within project B2

P 11.27 Wed 14:00 HSZ EG

Electric probe measurements inside and outside of magnetic islands in the SOL of Wendelstein 7-X. — •Dario Cipciar[1], Carsten Killer[1], Olaf Grulke[1], Jiri Adamek[2], and W7-X Team[1] — [1]Max Planck Institute, Greifswald, Germany — [2]IPP of the CAS, Prague, Czech Republic

We report on electric probe measurements in the Scrape-Off Layer (SOL) plasma of the W7-X stellarator. In this device, the SOL is formed by a chain of magnetic islands that separate the SOL into different topological regions and furthermore contain regions of closed magnetic field lines around the island centers ("O-points"). Measurements inside and outside of magnetic islands are performed using the multipurpose manipulator equipped with a probe head carrying 27 Langmuir and 2 ball-pen probes (BPPs). One of the BPPs is floating and measures the electron temperature and plasma potential and is used to cross-validate of the newly installed BPPs against triple probe measurements. The second BPP is in a swept regime for ion temperature measurements and will be compared to RFA results from similar discharges. The probe head also features poloidal and radial measurements of key fluctuating parameters (floating potential V_{fl} and ion saturation current I_{sat}) and, inferred from these are the turbulent radial particle fluxes, radial and poloidal electric fields. With these measurements we aim to assess the SOL plasma profiles and turbulence.

P 11.28 Wed 14:00 HSZ EG

Study of fast electrons population in the TJ-K stellarator. — •EdgardO Villalobos Granados and Alf Köhn-Seemann — IGVP, University of Stuttgart, Germany

Microwaves provide one of the most widely used methods for heating plasmas. If the plasma density becomes too high, the microwave is in cut-off, it cannot propagate any further and is reflected. Such plasmas are often referred to as over-dense. The stellarator TJ-K is typically operated with over-dense plasmas. Preliminary studies in TJ-K have shown that during these kinds of scenarios a component of fast electrons can be detected.

In this work, a pulse-height analyzer including a semiconductor detector being sensible in the soft X-ray range was used to measure the spectral distribution of the soft X-rays emitted by the plasma. Part of this radiation is generated by a hot electron component whose energy can be determined after calibrating the diagnostic against known X-ray sources. The occurrence of the hot electron component is studied under different discharge conditions to identify their generation mechanism.

P 11.29 Wed 14:00 HSZ EG

Properties of Metal Droplets Ejected During Arcing — •Alberto Castillo Castillo[1,2], Martin Balden[1], Volker Rohde[1], Peter Siemroth[3], Michael Laux[3], Heinz Pursch[3], Juergen Sachtleben[3], and Rudolf Neu[1,2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Technische Universität München, 85748 Garching, Germany — [3]retired, was with Arc-Precision GmbH, 15711, Germany

Droplet generation by arcing is one of the mechanisms that can generate dust in a fusion device. Metal droplets expelled by arcs can potentially introduce impurities in the plasma and influence operation. The diameter and velocities of droplets determine their capacity to penetrate the outer layers and, therefore, the measurement of their distributions allows prediction of the impact on plasma operation.

In order to investigate the properties of the droplets produced by arcs a dedicated laboratory device is used based on time of flight detection by light scattering. Additionally, a high speed camera has been added for the observation of expelled droplets in larger quantities than the time of flight system. Tracking software obtains trajectories from video recording to complement the statistics obtained from the time of flight system and allow back-tracking of the droplets point of origin as well as calculating the velocity distribution. Video recording reveals the existence of explosive droplet emission events that could potentially be the source of larger diameter droplets. Microscopy observations of the remaining origin craters provide insight on the emission process of different fusion relevant materials, focusing on tungsten.

P 11.30 Wed 14:00 HSZ EG

First Measurements of the Imaging Heavy Ion Beam Probe at ASDEX Upgrade — •Hannah Lindl[1,2], Gregor Birkenmeier[1,2], Pablo Oyola[3], Jose Rueda Rueda[3], Balazs Tal[1], Joey Kalis[1,2], and The ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Physics Department E28, Technical University Munich, Garching, Germany — [3]Department of Atomic, Molecular and Nuclear Physics, Universidad de Sevilla, Sevilla, Spain

The imaging Heavy Ion Beam Probe (i-HIBP) is a new diagnostic developed at the tokamak ASDEX Upgrade in order to measure perturbations of the magnetic field, density and electrostatic potential at the plasma edge. The i-HIBP is based on launching neutrals into the plasma, where they are ionized and deflected by the Lorentz force due to the tokamak magnetic field onto a scintillator detector placed in the limiter shadow inside the vacuum vessel. The light pattern created by the scintillator contains information about the above mentioned quantities. First measurements have been obtained recently and are now evaluated. In order to obtain a quantitative understanding of the results, the simulation code iHIBPsim is used. The code solves the equation of motion for 3D fields including ionization and attenuation models for a beam with finite width and divergence.

Results will be shown demonstrating the agreement of simulation and experiment as well as the ability to observe perturbations in the edge plasma quantities. The ability of the i-HIBP to measure filaments, edge current densities and zonal flows is discussed in this contribution.

P 11.31 Wed 14:00 HSZ EG

Influence of beam profile on ion-driven permeation experiments — Philipp Sand and •Armin Manhard — Max Planck Insitute for Plasma Physics, 85748 Garching, Germany

Ion-driven permeation experiments can be used to determine e.g. solubility, diffusivity, defect binding energies and surface/interface transport in materials relevant for wall components in nuclear fusion devices. Especially under conditions where surface processes or trapping of hydrogen isotopes at defects play a significant role, such experiments are influenced by the distribution of the ion flux density across the irradiated surface. In suitable energy and ion flux ranges, the beam profile can be quantified by measuring the height profile across the sputter erosion crater of a bulk Cu sample. In this contribution, the beam profile in the high-current, ion-driven permeation setup TAPAS was determined. A 200 eV/D beam with a total current of 80 μA of D_3^+ ions was characterised and exhibits an averaged ion flux densitiy of $8\text{x}10^{19}$ D/m^{2}s, while local values vary from $1\text{x}10^{19}$ to $3\text{x}10^{20}$ D/m^{2}s. A calculation scheme was implemented in the diffusion trapping code TESSIM-X. Permeation data for tungsten annealed at 2000 K was measured at 600 K and compared to simulations using the averaged ion flux as well as the detailed histogram of ion flux density. The relevance of the ion flux histogram is shown for 600 K, where trapping appearantly still plays a significant role. The best agreement between simulations and experiment was obtained for a trap concentration of $1.2\text{x}10^{-4}$ and a binding energy of 1.45 eV. For high temperatures, where most traps are empty, both calculated solutions converge.

P 11.32 Wed 14:00 HSZ EG

Experimental characterization of the quasi-coherent mode in EDA-H and QCE plasmas — •Joey Kalis[1,2], Gregor Birkenmeier[1,2], Peter Manz[3], Ridhesh Goti[1,4], Michael Griener[1], Elisabeth Wolfrum[1], Thomas Eich[1], and Ulrich Stroth[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Garching — [2]Physik-Department E28, TUM, Garching — [3]Institut für Physik, Universität Greifswald, Greifswald — [4]Ludwig-Maximilians-Universität, München

For future reactors based on the tokamak concept, it is necessary to establish high confinement modes without type-I ELMs. In the past years, several natural ELM-free operation scenarios, such as EDA-H-mode or quasi-continuous exhaust (QCE), have been achieved in ASDEX Upgrade. A quasi-coherent mode (QCM) appears in both scenarios at the plasma edge and may be the key feature for the stabilization of ELMs and thus the better confinement. In order to understand and extrapolate a possible EDA-H or QCE scenario at large-scale machines like ITER or DEMO, it is necessary to determine different spectral properties of the QCM. Due to its high spatial and temporal resolution, the He-beam diagnostic and magnetic pick-up coils are used for this purpose. The results include frequency scaling and coherency behaviour, poloidal and radial wavenumber analysis and radial localization as well as a link of the QCM to other higher harmonic modes (HHMs) appearing in the magnetic coils, and are compared with theoretical predictions.

P 11.33 Wed 14:00 HSZ EG

GPU development of the Gyrokinetic Turbulence Code GENE-X with Native Fortran/C++ Interface — •Jordy Trilaksono[1], Philipp Ulbl[1], Andreas Stegmeir[1], and Frank Jenko[1,2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]University of Texas at Austin, Austin, TX 78712, USA

Turbulence plays a significant role in plasma confinement inside of magnetic confinement fusion devices. A gyrokinetic turbulence model is used in the GENE-X code [1-3] to simulate turbulence anywhere within magnetic confinement fusion devices from the core to the edge and scrape-off layer. GENE-X leverages hybrid MPI+OpenMP parallelization to meet its expensive computational demands. Here, our effort extends this to GPUs for extensive scalability towards simulations of larger reactor-relevant devices which currently are not feasible with a reasonable amount of computing resources. The abstraction of several GPU backends via native Fortran/C++ interfaces provides portability and non-invasive development parallel to the main Fortran layer. Our Fortran/C++ hybrid approach overcomes compiler limitations that often hinder GPU development of Fortran legacy codes. The current build configuration of GENE-X supports GPU backends such as OpenACC, OpenMP offload and CUDA. Directive-based OpenACC and OpenMP offload are prioritized in the C++ layer of GENE-X.

[1] D. Michels, et. al., Comput. Phys. Commun. 264, 107986 (2021)
[2] D. Michels, et. al., Phys. of Plasmas. 29, 032307 (2022)
[3] P. Ulbl, et. al., Contrib. Plasma Phys., e202100180 (2021)

P 11.34 Wed 14:00 HSZ EG

Helium exhaust and impurity transport in W7-X — •Thilo Romba, Felix Reimold, Thomas Klinger, and W7-X team — Max-Planck-Institut for Plasmaphysik, 17491 Greifswald, Deutschland

The precise monitoring of the impurity content and the understanding of the transport mechanisms is crucial for future fusion reactor operation due to the associated restrictions to the operational parameter space via dilution and increased radiative losses.

This work aims to analyze the transport of impurities in the confined region of the optimized stellarator Wendelstein 7-X (W7-X) [1] with focus on the fusion ash helium. Local impurity densities are measured using charge exchange recombination spectroscopy (CXRS) [2]. While CXRS allows to measure profiles of densities of individual impurity charge states, it has a low sensitivity to the transport coefficients in steady state scenarios [3]. To increase the sensitivity to the transport coefficients in those scenarios, modulated impurity sources outside the confined region are used.

The impurity transport will also be assessed in transient phases of neutral beam heated plasmas. In these scenarios it was found that impurity transport is dominated by inwards directed neoclassical convection and impurity density peaking is observed [4]. This work aims to extend this analysis to different magnetic configurations and impurity species.

[1] Erckmann 1997, [2] Fonck 1985, [3] Romba, in preparation [4] Romba, in preparation

P 11.35 Wed 14:00 HSZ EG

Automated workflow for energetic particle stability — •Virgil - Alin Popa, Philipp Lauber, and Thomas Hayward-Schneider — Max Planck Institute for Plasma Physics, Garching, Germany

EPs (Energetic Particles) driven instabilities are a concern for present (AUG, JET) and future (ITER, DEMO) fusion devices. These particles can come from Neutral Beam Injection or be generated from fusion reactions (alpha particles). Their impact on electromagnetic instabilities in tokamak plasmas can lead to energetic particle transport which affects the heating efficiency of the plasma. Different codes that can study predictive scenarios and/or experimental results are emerging and with them the need of automatic analysis and management of the data they produce. In order to study the linear/non-linear, local/global effects, a workflow that manages the work of several codes is necessary and has been developed using the IMAS framework (Integrated Modelling & Analysis Suite). In addition, several techniques for reducing the dimensionality of the physics results have been implemented, such as: using statistical methods to improve analytical formulas and splitting of the workload in relevant/non-relevant data.

P 11.36 Wed 14:00 HSZ EG

Quasi-Neutral Multi-Fluid Models: A Variational Principle and Numerical Methods — •Sayyed Amin Raiessi Toussi, Omar Maj, and Tomasz Tyranowski — Max Planck Institute for Plasma Physics, D-85748 Garching, Germany

Quasi-neutral multi-fluid models are commonly used to describe particle and energy transport in the edge and scrape-off layer (SOL) of magnetically confined fusion plasmas [R. Schneider, Contrib. Plasma Phys., 46, 2006]. In this work we present a generalization of the variational principle for incompressible Euler equations [V. Arnold, Ann. Inst. Fourier 16, 319-361 (1966)] to quasi-neutral multi-fluid models, including only ideal processes. Also some preliminary considerations on appropriate numerical methods are offered.

P 11.37 Wed 14:00 HSZ EG

Towards Laboratory Astrophysics in Wakefield Accelerators — •Erwin Walter[1], John P. Farmer[2], Martin S. Weidl[1], Patric Muggli[2], and Frank Jenko[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Max Planck Institute for Physics, 80805 Munich, Germany

From supernovae in distant galaxies to wakefield accelerators in laboratories, the interaction of relativistic particles with plasma is relevant to many physical scales. The electromagnetically dominant current filamentation instability (CFI), which transversely breaks the beam into narrow filaments, may generate a sufficiently strong magnetic field to form collisionless shocks. By changing the operating parameters of beam-driven wakefield accelerators, it may be possible to access this regime relevant to astrophysics.

Due to the large difference in scales, numerical studies with quasistatic particle-in-cell (PIC) methods greatly reduce computational overhead compared to fully electromagnetic PIC. A quasineutral fireball beam consisting of positrons and electrons is simulated to determine to what extent the physics of CFI can be modelled by quasistatic codes and how different numerical methods affect the instability.

This work potentially paves the way to provide insight into analogous astrophysical scenarios in a laboratory setup.

P 11.38 Wed 14:00 HSZ EG

Integrated modelling of impurity transport in ASDEX Upgrade — •Daniel Fajardo[1], Clemente Angioni[1], Giovanni Tardini[1], Emiliano Fable[1], Pierre Manas[2], Rachael McDermott[1], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]CEA/IRFM, Saint-Paul-les-Durance, France

A database of experimentally measured boron (B) density profiles at ASDEX Upgrade (AUG) [R.M. McDermott *et al* 2022 *Nucl. Fusion* **62** 026006] is studied via 1.5D integrated modelling with ASTRA. An additional tungsten (W) impurity is evolved and the profile predictions are compared to experiments, which feature variations of the NBI–ECRH heating power mixture. The turbulent transport is calculated with the quasilinear codes TGLF and QuaLiKiz, allowing us to validate the impurity transport predictions of these models. The neoclassical component of B is calculated with NCLASS, whereas the FACIT model is used for W due to the stronger effects of rotation-induced poloidal asymmetries on heavy impurities. The correlation between the predicted logarithmic impurity density gradients and the main plasma gradients is discussed, also in comparison with gyrokinetic results. Moreover, in an additional set of simulations STRAHL is used for the self-consistent calculation of radiated power profiles, which are compared to experimental bolometry estimations.

P 11.39 Wed 14:00 HSZ EG

ECRH in early plasma formation — •Carl Albert Vilhelm Johansson and Pavel Aleynikov — IPP Greifswald, Wendelsteinstraße 1, Germany

The usage of electron cyclotron resonant heating (ECRH) is important in current operation of, amongst other devices, Wendelstein 7-X (W7-X) stellarator, and for future fusion devises. ECRH in the quasi–linear limit is theoretically well understood. However, because the ECRH system is used for plasma breakdown, there exists an interest in understanding the non–linear limit.

In this work, we consider the pre–ionization state. We show the energy gain of a single-electron interacting with the gyrotron beam once. For this interaction, we consider different magnetic field configurations. The interaction between electron and gyrotron beam yield a stronger coupling when located at the slope of the background magnetic field. The slope of the magnetic field dominates the effect for third harmonic interaction, whereas the second harmonic is less affected by the slope.

P 11.40 Wed 14:00 HSZ EG

Modeling of runaway electrons in disruption mitigation scenarios with DREAM — •Peter Halldestam[1], Gergely Papp[1], Hannes Bergström[1], Mathias Hoppe[2], Oskar Vallhagen[3], István Pusztai[3], and Tünde Fülöp[3] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Swiss Plasma Center, Lausanne, Switzerland — [3]Department of Physics, Chalmers University of Technology, Göteborg, Sweden

One of the main issues threatening the success of future reactor-scale tokamaks is disruptions. It is the sudden loss of confinement where the plasma rapidly dissipates its energy onto the surrounding structures, exposing the device to excessive mechanical stress and heat loads. In addition, an electric field is induced that can accelerate a significant fraction of the electrons to relativistic energies, giving rise to runaway electrons (REs). Unmitigated disruptions could potentially cause severe damage to the device and, thus, modeling such events is crucial for being able to assess the effectiveness of various mitigation techniques.

Using the numerical RE modeling framework DREAM [Hoppe CPC 2021], we study the effects massive material injection (MMI) of deuterium and neon has on disrupting plasma representative of ITER, particularly the RE generation and the dissipation of its energy content. We self-consistently evolve the electric field, ion charge state densities, thermal electron temperature and density as well as the RE density in a flux surface-averaged fluid description of the plasma. This model is used together with a Bayesian optimisation tool to find suitable MMI parameters that minimise potential damage to the device.

P 11.41 Wed 14:00 HSZ EG

Electromagnetic flutter in the full-f edge turbulence fluid code GRILLIX — •kaiyu zhang, wladimir zholobenko, andreas stegmeir, christoph pitzal, konrad eder, and frank jenko — Max Planck Institut für Plasmaphysik, Boltzmannstr.2, 85748 Garching, Germany

Electromagnetic flutter has been implemented and verified in GRILLIX, a full-f turbulence code for the edge and scrape-off layer in tokamaks. Simulations for L-mode ASDEX Upgrade are performed with electromagnetic flutter. We particularly investigate how flutter transport contributes to the density advection and heat conduction perpendicular to the magnetic flux surfaces.

An issue arising during the computation of flutter is that a large-scale magnetic shift will be double-counted in the fixed background magnetic equilibrium and in the full-f turbulence. Commonly, the toroidal average of magnetic potential was stripped to remove this shift. However, this method is found to cause a spurious reduction of the perpendicular flutter turbulent transport in GRILLIX. Two refined methods are explored: (1) removing the time averaged magnetic field; (2) tracing the evolution of Pfirsch-Schluter currents analytically and removing the corresponding induced magnetic field. The new methods seem superior in preserving the amplitude of the perpendicular flutter turbulence transport.

P 11.42 Wed 14:00 HSZ EG

Engineering tool for the robust optimization of a full-W divertor in W7-X — •Antara Menzel-Barbara[1,2], Joris Fellinger[1], Rudolf Neu[2,3], Dirk Naujoks[1], and Thomas Pedersen[1] — [1]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [2]Technische Universität München, 85748 Garching, Germany — [3]Max Planck Institute for Plasma Physics, 85748 Garching, Germany

High levels of fuel retention due to co-deposition make C-based materials such as CFC, currently used on the W7-X divertor, incompatible for a fusion reactor. As part of an ongoing investigation into a W-based divertor for W7-X, an engineering tool for the robust optimization of leading edges is being developed. Leading edges, resulting from assembly tolerances and deformation during operation, lead to very high incidence angles and to strongly increased heat fluxes. Compared to a C-based divertor, leading edges in a W design are more problematic because of W melting. Since manufacturing and assembly tolerances are major cost drivers, relaxing them is another priority for a new divertor. Because particles in W7-X can come from opposite directions on the target surface in different magnetic configurations, the usual strategy of entirely shadowing divertor plates to avoid leading edges is not possible. Instead, a more refined approach that optimizes the divertor surface while considering all major magnetic configurations simultaneously is necessary. A variety of tools, including the code EMC3-Lite and Ansys, is used to rapidly evaluate a modified surface, and identify the problematic areas. Strategies to effectively explore the design space of geometric modifications are currently being investigated.

P 11.43 Wed 14:00 HSZ EG

Validation of theoretical upper bounds on local gyrokinetic instabilities — •Linda Podavini, Per Helander, Gabriel Plunk, and Alessandro Zocco — Max-Planck-Institut für Plamsaphysik, Wndelsteinstraße 1, 17491 Greifswald

Turbulence in magnetic confinement fusion devices is driven by the presence of gyrokinetic microinstabilities. In the last decades these instabilities have been extensively studied considering various assumptions about plasma parameters and magnetic geometry, thus hampering a desirable unified theory.

Only recently, it was shown by Helander and Plunk [1] that it is possible to obtain universal upper bounds on the growth rates of local gyrokinetic instabilities via thermodynamic considerations. These bounds are valid for all possible microinstabilities and they are independent of the magnetic field configuration and some plasma parameters, such as the number of particle species, beta and collisions.

In this work, we compare the theoretical upper bounds on growth rates with numerical and analytical results in different geometries, including stellarator, tokamak and z-pinch. For the numerical results, linear, flux-tube simulations are obtained using the gyrokinetic code stella.

[1] P. Helander and G. G. Plunk, Physical Review Letters, 127, 155001, (2021)

P 11.44 Wed 14:00 HSZ EG

Experimental impurity transport analysis for the tokamak plasma edge — •Tabea Gleiter[1,2], Ralph Dux[1], Francesco Sciortino[1], and the ASDEX Upgrade Team[3] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Physik-Department E28, Technische Universität München, Garching, Germany — [3]Authors of U. Stroth et al. 2022 Nucl. Fusion 62 042006

Impurity transport in the pedestal and SOL region impacts energy confinement and radiative power exhaust in tokamaks. However, thorough understanding is lacking for many confinement modes. This includes promising regimes for future reactor scenarios without type-I ELMs, such as the quasi-continuous exhaust (QCE) mode.

A series of impurity seeded (Ne, Ar or N) discharges in various confinement modes was conducted at ASDEX Upgrade. Their experimental setup was tailored for high resolution charge exchange recombination spectroscopy (CXRS) measurements at the plasma edge. From the observed line radiation, density profiles of multiple impurity charge states are derived, making use of a neutral beam model, the beam attenuation code COLRAD and ADAS atomic rates. Fitting the charge state distribution with a diffusive-convective transport model such as STRAHL or Aurora, insight can be gained about the impurity transport. Both a Levenberg-Marquardt fit as well as a Bayesian nested sampling algorithm are used for this inverse inference.

Current work focuses on the QCE plasmas in our dataset, comparing them to H-mode with type-I ELMs. In particular, discharges with a stepwise transition between both regimes are evaluated.

P 11.45 Wed 14:00 HSZ EG

ASDEX Upgrade shattered pellet injection experiments

— •Paul Heinrich[1], Gergely Papp[1], Matthias Bernert[1], Pascal de Marné[1], Mathias Dibon[1], Stefan Jachmich[2], Michael Lehnen[2], Tobias Peherstorfer[3], Umar Sheikh[4], Jakub Svoboda[5], The ASDEX Team[6], and The MST1 Team[7] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]ITER, St. Paul-lez-Durance, France — [3]Institute for Applied Physics, Wien, Austria — [4]EPFL, Lausanne, Switzerland — [5]IPP CAS, Prague, Czech Republic — [6]See author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006 — [7]See author list of B. Labit et al. 2019 Nucl. Fusion 59 086020

In December 2021, the shattered pellet injection (SPI) system was successfully installed on the tokamak ASDEX Upgrade (AUG). Hereby, large amounts of material are injected into the plasma, radiating strongly and thereby spreading the previously confined energy over a larger area in comparison to unmitigated disruptions. The AUG SPI system allows a large variation in pellet parameters – such as pellet size, velocity or composition – and different shatter geometries. The ultimate goal is to assist the design of the ITER disruption mitigation system (DMS). In the 2022 campaign at ASDEX Upgrade around 240 discharges were performed for the SPI experiments. Different shatter heads were installed at the end of each of the three independent guide tubes. The focus of the analysis presented here is to find the optimal pellet parameters and shatter geometries for maximizing the radiated energy, while reducing localized heat loads.

P 11.46 Wed 14:00 HSZ EG

Investigation of Tearing Modes in ASDEX Upgrade — •Magdalena Bauer, Louis Giannone, Anja Gude, Felix Klossek, Marc Maraschek, Bernhard Sieglin, Wolfgang Suttrop, Hartmut Zohm, and The ASDEX Upgrade Team — Max Planck Institute for Plasma Physics, Garching

Tearing modes with toroidal mode number n=1 are precursors of and significantly involved in disruptions, especially when they are locked to the vessel. While rotating modes can be observed by many Mirnov coils measuring the time derivative of the poloidal magnetic perturbation field, locked modes require a radial field measurement. In addition to the saddle coils on the high field side, toroidally distributed radial field coils at two different poloidal positions on the low field side can be used to gain information on slowly rotating and locked modes. A 3D finite element model, simulating the field generated by a single helical perturbation current in all coils, has been improved by considering the detailed coil geometry and a better description of conducting in-vessel parts in which mirror currents affecting the local perturbation field are induced. Coupling of n=1 modes with different poloidal mode numbers is believed to play a large role in the disruption process. The projection of the measured complex amplitudes in all coils on the modelled perturbation amplitudes with single helicities allows to determine the contribution of different poloidal mode numbers for rotating modes. For locked modes, only the three poloidal positions of the radial field coils are available. The opportunities and limitations of the poloidal mode structure analysis are investigated.

P 11.47 Wed 14:00 HSZ EG

Power balance analysis and predictive modelling using the codes neotransp and NTSS — •Markus Wappl, Marc Beurskens, Sergey Bozhenkov, Hakan Smith, and Yuri Turkin — Max-Planck-Institute for Plasma Physics, Greifswald, Germany

One effect seriously limiting the plasma performance of the stellarator Wendelstein 7-X is ion temperature clamping, which restricts ion temperatures to about 1.5 keV in a wide range of scenarios. Empirical scaling laws such as ISS04 predict the performance of stellarators. However, no first-principle models offering a physical understanding or a clear explanation for the clamping are available. It has been shown that turbulent flux losses limit the achievable performance of a stellarator. ITG modes are thought to be the dominating turbulent process for ion heat losses and might be the cause for the ion temperature clamping observed at W7-X.

Power balance analysis allows a physics-motivated understanding of plasma performance including ion temperature clamping. Detailed modelling of neoclassical and turbulent heat fluxes is critical for this approach. A novel webtool for the power balance analysis of Wendelstein 7-X plasma discharges is presented. It employs the codes neotransp and NTSS for neoclassical calculation as well as Monte Carlo sampling for reliable error propagation. Predictive modelling of ion temperature profiles is performed in the code NTSS using a dummy density profile and ECR heating deposition profile. Ion temperature clamping is reproduced with simplified model assumptions which indicates that ITG modes might not be the primary reason for clamping.

P 11.48 Wed 14:00 HSZ EG

Non-Axisymmetric Generalization of the Gyrokinetic Turbulence Code GENE-X — •Marion Smedberg[1], Andreas Stegmeir[1], Philipp Ulbl[1], and Frank Jenko[1,2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]University of Texas at Austin, Austin, TX 78712, USA

For optimized stellarators, edge plasma turbulence both sets the boundary condition for core performance and determines the heat fluxes onto the plasma-facing components. Thus realistic simulations of plasma turbulence in the edge and scrape-off layer (SOL) are a key step towards a stellarator power plant. The gyrokinetic turbulence code GENE-X [1] is well-equipped to simulate edge and SOL turbulence due to the use of a flux-coordinate independent (FCI) coordinate system [2]. However, until now the code has only simulated in axisymmetric geometries, such as tokamaks. Here progress towards a non-axisymmetric upgrade of the GENE-X code is presented. The focus will be on the implementation of stellarator magnetic fields, the development of numerical methods for representing the shape of three-dimensional flux surfaces, and simulating simple diffusion and advection models in a fully three-dimensional geometry.

[1] D. Michels, et. al., Comput. Phys. Commun. 264 (2021)
[2] F. Hariri, et. al., Comput. Phys. Commun. 184 (2013)

P 12: Poster II

Time: Wednesday 17:30–19:00 Location: HSZ EG

P 12.1 Wed 17:30 HSZ EG

Laser-induced charge ablation in surface DBD — •Robin Labenski, David Steuer, Henrik van Impel, Volker Schulz-von der Gathen, Marc Böke, and Judith Golda — Ruhr-University Bochum, D-44801 Bochum, Germany

In the emerging field of plasma catalysis, atmospheric pressure plasmas turned out to be promising candidates. Especially micro cavity plasma arrays allow for fundamental investigation of the interaction between the plasma and catalytic surfaces. As this reactor is a surface DBD, the used dielectric (e.g., catalyst) plays a crucial role in its discharge behavior since it can be charged during ignition. To visualize these charges and investigate their impact on catalysis, the array (15kHz, 400-800V) is irradiated using a nanosecond Nd:YAG-laser (20Hz, 532nm/1064nm) to ablate the charges during/after ignition. The impact of the laser is detected using global (and eventually local) electrical measurements as well as optical emission spectroscopy. While global electrical measurements involve current and charge measurements (i.e., Lissajous- figures), local measurements are planned to be performed using a Picoamperemeter directly picking up the ablated charges. Measurements show a lower/higher ignition voltage in the consecutive (half-) cycle and a decrease of charge in the Lissajous-figure immediately after laser irradiation.

This work is supported by the DFG via SFB 1316 (project A6).

P 12.2 Wed 17:30 HSZ EG

Characterization of the atmospheric plasma source HelixJetS: generation of silicon nanoparticles — •Leonie Mohn, Maren Dworschak, and Jan Benedikt — Institut of Experimental and Applied Physics, Kiel University, Germany

Silicon nanoparticles are of interest in developing new technologies such as next generation solar panels. Low-pressure discharges can produce silicon nanoparticles reliably but the cost effective and modular nature of atmospheric discharges makes them compelling to study. The atmospheric plasma source HelixJetS is analyzed to determine its ability to produce such silicon nanoparticles. The HelixJetS, a scaled down version of the HelixJet, has two electrodes that form a double helix, one of which is driven by RF power. The jet is operated with gas mixtures consisting of He, Ar, H_2 and SiH_4. To minimize the material deposition, there are two spatially separated gas inlets for He/H_2 on the outer diameter and for He/Ar/SiH_4 on the jet axis. The flow rates are simulated with Comsol to find those that achieve laminar flow. The Jet is characterized by varying the gas composition and the power deposited into the plasma and analyzing the resulting plasma by means of optical emission spectroscopy. The resulting nanoparticles are analyzed in regards to size, composition and photoluminescence. A Scanning mobility particle sizer is used to obtain the size distributions. FTIR and *in situ*-FTIR are used to determine the chemical composition of the particles. If the silicon nanoparticles crystallize, they exhibit photoluminescence, which is also qualitatively analyzed.

P 12.3 Wed 17:30 HSZ EG

Deposition of thin films from organosilicon precursors by means of photochemistry with VUV-radiation from an atmospheric pressure plasma jet — •Christina Reiser, Tristan Winzer, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

Deposition of thin films using atmospheric pressure plasma (APP) is still limited due to the high collision rates and in the case of many precursors (C_2H_2, SiH_4) also due to fast formation of particles in the gas phase, resulting from the fast polymerization of negative molecular ions. Activation of these precursors with VUV-photons should avoid the formation of the negative ions and, therefore, also particles.

In this work, a high purity noble gas plasma is used for producing intense VUV-radiation from noble gas excimer species. The gas flow through the plasma is guided in such a way, that the plasma and the effluent have no contact with the precursor gas flow, while the emitted radiation produces ions and radicals in the precursor gas flow directly in front of the treated surface. For optimizing deposition rates and film quality, parameter variations are carried out in which the photochemistry of organosilicon precursors is analyzed by ion mass spectrometry. Deposited films are characterized using Fourier transform infrared spectroscopy (FTIR).

P 12.4 Wed 17:30 HSZ EG

Numerical modeling of CO_2 microwave discharges: first verification steps of electromagnetics — •Pirmin Almanstötter[1], Dominikus Zielke[1], and Ursel Fantz[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching — [2]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg

To optimize the efficiency of CO_2 conversion processes, microwave plasmas (2.45 GHz) are very promising. Examples are the plasma torch (pressure 20-1000 mbar, power: 0.3-3 kW, flow: 3-100 slm), which can even operate at atmospheric pressure and the surfaguide (pressure 0.3-100 mbar, power: 0.3-1.2 kW, flow: 0.3-10 slm). To accompany experimental optimization efforts and for a systematic investigation, a numerical model is needed that describes the electromagnetics and plasma self-consistently. Before the model can be applied with confidence verification and validation is necessary. This is done for the electromagnetics and the discharge part separately, which consequently will be coupled. The contribution covers the verification of the electromagnetics part. As a first example, solutions of waveguides in cylindrical and rectangular geometries with either dielectric or conducting walls are investigated. It is shown that the solutions obtained by the numerical model match the analytical results.

P 12.5 Wed 17:30 HSZ EG

Durability of metal-organic-frameworks (MOFs) in non-equilibrium atmospheric pressure plasmas — •Alexander Quack[1], Kerstin Sgonina[1], Hauke Rohr[2], Norbert Stock[2], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University — [2]Institute of Inorganic Chemistry, Kiel University

Metal-organic-frameworks (MOFs) have a large surface area and different metallic structures, which gives them good catalytic properties. Nevertheless, MOFs mostly can not withstand high temperatures, which are needed for their activation in classical catalytic reactions. Non-equilibrium atmospheric pressure plasmas provide reactive and internally excited particles and allow for plasma assisted catalysis at lower temperatures. For these processes MOFs can be used as a catalyst, if they withstand the plasma conditions.

We have developed a dielectric barrier discharge (DBD) reactor (21 kHz, up to 17 kV_{pp}) to determine the stability and suitability of different MOFs for plasma assisted catalysis. Reactive plasmas using gas mixtures based on N_2, H_2 and CO_2 gases and post- and in-plasma treatment under externally controlled temperature up to 200 °C have been applied to several MOFs including Zif-8, Zif-67 and MAF-6. Structural MOF analysis (XRD, FTIR) allows us to judge the stability of the MOF in the applied plasma treatments.

P 12.6 Wed 17:30 HSZ EG

Space resolved temperature measurements in an atmospheric pressure argon methane microwave plasma — •Simon Kreuznacht, Marc Böke, and Achim von Keudell — Experimental Physics II, Ruhr University Bochum, Germany

Hydrogen is often envisioned as the energy carrier and green fuel of the future. However, new energy efficient and greenhouse gas free production methods are needed to utilize hydrogen as energy carrier on larger scales. A promising production method is the pyrolysis of methane in a microwave plasma. Here, we present a microwave plasma torch operated in an argon methane mixture (60 slm total flow rate, up to 35 % methane admixture) at atmospheric pressure. Microwaves with a frequency of 2.45 GHz and up to 6 kW of forward power are used to sustain the plasma. The methane is converted to hydrogen, solid carbon, acetylene and ethylene inside the plasma. The emission spectrum from the plasma is dominated by black body radiation from hot carbon particles and the dicarbon Swan bands. Broadband spectra of the black body radiation and high-resolution spectra of the dicarbon Swan bands are used to estimate the space resolved gas temperature from the black body temperature and the dicarbon rotational temperature. In the center the plasma reaches temperatures of up to 4600 K with large gradients of about 500 K in radial direction and 50 K in axial direction.

P 12.7 Wed 17:30 HSZ EG

Exploration of New Use Cases of Cold Atmospheric Plasma in Medicine, Surface Decontamination and Astronautics — •Alisa Schmidt and Markus H. Thoma — Justus-Liebig-Universität, Gießen, Deutschland

Wound healing, the corona pandemic and manned spaceflight - how can a connection be drawn between all these different areas via physics?

All of these three areas have their own problems: the healing of chronic wounds, for example, can be inhibited by wound healing disorders and infections, in the corona pandemic there were supply shortages of protective equipment and respiratory masks - which led to the reusability of protective equipment becoming a subject of discussion - and finally manned space flight, according to NASA, aims to bring humans to the moon again in 2025 and even fly them to Mars by 2040 - however, there is the problem of keeping the closed life support systems on space vehicles and future lunar or even planetary stations clean.

We have approached these problems with a common solution approach - treatment with physical cold atmospheric plasma. Experimental design and results will be presented in this contribution.

P 12.8 Wed 17:30 HSZ EG

Research data management in plasma science — •Markus M. Becker[1], Kerstin Sgonina[2], and Marina Prenzel[3] — [1]Leibniz Institute for Plasma Science and Technology (INP) — [2]Institute of Experimental and Aplied Physics, Kiel University (CAU) — [3]Research Department Plasmas with Complex Interactions, Ruhr-University Bochum (RUB)

Implementation of data management standards and adoption of the FAIR data principles are more and more requested by funding agencies in recent years. This results in several new challenges for the scientific community. Research in low-temperature plasma physics is characterized by table-top experiments and a large variety of plasma sources and measurement devices, which are often first developed in the course of the research. Therefore, there are usually no established research data management (RDM) standards. Moreover, the documentation of research results is extremely heterogeneous. This not only complicates the implementation of structured RDM, but also reduces the comparability and reusability of data. To overcome this challenges, research groups at INP, RUB and CAU have joined forces to develop common RDM standards and tools. In monthly workshops, local requirements are discussed and gradually transformed into proposals for community standards, see https://www.plasma-mds.org. The poster reports on the status of the activities and presents how everyone can contribute and use the already developed tools for their own work.

The work was supported by grants 16QK03A (BMBF) and 327886311 (DFG).

P 12.9 Wed 17:30 HSZ EG

Dust flows around an obstacle under microgravity — •Stefan Schütt, Christina Knapek, Daniel Maier, Daniel Mohr, and André Melzer — University of Greifswald, Greifswald, Germany

Dust flows around an obstacle in three-dimensionally extended dusty plasmas have been investigated on parabolic flights. A fixed tungsten wire has been installed in the plasma chamber perpendicular to the observation plane of a video microscopy setup and serves as an obstacle. Three different situations were created. First, the dust flow around the wire was investigated during the pull-out phase at the end of each parabola, when gravity sets in and the dust cloud moves downward past the wire. Second, a dust motion with respect to the fixed wire was generated by modulation of the electrode bias. And third, the wire was electrically biased and the reaction of the dust to bias voltage changes was studied. In this contribution, a first evaluation of all three situations will be presented.

This work was supported by DLR under grant no. 50WM1962.

P 12.10 Wed 17:30 HSZ EG

Development of a holographic optical trap design — •Christian Theden, Natascha Blosczyk, and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

In the research focus of dusty plasmas, a controlled manipulation of dust particle position is considered a major challenge. Especially in the field of binary mixtures, there is great interest in being able to control the positions of the particles to create binary crystals or liquids with periodic particle arrangement. First experiments show that optical tweezers can manipulate single particles in a dusty plasma [1, 2]. The problem here is that only one particle can be moved at a time. This is different for holographic-optical tweezers. Here the basic idea is to generate digitally a hologram and displayed on a spatial light modulator (SLM). Laser illumination of the SLM can create arbitrary light field and thus realize multiple tweezers at once. In this way, several tweezers can be projected at the same time. In addition, the hologram can be varied dynamically. The aim of this work and the first step towards such a powerful device is a single tweezer setup with a SLM. To determine the forces in the plasma that a holographic-optical tweezer exerts on a particle, the radiation pressure and the gradient forces are examined. This allows to develop a trap design and implement the holographic-optical tweezers in a dusty plasma experiment.

[1] V. Schneider, H. Kersten, 2018 Rev. Sci. Instrum. 89

[2] J. Schablinski, F. Wieben and D. Block, 2015 Phys. Plasmas 22

P 12.11 Wed 17:30 HSZ EG

Influence of the ion focus on diagnostics and simulations in 2D dusty plasmas — •Natascha Blosczyk, Yang Liu, and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Evaluating dust particle properties is an important part in the field of dusty plasmas as properties such as charge can strongly influence the behaviour of single particles and, because of their coupling, of the entire system. A current interest is the description and evaluation of wave propagation in a 2D cluster, especially in clusters of binary mixtures. For this purpose, phonon dispersion relations and configurational temperature can be used as diagnostics to evaluate wave frequencies and charge respectively. These methods rely on a full and correct description of the interaction forces. Until now it has been mostly assumed to be a purely repulsive Yukawa interaction, disregarding the influence of a positive ion focus charge. Based on MD simulations, this poster will discuss the importance of the ion focus in simulations and diagnostics and wether it can really be disregarded.

P 12.12 Wed 17:30 HSZ EG

Creating nanodust clouds with different electrode geometries — •Franko Greiner, Andreas Petersen, and Alexander Schmitz — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität Kiel

In a radio-frequency driven parallel plate reactor, nanodusty plasmas are created by means of reactive argon acetylene or argon silane plasmas. Switching off the reactive gas admixture creates a pure dusty plasma, consisting only of electrons, ions, and dust with a predeterminable radius. Using Mie polarimetry, Video aided extinction measurements (VAEM), and dust density wave diagnostic (DDW-D), the nanodusty plasma can be fully diagnosed [1]. For our standard setup of 60 mm circular electrodes with a 32 mm electrode gap we found dust densities of up to $6 \cdot 10^{13}\mathrm{m}^{-3}$, creating a strongly electron-depleted plasma. We investigate the impact of different electrode geometries on the dust and plasma parameters of the created nanodusty plasmas. [1] A. Petersen et al, Communications Physics (2022), https://doi.org/10.1038/s42005-022-01060-5 (open access)

P 12.13 Wed 17:30 HSZ EG

Anaylsis of microparticle trajectories during free fall — Andreas S. Schmitz[1], •Luisa Hanstein[1], Michael Kretschmer[1], Christoph Lotz[2], and Markus H. Thoma[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Germany — [2]Instititut für Transport- und Automatisierungstechnik, Gottfried Wilhelm Leibniz Universität Hannover, Germany

In a radiofrequency plasma chamber microparticles were placed in a low-pressure plasma, where they became charged and levitated against gravity by an electric field. The argon-filled chamber was installed in the University of Hannover's drop tower, the Einstein Elevator. As the setup fell, the microparticles spread into the bulk plasma due to the electric field and were imaged with a CCD camera. The trajectories of the microparticles, which were determined by image analysis, were used to determine the electric forces acting on the microparticles. Considering fluid dynamic simulations, we were able to determine the electric field acting on the microparticles.

P 12.14 Wed 17:30 HSZ EG

Investigation of Screw-Like Wave Phenomena in DC-Discharged Plasma with PK-4 — •Lukas Wimmer and Markus H. Thoma — Justus-Liebig-University Gießen, Germany

If micrometer to nanometer-sized microparticles are introduced into a plasma, it is referred to as dusty or complex plasma. The Plasmakristall-4 facility (PK-4) is the fourth and latest version of a successful series of experiments for the fundamental research of complex plasmas. If PK-4 is operated at low pressure, $p < 25$ Pa, as well as at low energy, and the dust particle size falls below a certain limit, screwed-like wave phenomena appear in ground-based experiments. Local system properties show that the wave structure is caused by the two-stream instability of ions and dust particles, assigned to the regime of dust-acoustic waves, and the superposition of longitudinal and transversal waves causes the curvature of the waves. Deeper analysis gives us information about the ion drag force in the low-pressure regime and the local electric field in the boundary region.

P 12.15 Wed 17:30 HSZ EG

Particle Chains in Dusty Plasmas under microgravity — •Daniel Maier, Michael Himpel, Stefan Schütt, and André Melzer — Institut für Physik der Universität Greifswald, Greifswald, Deutschland

Chain-like structures of charged dust particles have been observed in dusty plasmas under microgravity conditions. These structures appear near the mid-plane and around the particle free zone (void) of the plasma. The previous 2-dimensional investigations of the chains have difficulties in separating chains from each other, proofing their authenticity or observing them at full length. The described experimental set-up, containing four high speed cameras allows a stereoscopic, 3-dimensional observation and investigation of these structures and the interaction of the included particles with high temporal resolution (up to 200 fps). Here a simple model to identify chains and first results of the stereoscopic investigations will be shown.

P 12.16 Wed 17:30 HSZ EG

Ion emission of various materials from laser plasmas using a pre-pulse — •Qëndresa Ibraimi, Lars Torben Schwabe, Jan Riedlinger, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Plasmas generated by ultra-short, intense laser pulses have high density and temperature, are far from equilibrium, and their dynamics is dominated by several transient processes. Therefore, the ion dynamics in the early phase of these plasmas is difficult to predict. Here, we present experimental data of the ion emission driven by single-digit-fs laser pulses with intensities up to $10^{17}\,\mathrm{W/cm^2}$ focused on various solid targets. The ions reach kinetic energies of several tens of keV and were characterized in terms of species, direction, and energies by a Thomson parabola spectrometer. The differences of the spectra for distinct materials and pre-plasma conditions may allow conclusion on processes during and after laser-surface interaction. These findings are presented and discussed.

P 12.17 Wed 17:30 HSZ EG

Influence of a pre-pulse on ultra-short laser-induced plasma emission — •Timo Wenier, Steffen Mittelmann, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

In the versatile field of Laser-Induced Breakdown Spectroscopy (LIBS), ultra-short laser pulses in the femtosecond range are promising tools for detecting impurities and material composition with very high lateral and depth resolution. It has been shown that double-pulse or pre-pulse systems may significantly enhance the emission of the detected spectral lines of atoms and ion species present in the laser-induced plasma. This effect is systematically studied in this work: We investigate the influence of a pre-pulse on the emitted spectral lines in a vacuum LIBS setup with laser pulses of durations in the sub-10-fs range. The main pulse delay is varied up to 800ps and the influence on plasma parameters and ablation yield is examined on polished copper and silicon samples. First results give evidence that there are regimes where higher ionization degrees and temperatures can be achieved. Significantly decreased ablation yield is observed at the same time, which is attributed to plasma shielding effects. These results path the way for further optimization of ultra-short pulse LIBS with even higher spatial resolution.

P 12.18 Wed 17:30 HSZ EG

Experimental determination of the phase shift upon reflection — •Johanna Köchling, Nico Potzkai, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Interferometry can determine the expansion of laser plasmas in their early stage with a temporal resolution down to 10 fs. However, with measurements in the reflection geometry, the phase shift of the light reflected at the surrounding undisturbed material must be known precisely as a reference. In this contribution, we present experimental results for this reflective phase shift for a series of thin metal layers of different thickness. The results are compared with with theory and extrapolated to other regimes.

P 12.19 Wed 17:30 HSZ EG

Interplay of turbulent density and momentum transport in TJ-K plasmas — •Ralph Sarkis and Mirko Ramisch — IGVP, University of Stuttgart, Germany

Turbulent fluctuations of the potential and density in the magnetically confined plasma at the TJ-K stellarator are coupled as to give rise to radial turbulent cross-field transport of particles and poloidal momentum. Both transport phenomena have mutually exclusive prerequisites, being a strong density-potential cross-coupling for the Reynolds stress and decoupling for the particle transport. A poloidal Langmuir probe array is used to understand the turbulent transport phenomena in dependence of the geometry. This also allows to examine temporal alternations in the density-potential cross-coupling as a possible explanation for their coexistence. Conditional sampling and cross-correlation of transport with respect to the occurrence of zonal-potential events is used to establish a temporal and spatial relation, unravelling the dependence and coupling factors at play in both turbulent processes. Spectral analysis is also applied to address the interplay and to distinguish amplitude from phase modulations.

P 12.20 Wed 17:30 HSZ EG

The sticking machine: measuring electron sticking coefficients using dusty plasmas — •Armin Mengel and Franko Greiner — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel

A central property of (micro-)particles in laboratory plasmas is the strong negative charge they accumulate. It is, among other things, dependent on the electron sticking coefficient of the particle material. In many descriptions of plasma-surface interaction, the electron sticking coefficient is, due to lack of better knowledge, assumed to be 1. However, recent quantum-mechanical calculations[1] hint at significantly smaller values for dielectric surfaces at low energies, while metallic surfaces are known to have a sticking coefficient very close to unity. Subsequent excitation and long-distance-microscopy measurements with SiO_2 and metal-coated particles under the same plasma conditions allow for the determination of the ratio of the particles' charge and sticking coefficient. We present a study comparing metal-coated particles with SiO_2 particles in order to obtain the sticking coefficient of the latter. This enables us to determine the low-energy sticking coefficient of dielectric materials using dusty plasma.

[1] F.X.Bronold et al., Plasma Phys. Cont. Fusion **59** (2017) 014011, https://iopscience.iop.org/article/10.1088/0741-3335/59/1/014011

P 12.21 Wed 17:30 HSZ EG

Characterization of low-pressure plasmas in highly porous and lightweight aeromaterials — •Karin Hansen[1], Lena M. Saure[2], Rainer Adelung[2], and Franko Greiner[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Institute for Materials Science, Kiel University, Kiel, Germany

Plasma catalysis is a research field of growing interest due to the ongoing challenges in environmental protection. For the understanding of plasma catalysis, the interaction between the plasma and the catalyst surface plays an important role. Highly porous materials are used to provide a large surface area for a catalytic reaction processes. As the interplay of a plasma with porous material is not well studied, but crucial for further research, we investigate aeromaterials, micron-sized frameworks with nano-sized walls, in low-pressure plasmas. Highly porous ($> 99.9\,\%$) and lightweight ($< 2\,\mathrm{mg\,cm^{-3}}$) aeromaterials are developed in the group of R. Adelung at Kiel University and can be generated from different materials and with different porosity and conductivity.

In this work we explore the interaction of aeromaterials with low-pressure argon plasmas. To this end, a radio-frequency argon plasma is ignited in cylindrical cavities in aeromaterial cylinders. The impact of the aeromaterial wall interfaces on the plasma is studied with optical emission spectroscopy (OES) and electrostatic probes.

P 12.22 Wed 17:30 HSZ EG

Effect of magnetic islands on fast ion confinement in toroidal devices — •David Kulla[1], Samuel Lazerson[2], Athina Kappatou[1], Robert Wolf[2], and Hartmut Zohm[1] — [1]MPI für Plasmaphysik, Garching — [2]MPI für Plasmaphysik, Greifswald

Fast ion transport and confinement is an important area of fusion research: the fast ions have to heat the thermal plasma collisionally to reach self-sustaining conditions, and must not be lost e.g. to the vessel wall beforehand. Tokamaks are largely axisymmetric, but suffer from magnetic perturbations which can break this property and lead to increased fast ion transport. Stellarators are intrinsically three-dimensional in their magnetic configuration, but are generally less prone to transient perturbations in their field. In present experiments, one of the main methods of generating fast ions is neutral beam injection (NBI). Magnetic islands arise from helical perturbations of the background magnetic field, either internally from the plasma or externally from magnetic coils.

BEAMS3D is a Monte Carlo code that simulates NBI deposition and collisional slowing down in stellarator and also tokamak plasmas. We present results of verification against NUBEAM as well as validation against experimental data at the ASDEX Upgrade tokamak using fast-ion D-alpha light (FIDA). The results show good agreement between the codes and to experimental data both in on- and off-axis NBI heating phases, demonstrating the capability of BEAMS3D. Additionally, first results comparing simulations and experimental data of plasmas with internal islands are presented.

P 12.23 Wed 17:30 HSZ EG

Towards non-linear hybrid simulations of the interaction between energetic particles and the plasma in realistic tokamak geometry — •Felix Antlitz, Xin Wang, and Matthias Hoelzl — Max Planck Institute for Plasma Physics, Garching b. M., Germany

Future burning plasma experiments will feature a high supra-thermal particle pressure which strongly interact with magneto-hydrodynamic instabilities. To describe these dynamics accurately in simulations, realistic tokamak geometry, the self-consistent evolution of the plasma equilibrium, and a full-f treatment of the energetic particle population are needed. This contribution describes developments towards this goal based on the non-linear MHD code JOREK, in which a hybrid mode for energetic particles had recently been introduced based on a pressure coupling and tested linearly. The non-linear evolution of fishbone instabilities is foreseen as one of the first applications.

P 12.24 Wed 17:30 HSZ EG

Thermal equilibrium for non-neutral plasma in a magnetic dipole trap — •Patrick Steinbrunner[1], Matthew R. Stoneking[2], Thomas M. O'Neil[3], and Daniel H. E. Dubin[3] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]Lawrence University, Appleton, USA — [3]University of California San Diego, La Jolla, USA

The confinement of a non-neutral plasma in a thermal equilibrium state is known to be possible in the uniform magnetic field of a Penning-Malmberg trap. We generalize the theory of these states to include inhomogeneous magnetic dipole fields. We present computational results for local thermal equilibria along magnetic field lines as well as global thermal equilibria and there respective zero-temperature limits. The distribution function of a global thermal equilibrium state is obtained by maximizing the plasma entropy subject to fixed values for the total number of particles, total energy and total canonical angular momentum. If a non-neutral plasma arrives in this state, there is no conceptual limit on the confinement time. Such a configuration also confines a quasi neutral plasma for a finite amount of time, making it an attractive candidate for the creation of an electron-positron pair plasma as planned by the APEX collaboration.

P 12.25 Wed 17:30 HSZ EG

Influence of Radial Electric Field and Ideal Ballooning Stability on the Pedestal Width — •Lidija Radovanovic[1], Elisabeth Wolfrum[2], Mike Dunne[2], Marco Cavedon[3], Georg Harrer[1], Friedrich Aumayr[1], and ASDEX Upgrade Team[4] — [1]Institute of Applied Physics, TU Wien, 1040 Vienna, Austria — [2]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [3]Universit'a di Milano-Bicocca, 20126 Milano, Italy — [4]see author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

Understanding the physical processes which govern the pedestal is crucial for reliable prediction and control of the plasma conditions and for its stability. The first experimental method investigates if the ideal ballooning modes at the pedestal top could cause additional transport and limit the pedestal width. A variation in the plasma stability is achieved by modifying the shape of the plasma. Increasing the triangularity of the plasma widens the electron pressure pedestal at a fixed gradient, which correlates with the minimum ballooning stability. The second method assumes that the turbulence in the plasma edge is suppressed due to the presence of a critical shear flow originating from radial electric field gradients. The radial electric field is varied by changing the density in discharges which use different heating systems to achieve the same total power, but which apply a different amount of torque to the plasma. It is shown that the electron density changes with shaping and the ion temperature with torque of heating method. Therefore it seems as if there is no clear actuator for the pedestal width, but each component is influenced individually by different physical processes.

P 12.26 Wed 17:30 HSZ EG

Causal coupling between small-scale fluctuations and zonal flows at the stellarator TJ-K — •Nicolas Dumérat and Mirko Ramisch — IGVP, University of Stuttgart, Germany

Convergent cross mapping (CCM) is a causality inference technique used to identify causal links and directions of influence between variables. In this work, Langmuir probe measurements of plasma potential and density fluctuations across TJ-K's whole poloidal cross section are used as input for the CCM to map causal links between turbulent phenomena across distant flux surfaces.

Thus, zonal potential (ZP) structures are found to be causally related to density fluctuations in the core, which could reflect equilibrium density modulation via transport regulation by ZP through the shearing of drift-wave structures. Causal coupling between plasma potential and ZP fluctuations has been found to exhibit a strong bi-directional relation around the region of both maximum Reynolds stress and turbulent particle transport. Moreover, ZP is found to be caused by small-scale density and potential fluctuations with density dominating over potential. This is in line with vortex tilting and subsequent zonal flow drive in consequence of strong density-potential coupling drift-wave turbulence. The expected predator-and-prey relationship between background turbulent structures and zonal flows is unveiled with CCM and further analysis concerning its poloidal locality is under investigation.

P 12.27 Wed 17:30 HSZ EG

Divertor spectroscopy during Detachment in Wendelstein 7-X — •Frederik Henke, Maciej Krychowiak, Ralf König, Felix Reimold, Erik Flom, and Dorothea Gradic — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

Detachment is a mandatory regime for running long discharges with high power in W7-X in order to not reach the power load material limits of the walls. As a future stellarator reactor will run steady state, the detachment regime has to be investigated. In this work, the mainly used diagnostic system is divertor spectroscopy. Various important aspects during this regime can be assessed using different spectroscopic methods. One challenging aspect is the density build up in detachment as high pressures are needed to have good impurity and density control via pumping. To measure this in the SOL, the Stark broadening of Balmer lines is analysed. Another important aspect is the composition of the SOL plasma. Radiation of a large fraction of the input power is necessary to enter the detachment regime. For reaching these radiation levels, hydrogens radiation capabilities are insufficient. Therefore, the intrinsic impurity carbon or seeded impurities nitrogen, neon or argon are needed. As carbon is no reactor relevant wall material, it is crucial to understand the behaviour of the seeded impurities. Only very low concentrations of impurities can be tolarated in the core plasma of future reactor because of fuel dilution and radiation, while they are needed at the edge. This aspect is investigated via line ratio divertor spectroscopy combined with CXRS in the core.

P 12.28 Wed 17:30 HSZ EG

Measurement and Modeling of radiation losses in the stellarator TJ-K — •Izel Gediz and Alf Köhn-Seemann — IGVP, University of Stuttgart, Germany

In the stellarator TJ-K cold plasmas of up to 20 eV are routinely produced. An 8-channel gold-foil bolometer is used to observe the radiation emitted by the plasma. Following the principle of a "camera obscura" the 8 channels observe the plasma through a small slit, allowing for reconstruction of the spatial profile of the emitted radiation. In this manner line integrated power profiles can be recorded, giving information about the absolute numbers of radiated power as well as the relative spatial distribution of the radiation. This diagnostic was recently reestablished and newly calibrated to aid parameter studies, including plasma density and temperature measurements. Line radiation is the major contributor to the radiation losses of typical plasmas in TJ-K. Information about the absolute loss term due to radiation will give further insights in the efficiency of confined plasmas as well as increase the accuracy with which other loss-terms (e.g. diffusion terms) in energy- and particle-balance equations can be estimated. Furthermore the spatial radiation profiles can reveal interesting parameter regimes where e.g. fast electrons in the plasmas edge regions could be observed. The radiation profiles are also being calculated and compared with the measurements, enabling adjustments of the model used to estimate the radiative loss term so far.

P 12.29 Wed 17:30 HSZ EG

Machine Learning Applications in Control at ASDEX Upgrade — •Johannes Illerhaus[1,2], Wolfgang Treutterer[1], Alexander Bock[1], Rainer Fischer[1], Paul Heinrich[1], Frank Jenko[1,2], Ondrej Kudlacek[1], Gergely Papp[1], Tobias Peherstorfer[1,4], Bernhard Sieglin[1], Udo von Toussaint[1,5], Hartmut Zohm[1,3], and the ASDEX Upgrade Team[6] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Technische Universität München, Garching, Germany — [3]Ludwig Maximilian Universität, Munich, Germany — [4]Technische Universität Wien, Vienna, Austria — [5]Technische Universität Graz, Graz, Austria — [6]see the author list of U. Stroth et al. 2022 *Nucl. Fusion* 62 042006

Plasma control is essential for the operation of fusion devices. The individual control tasks depend on high-dimensional and possibly noisy input data and typically have a latency requirement of milliseconds to be real-time capable. Machine learning (ML) models are well suited for this application. While they are often computationally expensive to train, they generally have a cheap, low-latency inference process. Additionally, deep learning models have been shown to be capable of extracting complex hidden interactions in high-dimensional, noisy data. This contribution will illustrate two ML applications in plasma control: real time capable approximations of high-fidelity offline models for kinetic profiles, and deep-learning-based augmentations to the accuracy of the pellet fragment analysis used in the development of the shattered pellet injection disruption mitigation system tested on ASDEX Upgrade for use in ITER.

P 12.30 Wed 17:30 HSZ EG

Non-linear free boundary simulations of resonant magnetic perturbations in ASDEX Upgrade — •Verena Mitterauer[1], Matthias Hoelzl[1], Matthias Willensdorfer[1], and ASDEX Upgrade Team[2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstrasse 2, 85748 Garching - Germany — [2]See author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

Resonant Magnetic Perturbations (RMPs) are used routinely in tokamaks to control type-I Edge Localized Modes (ELMs). To improve the understanding of the effect of the helical magnetic field perturbations, numerical simulations of their penetration into the plasma are carried out using the free boundary non-linear MHD code JOREK-STARWALL. The use of free boundary conditions allows a self-consistent development of the plasma response within the complete computational domain.

Several aspects of RMP physics are investigated in simulations based on ASDEX Upgrade discharges with fully realistic plasma parameters and profiles. The comparison of the field line corrugation to experimental measurements shows that a valid representation of the plasma response is achieved. In subsequent simulations, the transition from ELM mitigation to suppression is shown, which allows the investigation of hypotheses concerning RMP-ELM suppression mechanisms, including the role of magnetic island positions relative to the pedestal, mode coupling and the impact of profile evolution on plasma stability. An extension of the fluid model to kinetic effects is on its way, which will allow the inclusion of the neoclassical toroidal viscosity.

P 12.31 Wed 17:30 HSZ EG

Enabling GENE for Exascale Computing via Modern Data Science — •Luciana Tanzarella[1], Tilman Dannert[2], Tobias Görler[1], and Frank Jenko[1] — [1]Max Planck Institute for Plasma Physics, Garching — [2]Max Planck Computing and Data Facility, Garching

The GENE (Gyrokinetic Electromagnetic Numerical Experiment) code represents the state-of-the-art in turbulence simulation in plasma physics, based on the Eulerian approach. Since these codes solve differential equations in 5 or 6 dimensions, over a very large parameter space, they require a very considerable computational power. Higher speed, lower communication and energy costs are all benefits of lower precision arithmetic, but the outputs must be accurately assessed. GENE allows for either single or double precision computations. The national DaREXA project's specific objective is to develop methods and architectures that will decrease the amount of data required for fusion research. The first steps in this direction, in particular, entail the creation and application of lower precision methods in selected operations performed by GENE. The precision must be scaled using existing libraries in addition to assessing how it impacts calculations as not every hardware supports arbitrary*precision. To ascertain how much the discretization order influences the outputs on grids, this must be done on each of GENE's several sections. The operation will be done on the stencil part first. In order to accurately evaluate the gain from implementing this reduced precision, an error model for the estimation of stencil and moments must be written.

P 12.32 Wed 17:30 HSZ EG

Enabling GENE for Exascale Computing via Modern Data Science — •Luciana Tanzarella[1], Tilman Dannert[2], Tobias Görler[1], and Frank Jenko[1] — [1]Max Planck Institute for Plasma Physics, Garching — [2]Max Planck Computing and Data Facility, Garching

Theoretical plasma turbulence studies are typically based on numerical solutions of integro-differential equations in 5 or 6 dimensions over a very large parameter space. So the required computational power is huge. Higher speed, lower communication and energy costs are all benefits of lower precision arithmetic, but the outputs must be accurately assessed. Particular focus is put on the world-leading gyrokinetic plasma turbulence code GENE, based on the Eulerian approach. GENE allows for either single or double precision computations.The national DaREXA-F project's specific objective is to develop methods to reduce the amount of data for transfer operations and leverage the power of reduced precision arithmetics on modern architectures. The first steps in this direction entail the creation and application of lower precision methods in selected operations performed by GENE. The precision must be scaled using existing libraries in addition to assessing how it impacts calculations as not every hardware supports arbitrary precision. To ascertain how much the discretization order influences the outputs on grids, this must be done on each of GENE's several sections. The operation will be done on the stencil part first. In order to accurately evaluate the impact of implementing this part with reduced precision, a respective error model has to be developed.

P 12.33 Wed 17:30 HSZ EG

Modeling of diagnostics for radiated power studies in Wendelstein 7-X — •G. Partesotti[1], F. Reimold[1], A. Demby[2], G. Wurden[3], and D. Zhang[1] — [1]IPP, HGW, DE — [2]UW-Madison, WI, US — [3]LANL, NM, US

In the field of magnetically confined fusion plasmas, stellarators like Wendelstein 7-X promise a more stable, steady-state operation, at the cost of increased, three-dimensional complexity of the magnetic field geometry. One of the many implications is the asymmetric distribution of impurities, which in turn causes radiative losses in the plasma to follow an inherently 3-D asymmetric pattern [1,2].

Given that radiation is a primary power dissipation mechanism, reliably estimating and predicting these patterns is crucial to accurately control the heat load on the divertor targets, so as to mitigate erosion and avoid exceeding material limits. For this purpose, it is therefore necessary to develop adequate 3-D signal post-processing techniques and diagnostic tools.

This contribution describes how the response of infra-red and resistive foil bolometer cameras was modeled with ray tracing [3], and how the so-obtained synthetic measurements can be combined to improve radiation tomography in W7-X. First, a set of emc3-calculated radiation patterns is studied to assess the 3-D aspects of the radiation distribution. Then, Gaussian Process Tomography is applied, combining physical and experimental constraints from multiple diagnostics and a newly designed Compact Bolometer Camera [4].

[1] Braun 2010, [2] Zhang 2021, [3] Carr 2018, [4] Moser 2020

P 12.34 Wed 17:30 HSZ EG

Overview of the neutral gas pressures in Wendelstein 7-X under boronized wall conditions — •Victoria Haak, Sergey Bozhenkov, Yuhe Feng, Amit Kharwandikar, Thierry Kremeyer, Dirk Naujoks, Valeria Perseo, Georg Schlisio, and Uwe Wenzel — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Gas exhaust is a key requirement for density control in a fusion device and, apart from the pumping speed and the subdivertor geometry, strongly dependent on the neutral gas pressure in the subdivertor and in front of the pumps. 13 neutral gas pressure gauges measured the neutral gas pressure in different locations in the plasma vessel of the stellarator Wendelstein 7-X during the first test divertor campaign, allowing for a detailed analysis of the neutral gas pressures, the compression ratios and the particle exhaust rates via the turbomolecular pumps in the different magnetic field configurations. Neutral gas pressures on the order of few 10^-4 mbar were measured in the subdivertor region, while the highest neutral gas pressure of 1.75*10^-3 mbar was obtained in the so-called high iota configuration featuring 4 edge magnetic islands per cross section. While measurements are only available in specific locations of the subdivertor, finite element simulations provide a detailed picture of the pressure distribution in the subdivertor volume.

P 12.35 Wed 17:30 HSZ EG

Uncertainty Quantification for Multiscale Turbulent Transport Simulations — •Yehor Yudin, David Coster, Udo von Toussaint, and Frank Jenko — Max Planck Institute for Plasma Physics, Boltzmannstrasse2, 85748 Garching, Germany

One of the challenges in understanding the energy and particle transport processes in the core plasma of a magnetic confinement fusion device is to quantify how they are affected by turbulent dynamics. This work considers a multiscale approach to modelling this problem, where the numerical solution is obtained for coupled models describing processes on different spatial and temporal scales. Furthermore, we investigate epistemic and aleatoric uncertainties in the profiles of the quantities transported in this model. This work proposes an application of a surrogate modelling technique to reduce the computational cost of resolving a quasi-steady state solution on the microscale when it is sufficient to capture only statistics of the turbulent dynamics. We study a Multiscale Fusion Workflow that utilizes turbulent energy and particle fluxes computed with a gyrofluid turbulence code GEM in flux tube approximation to calculate the transport coefficients for core transport code ETS. In this work, a data-driven probabilistic surrogate model based on Gaussian Process Regression is used to infer flux values computed by a turbulence code for given core profiles and to calculate related uncertainties. We use the VECMA/SEAVEA toolkit to perform uncertainty quantification as well as to train, test, and utilize surrogate models.

P 12.36 Wed 17:30 HSZ EG

Self-consistent neutral gas description in the edge turbulence fluid code GRILLIX — •Konrad Eder, Andreas Stegmeir, Wladimir Zholobenko, and Frank Jenko — Max Planck Institute

for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany

The edge turbulence fluid code GRILLIX employs a diffusive neutral gas model to describe plasma-neutrals interactions arising from ionization, recombination, and charge exchange processes [1]. This inclusion of neutral gas physics has been found to significantly improve the agreement of simulated plasma profiles with experiment data [1,2,3].

Presently, the model requires prescribing the neutrals density at the divertor, introducing a new free parameter to the code. As we move toward simulations of detached plasmas, we seek to alter this boundary condition in order to self-consistently describe the recycling fluxes at the targets. For this purpose, a diagnostics framework has been developed to verify the implementation of recycling boundary conditions and assess particle conservation properties of the code.

[1] W. Zholobenko et al., 2021 Nucl. Fusion, 61 116015.
[2] D.S. Oliveira and T.Body et. al., 2021 Nucl. Fusion 62 096001.
[3] K. Eder, 2022 Technical University of Munich, Master thesis.

P 12.37 Wed 17:30 HSZ EG

Simulation of electromagnetic turbulence in the stellarator W7-X — •Yann Narbutt, Aleksey Mischchenko, Alessandro Zocco, and Per Helander — Max Planck Institute for Plasma Physics, Wendelsteinstraße 1, 17489 Greifswald, Germany

Abstract. Fusion plasmas need high $\beta = \langle p \rangle / (B^2/2\mu_0)$, i.e. the ratio of plasma pressure to magnetic pressure. Going from low to high β first weakens ion-temperature-gradient mode activity and then causes strong kinetic-ballooning-mode (KBM) activity [1], with the latter being inherently electromagnetic. This can lead to particle and energy fluxes [2] which degrade plasma confinement. It is therefore of great importance to understand KBM turbulence for attaining high-performance plasmas. This poster presents first results of linear and non-linear simulations of KBM activity in the geometry of the stellarator Wendelstein 7-X using the global gyrokinetic code Euterpe [3].

References

[1] K. Aleynikova et al. "Kinetic ballooning modes in tokamaks and stellarators". In: Journal of Plasma Physics 84.6 (2018), p. 745840602. doi: 10.1017/S0022377818001186.

[2] A. Mishchenko et al. "Gyrokinetic particle-in-cell simulations of electromagnetic turbulence in the presence of fast particles and global modes". In: Plasma Physics and Controlled Fusion 64.10 (Sept. 2022), p. 104009. doi: 10.1088/1361-6587/ac8dbc.

[3] E. Sánchez et al. "Nonlinear gyrokinetic PIC simulations in stellarators with the code EUTERPE". In: Journal of Plasma Physics 86.5 (Sept. 2020). doi: 10.1017/s0022377820000926

P 12.38 Wed 17:30 HSZ EG

Structure-preserving hybrid code, STRUPHY: energy-conserving hybrid MHD-driftkinetic models — •Byung Kyu Na[1,2], Stefan Possanner[1], Florian Holderied[1], and Yingzhe Li[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technical University of Munich, Garching, Germany

STRUPHY (STRUcture-Preserving HYbrid codes) is a Python package for the simulation of energetic particles (EPs) in plasma. The package features a collection of PDE solvers for hybrid fluid-kinetic systems in curved three-dimensional spaces where the bulk plasma is treated as a fluid and the EPs are described kinetically (Particle-In-Cell method). The discretization is based on the GEMPIC framework. We will introduce energy-conserving hybrid MHD-driftkinetic models which were newly implemented in STRUPHY. Existing hybrid MHD-kinetic models often suffer from not conserving the total energy, especially when reduced kinetic models are used to describe EPs such as driftkinetic or gyrokinetic. However, this property was recently recovered by adding additional terms derived from variational principles. The investigation of the conservation laws on the discrete level will be considered with some simulation results.

P 12.39 Wed 17:30 HSZ EG

Modelling the effects of geometry modifications on the divertor heat loads of W7-X — •Amit Kharwandikar, Dirk Naujoks, Felix Reimold, Ralf Schneider, Thomas Sunn Pedersen, and The W7X Team — Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany

Wendelstein 7-X (W7-X) is an advanced stellarator device operated in Greifswald, Germany, to provide the proof of principle that the stellarator concept can meet the requirements of a future fusion reactor. It employs the island divertor concept to handle the heat and particle fluxes. In the recent experimental campaign OP1.2, unacceptably high heat loads limited the operation of the device. This immediate concern and the need to investigate a subsequent transition to fusion reactor relevant material (e.g. tungsten) for plasma facing components (PFCs) motivate the need for an improved divertor design. This poster discusses the investigation of such an optimized divertor via modelling. The simplified heat transport code, EMC3-Lite, is used as a fast tool to assess different design modifications of the current high-heat-flux (HHF) divertor. Moreover, using the functionalities of the code, a further reduced model for heat load calculations primarily depending on the inclination of magnetic field lines on the plasma-facing surface (PFS) and their connection lengths is derived. This new model introduces the possibility to gain insights into the main parameters determining heat loads and add more physics effects (e.g. radiation loss) in an attempt to fit with experiments. Finally, an iterative scheme for finding an optimum PFS is proposed.

P 12.40 Wed 17:30 HSZ EG

Characterisation of edge-SOL turbulence with `GRILLIX` in single null and advanced divertor configurations — •Jan Pfennig, Wladimir Zholobenko, Andreas Stegmeir, and Frank Jenko — Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching bei München, Germany

Turbulent transport across the magnetic field in magnetic confinement fusion devices, especially in the plasma edge and scrape-off layer (SOL), where steep gradients are observed, is of key interest because of two main reasons:

(i): It has a severe impact on the heat exhaust and hence on the energy confinement of the device

(ii): It is also responsible for the exhaust of helium ashes produced by the fusion reaction

Turbulence phenomena remain difficult to analyze experimentally and are not fully captured by transport codes due to non-local drive of turbulence as well as intermittent, ballistic transport of filaments (blobs) into the SOL. Hence, high-fidelity global turbulence simulations in realistic diverted geometries represent an important tool in quantitative predictions of tokamak plasma turbulence. Here we present in-depth analysis of global turbulence simulations performed with the `GRILLIX` code, which implements the two-fluid Braginskii equations in the flux-coordinate indepented (FCI) approach. Thus, abirtrarily complex magnetic geometries can be investigated.

P 12.41 Wed 17:30 HSZ EG

Conceptualization of an EM-upgrade for the gyrokinetic full-f code picls — •Annika Stier and Alberto Bottino — IPP, Garching, Germany

The gyrokinetic particle-in-cell code picls is a full-f finite element tool to simulate turbulence in the tokamak scrape-off layer. Up until now however, picls is a purely electrostatic code with a constant background magnetic field. In order to adequately model the phenomena of the scrape-off layer, taking into account electromagnetic effects is a necessity. To this end, the contribution at hand identifies due changes in the theoretical foundation of picls and proposes suitable modifications in its field solver and particle pusher stages.

P 12.42 Wed 17:30 HSZ EG

Hybrid gyrokinetic simulations for weakly magnetized plasmas — •Sreenivasa chary Thatikonda, Felipe nathan De Oliveira lopes, Aleks Mustonen, Daniel Told, and Frank Jenko — Max planck institute for plasma physics, Garching, Germany

We aim to study instabilities, turbulence and reconnection phenomenon in weakly magnetized plasmas. Such conditions may found in natural plasmas such as the solar wind, but also in laboratory applications, e.g. in the edge of fusion plasmas. Due to steep gradients in the edge of fusion plasmas and high frequencies in space plasmas, the ordering assumptions of gyrokinetic theory (like low frequency or moderate gradients) may be challenged, particularly for ions. To overcome these limitations, the group derived equations for a hybrid model that includes fully kinetic physics for the ions, but gyrokinetic physics for the electrons. Thereby, only the slower ion gyration needs to be followed, while still benefitting from a faster treatment of the electrons and this approch also saves computation costs. The numerical implementation of the hybrid model for electrostatic version has been implemented into the existing simulation code ssV, ssV was developed initially at the department of Theoretical Physics I at RUB, Bochum. Semi-Lagrangian schemes (e.g. the PFC scheme) are employed in ssV. This approach tracks down characteristics from the mesh point backwards in time to get the new value of flutter. Ongoing work on ssV involves the addition of electromagnetic capabilities, which will enable application to space and astrophysical plasmas.

P 12.43 Wed 17:30 HSZ EG

Interaction of relativistic electrons with MHD activity during disruptions — •Hannes Bergstroem, Konsta Särkimäki, and Matthias Hoelzl — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching b.~M., Germany

In spite of all the promise that fusion energy holds, there are several obstacles that one must overcome before commercially viable fusion reactors can be realized. One issue that looks to be ever more prominent in future tokamak reactor designs such as ITER is the type of operational failure known as disruptions, triggered by a sudden loss of plasma confinement. During these off-normal events it is possible for electrons to be accelerated towards relativistic velocities. These highly energetic particles could then accumulate and strike the wall, causing sub-surface melting which is difficult to repair. As such, disruption events could potentially put reactors out of commission for extended periods of time, which cannot be tolerated. In order to fully understand the evolution and consequences of disruptions it is vital that the dynamics of the relativistic electrons are studied in detail, which includes aspects such as how they are generated, to what extent they interact with the bulk plasma, what the transport looks like and where they eventually strike the wall. This work aims to answer these questions by extending the non-linear MHD code JOREK to kinetic particle-in-cell treatment for the phase-space evolution of relativistic electrons. In addition we use ray-tracing methods to determine where the particles intersect a 3D wall, allowing us to estimate localized heat loads.

P 12.44 Wed 17:30 HSZ EG

Tungsten-copper composites based on additively manufactured tungsten preforms for high heat flux applications — •Robert Lürbke[1,2], Alexander von Müller[2], Alexander Feichtmayer[1,2], Thomas Bareth[3], Armin Rieser[3], Georg Schlick[3], and Rudolf Neu[1,2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Deutschland — [2]Technische Universität München, 85748 Garching, Deutschland — [3]Fraunhofer IGCV, 86159 Augsburg, Deutschland

In future fusion reactors, plasma-facing components (PFCs) have to sustain high heat fluxes and neutron irradiation. This creates the need for advanced materials that can withstand such an environment. Tungsten (W) is considered the preferred plasma-facing material for use in fusion devices due to its low hydrogen retention, high melting point as well as its low physical sputtering yield. Against this background, additive manufacturing (AM) of W can be considered a useful tool to provide tailored W structures for reinforcing copper (Cu) based heat sinks due to a tailored thermomechanical behaviour. The present contribution will illustrate the possibilities of tailoring macroscopic properties of W-Cu PFC materials. In this context, basic observations like rules of mixture for composite materials will be discussed. Based on that, it will be shown how the exploitation of complex composite structures can open up new possibilities for material and component design.

P 12.45 Wed 17:30 HSZ EG

Analysis of Nonlinear Dynamics of Shear Alfvén Waves Driven by Energetic Trapped Particles — •Farah Atour — IPP Garching

In controlled fusion devices, shear-Alfven waves can be driven unstable by resonant interactions with energetic alpha particles. This results in many issues regarding the confinement of the particles and therefore can prevent the thermalization of the plasma core or increase the thermal load on the material's wall. The source of these particles is either the nuclear fusion reaction produced by the background plasma and/or external heating systems. Due to the importance of these issues, there exists an extensive literature on this topic. These studies mostly focus on the nonlinear dynamics of passing particles since they have more significant impacts. However, the nonlinear dynamics of shear-Alfven waves driven by energetic trapped particles deserves also depth analysis and will be the focus of this study. The overall goal of this work is to investigate on a deeper level the fundamental physical processes regarding both the linear stability properties and the nonlinear saturation mechanisms for single and multi modes. For this reason, to keep the context of the dynamical study simplified, these phenomena are investigated by HMGC code, which has a simple circular geometry and is based on the hybrid reduced MHD gyrokinetic model.

P 13: Laser Plasmas I

Time: Thursday 11:00–13:00 Location: CHE/0089

Invited Talk P 13.1 Thu 11:00 CHE/0089

Acceleration of spin-polarized ion beams from laser-plasma interaction — •Lars Reichwein[1], Markus Büscher[2,3], and Alexander Pukhov[1] — [1]Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany — [2]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich, 52425 Jülich, Germany — [3]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

Spin-polarized particles are of interest for a variety of applications such as fusion, where the use of spin-polarized reactants may increase the nuclear cross-section, or further investigation of the nucleon structure by means of deep inelastic scattering. In recent years, the acceleration of such polarized particles via laser-plasma interaction has gained traction in research due to the short acceleration distances needed compared to conventional accelerators. While several schemes for efficient proton and ion acceleration are generally known, many of them are not feasible for polarized beams since the target needs to be prepolarized. In our talk, we give an overview of the current experimental and theoretical state-of-the-art for polarized ion beams. Two acceleration mechanisms, Magnetic Vortex Acceleration and Collisionless Shock Acceleration, will be studied by means of particle-in-cell (PIC) simulations. These schemes can be used to obtain highly polarized ion beams even in the regime of near-future laser facilities.

P 13.2 Thu 11:30 CHE/0089

Influence of plasma profile on injection dynamics in a proton-driven wakefield accelerator. — •Pablo Israel Morales Guzmán, Patric Muggli, and John Farmer — Max-Planck-Institut für Physik

Plasma wakefield accelerators (PWFA) have been proposed as a novel technique to accelerate particle bunches to high energies. Due to the high electric fields supported in plasma, this can be done in a shorter distance than in conventional accelerators. PWFA use a relativistic particle bunch to drive wakefields. When the bunch density is much larger than the plasma density, it induces a non-linear plasma response. For negatively charged bunches, there is blow-out of plasma electrons. For positively charged ones, plasma electrons flow towards the axis, creating a high-density filament. This filament sustains defocusing fields for negatively charged bunches.

A proton bunch much longer than the plasma wavelength drives high-amplitude wakefields only after undergoing self-modulation (SM). SM transforms it into a microbunch train that resonantly drives wakefields. An electron bunch can be injected to seed SM or be accelerated.

We present results of a numerical study using particle-in-cell simulations with parameters similar to those of the AWAKE experiment. We show that along the low density ramp leading to the plasma entrance, the proton bunch generates a filament of plasma electrons. These results indicate that the accelerator plasma of future experiments relying on self-modulation, and a drive and accelerated bunch of different charge, cannot have a density ramp.

P 13.3 Thu 11:45 CHE/0089

Relativistic High Harmonic Generation from solid density foils with a PW class short pulse laser. — •Milenko Vescovi[1], Marvin Elias Paul Umlandt[1,2], Stefan Assenbaum[1,2], Thomas Meric[1,2], Florian Kroll[1], Martin Rehwald[1], Radka Stefanikova[1,2], Thomas Püschel[1], Irene Prencipe[1], Stephan Kraft[1], Ulrich Schramm[1,2], and Karl Zeil[1] — [1]Helmholtz-

Zentrum Dresden-Rossendorf, 01328, Dresden — [2]Technische Universität Dresden, 01062, Dresden

Relativistic High Harmonic Generation (HHG) from the interaction of high intensity lasers with over dense targets has become a topic of great interest in recent years because of its potential to achieve high energy, coherent short pulses of XUV emission. Several studies have shown the mechanism to be highly sensitive to the laser-plasma interaction conditions. Characterization of the high harmonic spectrum could then be used to probe the interaction during the high intensity fraction of the laser pulse, which is usually of most interest because of the extreme matter conditions but challenging to access experimentally. Measurements of the XUV harmonic spectrum have been conducted with the Draco PW laser (peak intensities up to $6\times10^{21}W/cm^2$ in 30fs FWHM). With the aim of using HHG to gain a better understanding about the interaction, different conditions were studied. Harmonics from 14nm to 17nm wavelength were measured from bulk SiO2 targets, metal foils and plastic foils, as well as driving laser energies. In this work, general features of this parameter scan are shown and its potential link to the laser plasma interaction is discussed.

P 13.4 Thu 12:00 CHE/0089

Setup and evaluation of a calibration free Thomson parabola spectrometer to study sub-MeV ions from laser plasmas — •Lars Torben Schwabe, Jan Riedlinger, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Since sub-MeV ions from laser pulse plasmas are only scarcely studied, we developed a special Thomson parabola spectrometer with a maximized dynamic range that maps these ions in a charge and energy dependent manner. Predictions for these types of ions tend to be inaccurate because of the amount of processes involved, acting on the particles on different time scales. The plasma is generated by a high-intensity ultrashort laser pulse with peak intensities up to 10^{17} W/cm^2 at pulse durations down to 8 fs focused on a solid. The emitted supra-thermal ions are investigated. These results are compared to simulations in terms of ionization state and energies. In this contribution, the design and construction of such a Thomson spectrometer is discussed, which allows us to detect ions over a wide energy range by utilizing variable fields. Furthermore, we present the multi-step evaluation process which eliminates the need for spectrometer calibration.

P 13.5 Thu 12:15 CHE/0089

Characterization of a laser driven supra-thermal ion source — •Jan Riedlinger, Lars Torben Schwabe, Qëndresa Ibraimi, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Today's laser systems achieve repetition rates up to 100 khz at pulse energies of 1 mJ and sub-10-fs durations. With these parameters, laser plasmas become viable ion sources for applications which require a small source size. We present the results of experiments performed with such a laser, reaching intensities up to 10^{17} W/cm^2 on the target surface. This interaction creates a high temperature plasma emitting bunched ions over a broad spectrum in the keV regime. Here, mostly bulk targets were used due to the nearly free choice of materials and high densities for an increased particle output. The talk gives an in-depth view into the ion emission in terms of its opening cone, ionization states and kinetic energies as well as the purposely designed diagnostics.

P 13.6 Thu 12:30 CHE/0089

Heating in Multi-Layer Targets at ultra-high Intensity Laser Irradiation and the Impact of Density Oscillation — •Franziska Paschke-Bruehl[1], Thomas Kluge[1], Motoaki Nakatsutsumi[2], Lisa Randolph[2], Tom Cowan[1], Ullrich Schramm[1], Lingen Huang[1], Mohammadreza Banjafar[2], and Brian Marré[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]European XFEL, Hamburg, Germany

We present a computational study of isochoric heating in multi-layered targets at ultra-high intensity laser irradiation(10^20W/cm^2). Previous studies have shown enhanced ion heating at interfaces, but at the cost of large temperature gradients. Here, we study multi-layered targets to spread this enhanced interface heating to the entirety of the target and find heating parameters at which the temperature distribution is more homogeneous than at a single interface while still exceeding the mean temperature of a non-layered target. Further, we identify a pressure oscillation that causes the layers to alternate between expanding and being compressed with non beneficial effect on the heating. Based on that, we derive an analytical model estimating the oscillation period to find target conditions that optimize heating and temperature homogeneity. This model can also be used to infer the plasma temperature from the oscillation period which can be measured e.g. by XFEL probing.

P 13.7 Thu 12:45 CHE/0089

K-alpha yield from laser-plasmas on thin layers — •Nico Potzkai and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

When intense sub 10-fs laser pulses create plasma on solid surfaces, they accelerate electrons into the vacuum as well as into the target. The latter electrons induce characteristic x-rays in the material, most of all characteristic K_α radiation, which constitutes a source of partly coherent x-rays due to the small source and narrow spectral line width. When optimizing the total radiation output of this source, we found that thin layers of aluminum on top of copper emit more K_α photons than expected. In our contribution, we present our experimental results and calculations describing this effect.

P 14: Magnetic Confinement IV/HEPP VI

Time: Thursday 11:00–13:10 Location: CHE/0091

Invited Talk P 14.1 Thu 11:00 CHE/0091

Experimental validation of turbulence codes — •Klara Höfler — Institut für Plasmaphysik, Greifswald, Germany

Turbulence is a main driver of heat transport, which deteriorates the performance of fusion reactors. Simulation codes aiming for identifying turbulence optimized devices need to be validated against experiments.

The comprehensive set of experimental turbulence data presented here is measured at the ASDEX Upgrade tokamak for two plasma scenarios. It includes wavenumber spectra, electron density and temperature fluctuation amplitudes and radial correlation lengths as well as the cross phase between density and temperature fluctuations. These quantities are measured for comprehensive code validation by Doppler reflectometers and an electron cyclotron emission radiometer. In this talk they are compared to the gyrokinetic code GENE because of its mature capabilities to assess and reproduce core turbulence. In addition synthetic diagnostic modeling is included to account for diagnostic effects on measurements.

The work presented in this talk shows the encouraging example of code validation where a remarkable number of measured physics quantities is successfully reproduced by the code. It comprises contributions of a variety of collaborators both on the experimental side – Institut für Plasmaphysik (IPP) in Garching, Plasma Science and Fusion Center of MIT in Cambridge and Laboratoire de Physique des Plasmas of the Ecole Polytechnique in Palaiseau – and on the theory side – IPP Garching and Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie in Stuttgart.

P 14.2 Thu 11:30 CHE/0091

Turbulence in stellarators with GENE-3D — •Felix Wilms, Alejandro Banon Navarro, and Frank Jenko — Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching b. München, Germany

GENE-3D is a code that is capable of simulating gyrokinetic plasma turbulence in stellarators globally (Maurer et al., Journal of Computational Physics, 2020). It has recently been upgraded to an electromagnetic version, expanding the variety of turbulent features that can be studied with it (Wilms et al., Journal of Plasma Physics, 2021). In this work, we present an overview over the most recent achievements of the code, including the study of electromagnetic effects on global turbulence (Wilms et al., Journal of Plasma Physics, 2021) as well as the impact of a surface-global effects on turbulence stabilisation (Wilms et al., to be submitted to Nuclear Fusion).

P 14.3 Thu 11:55 CHE/0091

Gyrokinetic simulations of turbulent transport in the edge and scrape-off layer of TCV — •Philipp Ulbl[1], Andreas Stegmeir[1], and Frank Jenko[1,2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]University of Texas at Austin, Austin, TX 78712, USA

Turbulence in the edge and scrape-off layer (SOL) region of magnetic confinement fusion devices is of high relevance for the feasibility of fusion energy. Two important properties of a future fusion reactor, confinement and heat exhaust, are largely affected by turbulence. This requires the development of predictive edge turbulence codes.

In this work, we present the latest improvements to the grid-based gyrokinetic turbulence code, `GENE-X` [1], with applications to the TCV tokamak [2]. `GENE-X` is specifically targeted for edge and SOL simulations, since it can perform simulations in realistic, diverted geometries. It features a full-f, electromagnetic, gyrokinetic turbulence model and recently, collisional effects were introduced.

We present the results of multiple `GENE-X` simulations using different collision models, which vary in their physics fidelity. We analyze the resulting plasma profiles and heat fluxes, and compare against the experiment. The code validation improves with the fidelity of the collision model. Based on this, we assess and discuss collisional effects on gyrokinetic turbulence in the edge and SOL.

[1] D. Michels, et. al., Comput. Phys. Commun. 264, 107986 (2021)
[2] D. S. Oliveira, T. Body, et. al., Nucl. Fusion 62, 096001 (2022)

P 14.4 Thu 12:20 CHE/0091

Investigation of driving mechanisms of dominant Alfvén eigenmodes at the Wendelstein 7-X stellarator — •Sara Vaz Mendes[1], Kian Rahbarnia[1], Henning Thomsen[1], Christoph Slaby[1], Charlotte Bueschel[1], Matthias Borchardt[1], Ralf Kleiber[1], Axel Könies[1], Jan-Peter Bähner[2], and Adrian von Stechow[1] — [1]Max-Planck-Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]MIT Plasma Science and Fusion Center, Cambridge, MA 02139, USA

The basis for characterizing dominant Alfvén mode activity in the Wendelstein 7-X (W7-X) stellarator plasmas is presented with the investigation of possible driving mechanisms. In previous W7-X operational phases, Alfvén mode activity was frequently observed during plasmas operated solely with electron cyclotron resonance heating. A broad range of frequencies is observed in measurements of the fluctuating poloidal magnetic field, $\dot{B}_\theta$. An essential analysis was developed to track the dominant frequency bands (DFBs) from the spectrograms of $\dot{B}_\theta$ between $f = 100 - 450$ kHz. The DFBs studies allowed us to draw novel and integral analyses of the dynamics of Alfvén modes through the entire length of W7-X plasmas. Correlations between the modes dynamics with general plasma parameters are determined, and we present in which plasma conditions the spectral properties of the Alfvén DFBs show relevant changes. The amplitude of the DFBs shows a strong correlation to turbulent density fluctuations measured with the Phase contrast Imaging (PCI) diagnostic in most W7-X regimes.

P 14.5 Thu 12:45 CHE/0091

Model based optimization of Advanced Tokamak scenarios — •Raphael Schramm[1], Alexander Bock[1], Emiliano Fable[1], Jörg Stober[1], Simon van Mulders[2], Maximilian Reisner[1], Hartmut Zohm[1], and the ASDEX Upgrade Team[1] — [1]Max-Planck Institut für Plasmaphysik, Garching, Germany — [2]École Polytechnique Fédérale de Lausanne, Switzerland

Advanced Tokamak scenarios increase the plasma safety factor (q) profile via external actuators in order to increase the bootstrap current, thereby reducing the inductive current fraction. In order to avoid an intermittent drop in q the actuators need to be applied already during the current ramp-up. A model in the transport code ASTRA, capable of predicitvely designing such a scenario by calculating temperature and q profiles based on the actuator setup has been developed and validated on AUG.

A scenario, considerably different from the validation case has been analyzed. In order to increase magnetohydrodynamic stability, the q-profile has been optimized. This is done by using an optimizer, running on simpler model to propose changes, which are then double-checked in the ASTRA model. Effects of the plasma current on stability and the performance of different setups have been explored. Results of the last AUG campaign will be shown.

The model can also be applied on different devices with minor changes. Results for JET, based on data from previous shots will be shown. Using the model to design a scenario to show the flux-pumping phenomenon on a larger device for the first time is planned.

P 15: Laser Plasmas II/Low Pressure Plasmas and their Applications II

Time: Thursday 14:00–15:30 Location: CHE/0089

Invited Talk P 15.1 Thu 14:00 CHE/0089

Tumor irradiation in mice with a laser-accelerated proton beam — •Florian Kroll[1], Florian-Emanuel Brack[1], Elke Beyreuther[1,2], Thomas Cowan[1,3], Leonhard Karsch[1,2], Josefine Metzkes-Ng[1], Jörg Pawelke[1,2], Marvin Reimold[1,3], Ulrich Schramm[1,3], Tim Ziegler[1,3], and Karl Zeil[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]OncoRay - National Center for Radiation Research in Oncology, Dresden, Germany — [3]Technische Universität Dresden, Dresden, Germany

We report on establishing a laser-plasma-based proton research platform for user-specific small animal radiobiology studies. The Draco PW laser at Helmholtz-Zentrum Dresden-Rossendorf drives the laser-plasma accelerator (LPA). We discuss the findings that allowed us to operate our LPA proton source with unprecedented stability and long-term reliability, featuring proton energies regularly exceeding 60 MeV.

These capabilities allowed us to conduct the first radiobiological in vivo study using an LPA proton source. The pilot study was performed on human tumors in a mouse model, showing the concerted preparation of mice and laser accelerator, the dose-controlled, tumor-conform irradiation using the LPA as well as a clinical reference proton source, and the radiobiological evaluation of irradiated and unirradiated mice for radiation-induced tumor growth delay. The prescribed homogeneous dose was precisely delivered at the laser-driven source.

The presented results prove that LPA proton sources have reached a new level of applicability and now enable systematic radiobiological studies within an unprecedented range of beam parameters.

P 15.2 Thu 14:30 CHE/0089

Comparison between THz absorption spectroscopy and ps-TALIF measurements — •Jente R. Wubs[1], Laurent Invernizzi[2], Kristaq Gazeli[2], Guillaume Lombardi[2], Uwe Macherius[1], Klaus-Dieter Weltmann[1], and Jean-Pierre H. van Helden[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Laboratoire des Sciences des Procédés et des Matériaux (LSPM), CNRS, Université Sorbonne Paris Nord, Villetaneuse, France

Terahertz (THz) absorption spectroscopy with quantum cascade lasers has recently been developed and implemented as a new diagnostic technique for investigating atomic oxygen densities in plasmas. It is based on the detection of the $^3P_1 \leftarrow {}^3P_2$ fine structure transition at approximately 4.75 THz. This allows for direct measurements (i.e. no calibration procedure required) of absolute ground-state atomic oxygen densities. A possible way to validate this method is by a comparison with two-photon absorption laser-induced fluorescence (TALIF), as this is currently the most established method for measuring atomic oxygen densities. TALIF measurements were done in this case with a picosecond (ps) laser system and using a streak camera for detection. Both ps-TALIF measurements and THz absorption spectroscopy were performed on the same low-pressure capacitively-coupled radio frequency plasma generated in pure oxygen, for a variation of the applied power (20–100 W) and gas pressure (0.7–1.3 mbar). A comparison between resulting atomic oxygen densities as obtained with the two different diagnostics is presented in this contribution.

P 15.3 Thu 14:45 CHE/0089

Characterization of the ion angle distribution function in low-pressure plasmas using a microelectromechanical system — •Marcel Melzer[1], Katja Meinel[1], Chris Stoeckel[1,2], Torben Hemke[3], Thomas Mussenbrock[3], and Sven Zimmermann[1,2] — [1]Center for Microtechnologies, Chemnitz University of Technology, Chemnitz, Germany — [2]Fraunhofer Institute for Electronic Nano Systems ENAS, Chemnitz, Germany — [3]Chair Electrical Engineering and Plasma Technology, Faculty of Electrical Engineering and Informationtechnology, Ruhr-University Bochum, Germany

It has been demonstrated for the first time that a microelectromechanical system (MEMS) can be used to characterize the ion angle distribution function (IADF) of a low-pressure plasma. The MEMS is piezoelectrically actuated. The piezoelectric AlN is used both to tilt a 30 μm thick silicon plate as well as to monitor the tilt angle. Holes with a diameter of 2 μm were etched into the tilting plate. These high aspect ratio holes allow selection of ion incidence angles depending on the tilt angle of the MEMS. Below the MEMS, the ions are detected by a metal electrode. A numerical method is presented to determine the ion angle distribution function based on the measured data for the resonant operation of the MEMS.

P 15.4 Thu 15:00 CHE/0089

Collisional radiative modelling for molecular hydrogen plasmas applying MCCC cross sections — •Richard Christian Bergmayr, Dirk Wünderlich, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik, Garching, Germany

Molecular hydrogen (H_2) occurs in a variety of plasmas (e.g. negative ion source and fusion divertor plasmas). Collisional radiative (CR) models enable the characterization of these plasmas not only by their plasma parameters in combination with emission spectroscopy, but also to evaluate effective reaction rates (e.g. for molecular assisted recombination (MAR), a mechanism that may contribute to the detachment in divertors). CR models balance (de-)populating mechanisms of excited states in terms of coupled rate equations. Recent studies using a CR model for the triplet system of H_2 have shown that applying electron impact excitation cross sections calculated by the molecular convergent close-coupling (MCCC) method in the adiabatic-nuclei formulation show an improved agreement with measurements in low-pressure plasmas compared to models based on previously available cross sections. In this work a CR model for the electronic states of the singlet system of H_2 applying MCCC cross sections is presented showing likewise as the triplet model better agreement with measurements than previous models. Furthermore, the models for the singlet and triplet system are coupled. Thereby it is possible to estimate also the influence of (optically forbidden) spin-mixing processes. In a next step this knowledge can be used to create a (ro-)vibrationally resolved model for H_2, as (ro-)vibrational excitation is expected to enhance MAR.

P 15.5 Thu 15:15 CHE/0089

First-principles simulation of optical emission spectra for low-pressure argon plasmas and its experimental validation — Fatima Jenina Arellano[1], Márton Gyulai[2,3], Zoltán Donkó[1,3], Peter Hartmann[3], •Tsanko Vaskov Tsankov[4], Uwe Czarnetzki[4], and Satoshi Hamaguchi[1] — [1]Center for Atomic and Molecular Technologies, Osaka University, Osaka, Japan — [2]Eötvös Loránd University, Budapest, Hungary — [3]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Budapest, Hungary — [4]Ruhr University Bochum, Faculty of Physics and Astronomy, Experimental Physics V, Germany

The emission intensity of various spectral lines are often used for the experimental characterization of low-temperature plasmas. However, the interpretation of the spectra requires knowledge of the electron distribution function and the population-depopulation kinetics of the emitting states. To investigate these relations and to test the suitability of numerical models for relating the measured emission spectra to the underlying plasma parameters, we perform here first-principle simulations for low-pressure radio-frequency driven capacitively-coupled argon plasmas via one-dimensional particle-in-cell/Monte Carlo collision (PIC/MCC) code coupled to a global collisional-radiative model. The model provides the emission intensities of various atomic lines which are compared with experimental data. The comparison shows good agreement for pressures up to about 20 Pa and increasingly notable deviations at higher pressures. Possible explanations for the deviations are discussed.

P 16: Plasma Wall Interaction II/Codes and Modeling I

Time: Thursday 14:00–15:30 Location: CHE/0091

Invited Talk P 16.1 Thu 14:00 CHE/0091

Development of a Laser-based Diagnostic for in situ Monitoring of Fuel Retention in ITER and future fusion devices — •Alexander Huber, M. Zlobinski, G. Sergienko, J. Assmann, D. Castano, S. Friese, I. Ivashov, Y. Krasikov, H. Lambertz, Ph. Mertens, K. Mlynczak, M. Schrader, A. Terra, S. Brezinsek, and Ch. Linsmeier — Institut für Energie- und Klimaforschung - Plasmaphysik, Forschungszentrum Jülich GmbH, Jülich

One of the most serious challenges for the operation of ITER and future fusion devices is the control of the inventory of tritium stored in the vessel walls which surround the plasma. For the operation of ITER and of a fusion reactor in general, the determination of the tritium inventory and the knowledge of its spatial distribution is essential. Its control without removal of wall tiles is also of paramount importance. A laser-based T-monitor diagnostic system is under development at Forschungszentrum Jülich (FZJ) to remotely provide information about the tritium content in the deposited layer on the inner divertor tiles of ITER. The T-inventory builds up through the interaction of wall erosion and co-deposition of hydrogen isotopes together with redeposited material. The limitation of the tritium content in the reactor is of course a safety requirement for the operation. The measurement concept is based on laser-induced desorption (LID) and detection of the released gases by Residual Gas Analysis (RGA).

The present contribution summarizes the results of an R&D programme on the LID method carried out at FZJ for the integration of this laser-based tool into ITER and future reactors.

P 16.2 Thu 14:30 CHE/0091

Multi-staged ERO2.0 simulation of material erosion and deposition in recessed ITER mirror assemblies — •Sebastian Rode[1], Juri Romazanov[1], Sebastijan Brezinsek[1], Andreas Kirschner[1], Sven Wiesen[1], Tom Wauters[2], Lucas Moser[2], and Richard Pitts[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung, 52425 Jülich, Germany — [2]ITER Organization, 13067 St Paul Lez Durance, France

The Monte-Carlo code ERO2.0 traces impurity particles throughout the volume of fusion devices providing the local erosion and deposition fluxes at plasma-facing components or recessed objects, delivering important information about sputtering or layer growth on those components. In recessed areas, e.g. mirror assemblies in the diagnostic first wall (DFW) of ITER, the code is approaching its limits. The necessary resolution of information on mirrors more than 50 cm away from the LCFS cannot be achieved with standard simulations as only a tiny fraction of impurity test particles and a large fraction of charge exchange hydrogenic neutrals (CXN) reaches this volume. Multi-staged ERO2.0 simulations are employed to overcome this challenge: Impurity particles from a global ERO2.0 simulation with its boundary close to the DFW are collected and subsequently injected into local simulations. The number of test particles representing the fluxes is scaled up, achieving far superior resolution. The results show that the sputtering is largely dominated by high energy CXN, with the patterns indicating a strong influence by the geometry of the assembly. Overall neglible deposition is expected on the mirrors for the full ITER operation time.

P 16.3 Thu 14:45 CHE/0091

Separation of plasma species fluxes for investigating plasma-surface interactions — •Adrian Heiler[1], Roland Friedl[2], and Ursel Fantz[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching — [2]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg

Low pressure plasmas are commonly applied for surface treatment processes. To investigate the role of the different plasma species in the plasma-surface interaction, a selective exposure is indispensable. Therefore, the separation of plasma species fluxes from an inductively coupled plasma source (27.12 MHz, 600 W max.) is demonstrated by using magnets and a MgF_2 window. The plasma source is operated in hydrogen at pressures of $4-10$ Pa and is connected to a vacuum chamber in which surfaces can be installed at a sample holder. The impinging fluxes of hydrogen atoms, positive hydrogen ions and UV/VUV photons (up to 15 eV) are quantified by using optical emission spectroscopy, a Langmuir probe and a VUV diagnostic. The VUV diagnostic is based on a photodiode and optical filters for wavelength selection and is calibrated against a VUV spectrometer.

The influence of the UV/VUV photons, hydrogen atoms and positive hydrogen ions on surfaces is exemplarily demonstrated by applying work function measurements of in situ caesiated metal samples. By this, it is shown that each species can affect the surface separately. The impact of the selective exposure is compared to the full plasma-surface interaction by the generation of well-characterized inductively coupled hydrogen plasmas directly in front of the surface.

P 16.4 Thu 15:00 CHE/0091

Hyperfine structure splitting and the Zeeman effect of ^{83}Kr in laser absorption spectroscopy investigated at the linear plasma device PSI-2 — •Marc Sackers[1], Oleksandr Marchuk[1], FNU Dipti[2], Stephan Ertmer[1], Yuri Ralchenko[3], and Arkadi Kreter[1] — [1]Forschungszentrum Jülich GmbH - Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]International Atomic Energy Agency, Vienna, Austria — [3]National Institute of Standards and Technology - Atomic Spectroscopy Group, 20899 Gaithersburg, USA

Comparing Ar I and Kr I laser absorption spectra obtained at the linear plasma device PSI-2 indicate an additional line broadening in the case of Kr due to isotopic effects. The magnetic field configurations at PSI-2 provide weak field conditions for even numbered isotopes, i.e., a small perturbation on the energy level splitting. However, concerning ^{83}Kr, the magnetic field strength (B) is de facto intermediate. This condition substantially increases the complexity of the spectra since the energy shift is non-linear in B and the intensities of the magnetic sub-transitions depend on B as well.

The analysis is based on a model by C. G. Darwin of the Zeeman effect at all field strengths [1]. Overall, the experimental investigation at the linear plasma device PSI-2 is limited to laser absorption spectra (20.5 mT to 90 mT) from the Kr I 5s J=2 and J=0 metastable levels using the 760.15 nm and 785.48 nm lines, respectively.

[1] C. G. Darwin, Proc. R. Soc. Lond. A **115**, 1-19 (1927)

P 16.5 Thu 15:15 CHE/0091

Application of Laser Ablation Molecular Isotopic Spectroscopy on a-(^{12}C,^{13}C):H layers in double pulse mode — •Erik Wüst, Rongxing Yi, Christoph Kawan, Timo Dittmar, and Sebastijan Brezinsek — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich

Following the injection of $^{13}CH_4$ into a Hydrogen plasma in Wendelstein 7-X, Laser Ablation Molecular Isotopic Spectroscopy (LAMIS) was utilised to quantify ^{13}C deposition patterns ex-situ on the graphite test divertor. LAMIS was applied in double pulse mode. The first pulse (355 nm, 35 ps, 1.1 J/cm^2) was applied for the production of a laser-induced plasma on the material's surface. A second laser pulse (1064 nm, 35 ps) followed typically 50 ns later. The second laser pulse was focussed into the laser-induced plasma plume of the first pulse in order to improve signal to noise ratio in the spectra and the sensitivity acquired from the emitted light.
In general a good agreement of the ^{13}C content and pattern with DP-LAMIS and the complementarily applied Nuclear Reaction Analysis was found for layers up to a few μm. Deviations were identified for thicker layers, therefore ablation process was investigated regarding the impact of the second laser pulse (2.3 J/cm^2, 50 ns after first pulse) on ablation rate per pulse pair and properties of the plasma plume. Results of these investigations and proposed ways to overcome the challenge of resolving ^{13}C content in thick mixed layers containing carbon and hydrogen are presented.

P 17: Complex Plasmas and Dusty Plasmas/Codes and Modeling II

Time: Thursday 15:45–17:15 Location: CHE/0089

P 17.1 Thu 15:45 CHE/0089

Size evolution and plasma-particle interaction of single MF particles in the plasma sheath — •Sören Wohlfahrt, Cassedyn Wirtz, and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Complex (dusty) plasmas consist of micrometer sized particles in addition to the typical plasma species of ions, electrons and neutrals. It has been observed, that the particle size decreases for many materials during plasma exposure and that the particle surface is modified/roughened. This process is commonly referred to as 'etching', although in the context of dusty plasmas the detailed mechanism and surface reactions behind the decreasing size is not known yet and proposed explanations range from physical sputtering, over melting of the particle material to ion enhanced chemical reactions. We use an advanced light scattering diagnostic based on Lorentz-Mie theory to determine size and size evolution of single melamine formaldehyde (MF) particles in situ and with high temporal resolution. By adding small amounts of oxygen to the discharge, the etch process and plasma particle interaction become accessible [1]. In this talk, we will present precise measurements of the size evolution of single particles complemented with a reactive site model [2] that suggests an increase in surface reactions due to a roughening of the particle surface.

[1] S. Wohlfahrt, C. Wirtz, D. Block, Phys. Plasmas 29, 123702 (2022)

[2] R. Bray, R. Rhinehart, Plasma Chem. Plasma Process 21, 149-161 (2001)

P 17.2 Thu 16:00 CHE/0089

Ex situ measurement of dust size distribution of nanoparticle growth process and comparison with in situ measurements — •Andreas Petersen, Jakob Wötzel, and Franko Greiner — Institute of Experimental and Applied Physics, Kiel, Germany

We present the result of a size distribution analysis for plasma grown dust particles in their accretion phase. A multi-sample extraction process was used to prepare samples for analysis with SEM (ex situ measurement). This allowed for eight consecutive samples, without terminating the discharge. We find that a normal distribution is an adequate description of the particle distribution for the whole growth process. It is noteworthy, that the standard deviation of the distribution increases approximately linearly with average size. We also compare these results with those from a light scatter analysis, which was performed simultaneously and can determine average size and refractive index without opening the discharge chamber (in situ measurement).

P 17.3 Thu 16:15 CHE/0089

Characterization of a Pulsed Plasma and Macroparticles in an Industrial Scale ta-C Laser-Arc Coating System — •Mathis Klette[1], Martin Kopte[2], Wolfgang Fukarek[2], and Holger Kersten[1] — [1]Kiel University, Germany — [2]VTD Vakuumtechnik Dresden GmbH, Germany

Tetrahedral amorphous carbon (ta-C) coatings are commonly used in industry to improve tribological as well as corrosion and wear properties of treated objects. While ta-C can be deposited using various techniques, the Laser-Arc technology allows for a strong temporal and spatial control of the deposition process while providing high deposition rate and enabling up-scaling for industrial applications. A major limiting factor of this technology is the generation of macroparticles and the resulting defects in the coating. In this contribution we present measurements of plasma parameters, neutrals and macroparticles in dependance on arc parameters to get a better understanding of the impact on film growth and system upscaling. The carbon Laser-Arc system produces 100-300 us, 1-3 kA pulses, which are observed with a custom-tailored diagnostic setup. The Langmuir probes, retarding field analyzers, and the optical emission spectroscopy allow for spatially and time resolved measurements of electron and ion energy distribution functions, and estimates of neutral densities. Calorimetric probes monitor the energy influx to the substrate which is of special importance when forming tetrahedral bonds. The temporal and special macroparticle velocity distributions have been investigated with high-speed cameras.

P 17.4 Thu 16:30 CHE/0089

Viscosity of finite Yukawa liquids — •Yang Liu, Natascha Blosczyk, and Dietmar Block — IEAP, Christian-Albrechts-Universität, D-24098 Kiel, Germany

Viscosity is one of the basic characteristics to describe the dynamic behavior of a fluid. For dusty plasmas established methods exist to measure viscosity [1,2]. However, these methods are limited to large/infinite systems while in some experiments (e.g for binary mixtures) the system size is limited. Whether and how these methods can be adapted to measure the shear viscosity of a finite two-dimensional (2D) Yukawa liquid is presented in this contribution using non-equilibrium Langevin simulations. Two counter-propagating shear forces are used to push the particles, causing shear-induced melting of the cluster. Based on the Green-Kubo relation (which relies on the random thermal motion of individual particles of the liquids) we obtain a reliable shear viscosity by diminishing the effect of shear and boundary conditions. We find that the shear viscosity is in good agreement with the results in Refs. [1, 2] if an effective coupling parameter Γ^* is used. Surprisingly, the shear viscosity with this normalization follows a simple universal scaling. For $\Gamma^*>20$ and $0.5<\kappa<2$, the shear viscosity increases monotonously, and thermal motion positively affects the transport properties of dust particles.

References

[1] B. Liu and J. Goree, Physical review letters 94, 185002 (2005).

[2] Z. Donkó, J. Goree, P. Hartmann, and K. Kutasi, Phys. Rev. Lett. 96, 145003 (2006).

P 17.5 Thu 16:45 CHE/0089

Neural network based surrogate models for tokamak exhaust — •Stefan Dasbach and Sven Wiesen — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany

For the design of future tokamak fusion reactors the heat transport in the scrape-off layer is a major challenge. A simulation can test only a single configuration at once and is computationally demanding, making it impossible to fully explore the high dimensional design parameter space with simulations alone. A promising approach to circumvent this is to use machine learning models trained on simulation data as surrogate models. After training such models can produce fast results for any configuration in the explored parameter space and could be used for rapid design studies of tokamak reactors or coupled with other models such as tokamak flight simulators or reactor control schemes. For the development of such models we created a dataset of 10.000 2D SOLPS-ITER simulations with reduced physical complexity. The simulations have eight varied parameters including a tokamak size scaling. Using this dataset neural networks are trained either to predict the electron temperatures in the whole 2D simulation domain or solely at the 1D divertor target. The accuracies of the network predictions in different physical regimes are evaluated and different network architectures are compared.

P 17.6 Thu 17:00 CHE/0089

Towards Machine-Learned Poisson Solvers for Low-Temperature Plasma Simulations — •Ihda Chaerony Siffa[1,2], Markus M. Becker[1], and Jan Trieschmann[2] — [1]Leibniz Institute for Plasma Science and Technology (INP), Felix-Hausdorff-Straße 2, 17489 Greifswald, Germany — [2]Kiel University, Kaiserstraße 2, 24143 Kiel, Germany

In multi-dimensional self-consistent low-temperature electrostatic plasma simulations, the computational effort for solving the Poisson equation can represent a large part of the overall evaluation runtime. Recently, it has been shown that by using machine learning (ML) techniques, in particular artificial neural networks (ANN), one can arrive to solutions of the Poisson equation faster (and with promising accuracy) than using the conventional numerical methods. However, the currently proposed ML-based Poisson solvers still fall short for being widely applicable in low-temperature plasma simulations, which may employ complex geometries, mixed boundary condition, etc. In this work, the requirements for making ML-based Poisson solvers applicable in low-temperature plasma simulations are discussed. Furthermore, a machine-learned Poisson solver that attempts to tackle these requirements is presented, with examples from dielectric barrier discharge (DBD) geometries. First results suggest that supervised training of an ANN with spatially dependent simulation properties and corresponding ground truth electric potential solutions allows for a machine-learned Poisson solver that generalizes well to various geometric and material configurations.

P 18: HEPP VII

Time: Thursday 15:45–17:00 Location: CHE/0091

P 18.1 Thu 15:45 CHE/0091

Electron kinetics in a high-Z plasmoid — •Alistair M. Arnold[1], Pavel Aleynikov[1], and Boris N. Breizman[2] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Deutschland — [2]Institute for Fusion Studies, University of Texas at Austin, Austin, TX, USA

The problem of the electron dynamics on a closed magnetic field line passing through a high-Z plasmoid is considered. The electron kinetic equation is integrated over bounce motion and pitch-angle, reducing the independent variables to a single adiabatic invariant plus time. Integration of the full Landau self-collision operator is carried out exactly, resulting in a nonlinear integro-differential operator in the new invariant. Conservation laws and the H theorem of the integrated self-collision operator are proven. Numerical solutions of the integrated kinetic equation are obtained with a self-consistent quasineutral electric potential, given the initial condition of a cold plasmoid immersed in a hot ambient plasma. The fact that cold electrons are deeply trapped in a potential with a parabolic peak leads to exactly 3/4 the usual rate of collisional heating by the ambient plasma, independent of any other parameters.

P 18.2 Thu 16:10 CHE/0091

Grad-Zhdanov multi-ion collisional closure for fluid edge codes — •Sergei Makarov and David Coster — Max-Planck-Institut für Plasmaphysik, D-85748 Garching, Germany

Moments of the distribution function form an infinite sequence of fluid equations. For the specific cases, this system can be cut to the finite amount of equations. For doing this we use, so called closure. In collisonal plasmas, which can be observed in the Edge and Scrape-off layer (SOL) in fusion magnetic devices, a collisional closure can be applied. When the impurity mass is significantly larger than the mass of the main ions the multispecies extension of the single ion Braginskii approach can be applied. However, for ions with close masses the Grad-Zhdanov 21N-moment method should be used for the transport coefficients estimation. It is necessary, for example, when He plasmas or D-T plasmas are considered. This approach takes into account masses of ions for kinetic coefficients calculation. It is the major improvement in comparison to the previous approach applied for the SOLPS-ITER code. Only hydrogen isotope plasma with heavy impurities could be treated by SOLPS-ITER versions prior to 3.0.8. This approach is implemented into the SOLPS-ITER code for multiple ion parallel transport description in collisional plasmas. The particular approach is discussed in. The complete multi-ion generalization of the SOLPS-ITER code has been preformed without explicit separation between main and impurity species. The new code is tested for the He and D-T mixtures. The new effects coming from the improved multi-ion treatment are analyzed.

P 18.3 Thu 16:35 CHE/0091

AI based Larde Eddy Simulations for Turbulence in Fusion Reactors — •Robin Greif[1], Frank Jenko[1], and Nils Thuerey[2] — [1]Max-Planck Institute for Plasma Physics, Garching bei München, Germany — [2]TUM Department of Mathematics, Garching bei München, Germany

In this talk, we demonstrate the effectiveness of using hybrid AI and numerical methods to produce practically endlessly stable turbulence simulations conserving physical, spectral, and statistical properties. Specifically, we look at the two-fluid Hasegawa-Wakatani model discretized in two spatial dimensions used for simulating drift wave turbulence in fusion reactors. The presented hybrid AI predictor-corrector model in the large eddy domain allows for reducing complexity by three orders of magnitude with negligible losses.

P 19: Magnetic Confinement V/HEPP VIII

Time: Thursday 17:30–18:40 Location: CHE/0089

Invited Talk P 19.1 Thu 17:30 CHE/0089

Numerical and experimental investigations of a linear microwave plasma source for metal foil pumps for DEMO — •Stefan Merli[1], Andreas Schulz[1], Matthias Walker[1], Yannick Kathage[2], Stefan Hanke[2], Christian Day[2], and Günter Tovar[1] — [1]IGVP, University of Stuttgart, Stuttgart, Germany — [2]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

In future fusion power plants like DEMO, minimizing the tritium fuel inventory is a critical design issue. Hydrogen isotopes have to be separated from the exhaust gas close to the diverter so that they can be immediately recirculated. At KIT a direct internal recycling system is being developed using a metal foil pump (MFP) which can selectively separate hydrogen isotopes by superpermeation even against a pressure gradient. For this process to work, the hydrogen must be in the form of atoms or ions, which is achieved with a linear microwave plasma source, the Duo-Plasmaline.

Since the Duo-Plasmaline is an integral part of the MFP, hydrogen plasmas from the Duo-Plasmaline are being investigated numerically and experimentally at the University of Stuttgart. In the numerical model the transport of electrons and heavy species are calculated self-consistently with the microwave el. field and a reduced set of plasma chemical reactions. Since the MFP will be in close proximity to the torus, the influence of strong magnetic fields up to 1 T is investigated. The results are compared to investigations in the experiment FLIPS with up to 250 mT. Results of the performance of the Duo-Plasmaline and the MFP from the HERMESplus experiment are presented as well.

P 19.2 Thu 18:00 CHE/0089

Physics-informed machine learning to approximate the ideal-MHD solution operator in Wendelstein 7-X configurations — •Andrea Merlo, Daniel Böckenhoff, Jonathan Schilling, Samuel Aaron Lazerson, Thomas Sunn Pedersen, and the W7-X Team — Max-Planck-Institute for Plasma Physics, 17491 Greifswald, Germany

The stellarator is a promising concept to produce energy from nuclear fusion by magnetically confining a high-pressure plasma. Magnetohydrodynamics (MHD) describes how plasma pressure, current density and magnetic field interact. In a stellarator, the confining field is three-dimensional, and the computational cost of solving the 3D MHD equations currently limits stellarator research and design. In this work, we present data-driven approaches to provide fast 3D MHD equilibria: we describe an artificial neural network (NN) that quickly approximates the ideal-MHD solution operator in W7X configurations. The model fulfils equilibrium symmetries by construction and the MHD force residual regularizes the solution of the NN to satisfy the ideal-MHD equations. The model predicts the equilibrium solution with high accuracy, and it faithfully reconstructs global equilibrium properties (e.g., magnetic well depth). We also optimize W7X magnetic configurations, where desiderable configurations can be found in terms of fast particle confinement. Moreover, preliminary results from solving the ideal-MHD equations for a generic stellarator geometry with a physics-informed model without any ground-truth data will be presented.

P 19.3 Thu 18:25 CHE/0089

Structure splitting at the transition to self-sustained turbulence in a magnetized cylindrical plasma — •Peter Manz[1], Stefan Knauer[1], Chanho Moon[2], Nils Fahrenkamp[1], and Akihide Fujisawa[2] — [1]Institut für Physik, Universität Greifswald, Greifswald — [2]Research Institution for Applied Mechanics, Kyushu University, Kasuga

When turbulent structures split more frequently before they decay, persistent turbulence forms in neutral fluid shear flows. Whether such behavior also occurs in magnetized plasmas is investigated in the experiment PANTA. With increasing control parameter the dynamics in the magnetized plasmas is known to undergo several changes from a quasiperiodic to a phase locked to a weakly turbulent regime. When the phase-locked regime breaks down, the splitting time approaches the decreasing lifetime reflecting self-sustained turbulence, as known from the pipe flow.

P 20: Laser Plasmas III/Codes and Modeling III

Time: Thursday 17:30–18:45 Location: CHE/0091

Invited Talk P 20.1 Thu 17:30 CHE/0091

Laser-Induced Breakdown Spectroscopy (LIBS) for the detection of hydrogen isotopes stored in high-Z metals tungsten and tantalum — •Steffen Mittelmann[1], Kévin Touchet[3], Xianglei Mao[3], Minok Park[3], Vassilia Zorba[3], Sebastijan Brezinsek[2], and Georg Pretzler[1] — [1]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf — [2]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik — [3]Laser Technologies Group, Lawrence Berkeley National Laboratory, Berkeley

Laser-Induced Breakdown Spectroscopy (LIBS) is a promising technology for in-situ analysis of plasma facing components in confinement fusion experiments. It is of major interest to monitor the hydrogen isotope retention over many operation hours to guarantee the safety and lifetime of the facility. To be able to get full information of deuterium deposition in different surface layers, a LIBS setup with a high depth resolution is required. We present a comparison of such LIBS experiments with several laser systems of strongly differing parameters for optimizing the conditions. In our final study, ultra-short (ps- to fs-) UV-laser pulses were focused on tungsten and tantalum tiles that were exposed by a deuterium plasma in the linear plasma device PSI-2 at Forschungszentrum Jülich. We show that this concept can lead a Calibration-Free technique for quantitatively determining the amount of deuterium stored in the tiles under investigation without a-priori knowledge on the plasma.

P 20.2 Thu 18:00 CHE/0091

Acceptance Rates of Invertible Neural Networks on Electron Spectra from Near-Critical Laser-Plasmas: A Comparison — •Thomas Miethlinger[1,2], Nico Hoffmann[1], and Thomas Kluge[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Deutschland — [2]Technische Universitat Dresden, 01069 Dresden, Germany

While the interaction of ultra-intense ultra-short laser pulses with near- and overcritical plasmas cannot be directly observed, experimentally accessible quantities (observables) often only indirectly give information about the underlying plasma dynamics. Furthermore, the information provided by observables is incomplete, making the inverse problem highly ambiguous. Therefore, in order to infer plasma dynamics as well as experimental parameter, the full distribution over parameters given an observation needs to considered, requiring that models are flexible and account for the information lost in the forward process. Invertible Neural Networks (INNs) have been designed to efficiently model both the forward and inverse process, providing the full conditional posterior given a specific measurement. In this work, we benchmark INNs and standard statistical methods on synthetic electron spectra. First, we provide experimental results with respect to the acceptance rate, where our results show increases in acceptance rates up to a factor of 10. Additionally, we show that this increased acceptance rate also results in an increased speed-up for INNs to the same extent. Lastly, we propose a composite algorithm that utilizes INNs and promises low runtimes while preserving high accuracy.

P 20.3 Thu 18:15 CHE/0091

Magnetohydrodynamic Simulations of a Tapered Plasma Lens for Optical Matching at the ILC e^+ Source — •Manuel Formela[1], Gudrid Moortgat-Pick[1], Niclas Hamann[1], Gregor Loisch[2], Mathis Mewes[2], Maxence Thévenet[2], and Jens Osterhoff[2] — [1]University of Hamburg, Hamburg, Germany — [2]Deutsches Elektronen Synchrotron DESY, Hamburg, Germany

The International Linear Collider is a planned electron-positron linear collider with its positron source producing positrons by exposing a target to undulator radiation. The resulting, highly divergent positron beam requires optical matching to improve its luminosity and therefore the success of the collision experiments. Here, optical matching refers to capturing particles, i.e. making them available for downstream beamline elements. In the past, this has been done with sophisticated coils, but recently the usage of a current-carrying plasma, a plasma lens, has been proposed. For the International Linear Collider particle tracking simulations have already concluded with an optimal plasma lens design with respect to the captured positron yield. This design is characterized by a linearly widening radius in beam direction. Now further research and development is required, including both experiments with a prototype set-up as well as simulations modeling the hydrodynamics of the current-carrying plasma and the resulting magnetic field. The accuracy of the latter will benefit greatly from the former. First results of these magnetohydrodynamic simulations are discussed in this work.

P 20.4 Thu 18:30 CHE/0091

1D Vlasov simulations of the Windowless Gaseous Tritium source of the Karlsruhe Tritium Neutrino experiment — •Anna Josephine Schulze and Felix Spanier — University of Heidelberg

The aim of the Karlsruhe Tritium Neutrino (KATRIN) experiment is to precisely determine the neutrino mass by measuring the electron energy spectrum of the tritium-beta-decay. The high energy of this decay is also the reason for a plasma to develop inside the windowless gaseous tritium source (WGTS). Interactions between the plasma and metallic walls lead to the formation of a plasma sheath and with it an electrostatic potential arises. This can modify the resulting energy spectrum. Therefore, the behaviour of the plasma and especially its wall-interaction was estimated using a 1D simulation. It is based on solving the Vlasov-Poisson system with an Eulerian scheme to compute the electric potential along the middle axis of the tritium source. This technique allows for stronger density gradients as well as atomic processes to be considered. In general, however, it is more computationally expensive than a particle-in-cell method. Initial results yield a plasma potential of $\Delta\phi = 0.047$ V and show a backflow of electrons, leading to the development of a two-stream instability in the plasma. Currently, the code is further developed to simulate a larger area of the WGTS and to consider more effects, including recombination.

P 21: Members' Assembly

Time: Thursday 19:00–20:00 Location: CHE/0089

All members of the Plasma Physics Division are invited to participate.