P 5: Poster Session 1

Time: Monday 16:30–18:30 Location: Empore Lichthof

P 5.1 Mon 16:30 Empore Lichthof

Statistical analysis of confinement data from pellet fuelled high-density plasmas in ASDEX Upgrade — •Tobias Engelhardt[1,2], Otto Kardaun[2], Peter Lang[2], Martin Prechtl[1], and Asdex Upgrade Team[2] — [1]Hochschule Coburg — [2]Max-Planck-Institut für Plasmapysik

A dataset of pellet-fuelled discharges in the high density regime of ASDEX Upgrade (AUG) has been collected, covering 8 years of operation. It comprises scenarios with moderate performance, as well as attempts to achieve high performance by applying either N-seeding or high shaping. This data shows that the H06 scaling, see [1], is more appropriate to describe plasma confinement in this regime, than the H98(y,2) scaling. Additionally, the enhanced confinement gained by the different methods cannot be maintained when the density n_e exceeds the Greenwald density n_{Gw}. Confidence bands, obtained from statistical analysis confirm this feature. According to observations at JET (with carbon wall), see [2], higher H-factors (H98(y,2)) at constant n_e/n_{Gw} were observed when the triangularity δ was increased. Whether this trend is also present at AUG (with tungsten first wall), will be investigated. The reduced confinement when exceeding n_{Gw} can possibly be attributed to a rising separatrix density $n_{e,sep}$. The approximation that primarily the divertor density n_0^{Div} influences $n_{e,sep}$, see [3], is somewhat simplified. Therefore, potential other correlations between $n_{e,sep}$ and other plasma physical parameters will be analysed. [1] J. Johner, FST 59 (2010) 308 [2] V. Mukhovatov et al., PPCF 45 (2003) A235 [3] A. Kallenbach et al., PPCF 60 (2018) 308

P 5.2 Mon 16:30 Empore Lichthof

Comparison of Spatiotemporal Turbulent Structures Measured with Doppler Reflectometry in the Tokamak ASDEX Upgrade with Gyrokinetic Simulations — •David Stockinger[1,2], Klara Höfler[1,2], Tim Happel[2], Tobias Görler[2], Ulrich Stroth[1,2], and the ASDEX Upgrade Team[2] — [1]Physics Department TUM, E28, Garching, Germany — [2]Max Planck Institut für Plasmaphysik, Garching, Germany

Plasma turbulence drives transport of particles and energy in magnetically confined fusion plasmas and thus determines the energy confinement, which is of key importance for the development of a fusion reactor. A better knowledge of the turbulence properties is crucial for the prediction of the performance of future devices. Theory develops gyrokinetic simulation codes to describe the turbulence and its associated particle and heat transport. In order to comprehensively test the physical models implemented is such codes, detailed comparison with experiment is required. On the ASDEX Upgrade tokamak, Doppler reflectometry is used to measure turbulence properties at various structure sizes. The strategy for the comparison of experimental data and equivalent quantities deduced from simulation results will be presented together with the first measurements.

P 5.3 Mon 16:30 Empore Lichthof

Improving Tokamak pedestal prediction — •Jonas Puchmayr[1,2], Mike Dunne[2], and Hartmut Zohm[2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Schellingstraße 4, D-80799 München — [2]Max-Planck-Institut für Plasmaphysik, D-85748 Garching bei München

The high confinement mode (H-mode) is a regime where self-organized suppression of turbulence in the edge region leads to increased profile gradients. The pedestal is limited by the occurrence of edge localized modes (ELMs), quasi-periodic bursts of particles and energy at the plasma edge. ELMs can be described as coupled peeling-ballooning modes in an MHD framework where the edge pressure gradient and current density provide the free energy to create an instability. The EPED framework is a predictive model which calculates the bootstrap current and uses equilibrium and stability codes to scan intermediate toroidal mode numbers. The pedestal width is self-consistently determined by a scaling law, which in later versions of EPED is proposed to be a kinetic ballooning mode (KBM). For high triangularities, the EPED model predicts enhanced pedestal pressure, the Super H-mode. In this work, the EPED model was improved by implementing a more accurate bootstrap model and scanning a wider range of toroidal modes. The effect of including lower mode numbers, using a critical gradient instead of the KBM is analyzed and different bootstrap models on the predicted pedestal are shown. Recovering published Super H-mode results from other machines and extending the model to ASDEX Upgrade is envisaged.

P 5.4 Mon 16:30 Empore Lichthof

Pedestal turbulence studies with means of O-mode correlation reflectometry on EAST — •Haoming Xiang[1,2], Tao Zhang[2], Xiang Gao[2], Fei Wen[2], Yumin Wang[2], Xiang Han[1,2], Jianbin Liu[2], Andreas Krämer-Flecken[1], and Yunfeng Liang[1] — [1]Institut für Energie- und Klimaforschung, Forschungszentrum Jülich, 52425 Jülich — [2]Institute of Plasma Physics, Chinese Academy of Sciences, PO Box 1126, Hefei, Anhui 230031, People's Republic of China

A multi-frequency ordinary-mode correlation reflectometer has been developed and operated on EAST to measure plasma electron density fluctuations. Simultaneous four-frequency operation makes it possible to measure the correlation between fluctuations at different radially separated cut-off layers. Furthermore, two poloidally spaced receiving antennas allows to investigate the correlation between fluctuations at different poloidal positions and thus determine of turbulence velocity. During the EAST experimental campaign in 2018, a low-frequency coherent mode($f \approx$ 1kHz) in the pedestal region during the ELM-free phase is investigated. Magnetic probes measurements show that the low frequency mode exhibits a structure of toroidal number (n=0) and poloidal number (m=1). Correlation reflectometer analysis show that there is no phase difference radially, i.e., not a radial traveling wave. Further study shows that pedestal density fluctuation and thus the pedestal density/density gradient are modulated by this low-frequency mode,the measurements will be discussed in this presentation.

P 5.5 Mon 16:30 Empore Lichthof

Disentanglement of density and rotation dependences of the field penetration threshold on the J-TEXT tokamak — •Zhuo Huang[1,2], Yunfeng Liang[1,2,3], Qiming Hu[4], Nengchao Wang[1], Da Li[1], Xiaoyi Zhang[1], Bo Rao[1], Zhipeng Chen[1], Song Zhou[1], Qi Zhang[1], Chengshuo Shen[1], Ying He[1], and Yonghua Ding[1] — [1]International Joint Research Laboratory of Magnetic Confinement Fusion and Plasma Physics, Huazhong University of Science and Technology, Wuhan, 430074, People*s Republic of China — [2]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung * Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [3]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, People*s Republic of China — [4]Princeton Plasma Physics Laboratory, Princeton University, P.O. Box 451, New Jersey 08543, USA

Penetration of perturbed fields into the magnetized plasma is a fundamental issue in fusion plasmas. The field penetration threshold of magnetic perturbations has been observed to vary non-monotonically with an increase of density in ohmic plasmas on the J-TEXT tokamak. This observation appears contradicting the previous empirical density scaling law. Disentanglement of plasma density and rotation dependences of the field penetration threshold has been carried out. It shows that the field penetration threshold depends only weakly on the density but linearly on the plasma rotation. This result is important for the prediction of error field tolerance in fusion devices.

P 5.6 Mon 16:30 Empore Lichthof

Local radiated power sensitivity and intrinsic impurity correlation analysis at the stellarator Wendelstein 7-X — •Philipp Hacker, Felix Reimold, Daihong Zhang, Rainer Burhenn, and Thomas Klinger — Max-Planck Institute for Plasma Physics, Greifswald, Germany

The two-camera resistive bolometer system at the stellarator Wendelstein 7-X with its blackened gold absorbers has provided a real time evaluation of the total radiated power for plasma feedback during the last experiment campaign. Based on the assumption of poloidal symmetry the radiated power loss of the plasma can been estimated independently for both cameras and each channel from line-integrated measurements. Using a limited set out of the total available fan of sight lines covering most radial emission shells the radiation level was calculated for plasma feedback control with fast auxiliary gas fueling as an actuator. Investigations regarding the best set of sight lines predicting the radiated power loss have been done for all camera and channel combinations as well as different mathematical weighting methods. Normalisation with individual cross correlations functions of single line integrated signals yields a set of channels with particular relevance for the total radiated power. Incorporating results from the 1-D impurity transport code STRAHL and spectroscopic diagnostics we attempt to link the contribution of different intrinsic impurities to the loss distribution.

P 5.7 Mon 16:30 Empore Lichthof

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

In a pair plasma, both particle species have the same mass. Compared to an electron–ion plasma, a pair plasma is predicted to have unique characteristics and excellent stability properties. A Positron–Electron eXperiment (APEX) has the goal to create such a kind of plasma in a magnetic dipole trap for the first time. An important step towards this goal is to know how parameters of the experiment, such as electrode biases, effect the radial deposition of positrons in the magnetic dipole field. For that, we reanalyzed experimental data, compared them to numerical single-particle simulations, and found multiple parameters that modify the radial deposition of positrons without deteriorating the required high injection efficiency. These results can be used to design upcoming experiments about long confinement and pulse stacking.

P 5.8 Mon 16:30 Empore Lichthof

Positron accumulation in Multicell Penning traps — •Martin Singer[1], Stephan König[2], Lutz Schweikhard[2], Gerrit Marx[2], Cliff Surko[3], James Danielson[3], and Thomas Sunn Pedersen[1] — [1]Max-Planck-Institut für Plasma Physik, Wendelsteinstraße 1, 17491 Greifswald, Germany — [2]Institut für Physik, Universität Greifswald, Felix-Hausdorff-Straße 6, 17489 Greifswald, Germany — [3]Physics Department, University of California, San Diego, 9500 Gilman Drive, La Jolla, California 92093, USA

Positron-electron plasmas, also pair plasmas, have not yet been studied experimentally. Due to their equal mass, many features that can be found in electron-ion plasmas will not occur in pair plasmas, and they are expected to be extraordinarily stable when magnetically confined. The APEX collaboration aims to create the first pair plasma with a spatial dimension of several Debye lengths so that collective behavior will be observable. To create such a plasma great care has to be taken since positrons are naturally rare. One crucial part is the accumulation of large numbers of moderated positrons. Therefore, a device is needed which is capable of storing up to 10^{12} positrons without heating and particle loss. One solution is the Multicell Penning trap (MCT) concept, which separates the space charge of the positrons into multiple radially arranged Penning traps. We will present first measurements with electrons stored in a single Penning trap in Greifswald and plans for the development of a MCT. This MCT will be used to confine plasmas simultaneously in different cells, investigate the confinement and different injection as well as ejection schemes.

P 5.9 Mon 16:30 Empore Lichthof

Investigation of disruptions at JET using interpretable machine learning methods. — •Victor Artigues and Frank Jenko — Max Planck Institute for Plasma Physics, Boltzmannstr.2, 85748 Garching, Germany

The sudden losses of plasma control in tokamaks, called disruptions, remain one of the main problems on the path towards fusion-based power plants. To address this problem, in parallel with the physics-based approaches, more and more data driven methods have been developed recently. These approaches compile a database made of disruptive shots and safe shots, and use more or less complex machine learning methods to answer different questions such as: disruption prediction, disruption type identification, transfer to future tokamaks,...

Although using complex machine learning algorithms have proven to be very powerful in many different domains, they often work as black-boxes and little knowledge can be extracted from them. This lack of interpretability slows the adoption of machine learning methods in, among others, the field of physics.

In an attempt to better understand the predictions, we investigate a two-step method. First, we train a standard recurrent neural network, the teacher, for disruption prediction. And in a second step, we train a student neural network, based on shapelets, to reproduce the results of the first. The teacher's goal is to provide a plausible prediction for the badly labeled data while the student network aims at providing insight into the decision through the learned shapelets.

P 5.10 Mon 16:30 Empore Lichthof

Integrated Data Analysis 2.0 — •Michael Bergmann, Frank Jenko, Rainer Fischer, and the ASDEX Upgrade Team — Max-Planck-Institute für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Using a combined analysis of multiple diagnostics as well as Bayesian probability theory the Integrated Data Analysis (IDA, see [Fischer 2010]) is capable of providing density and temperature radial profiles of ASDEX-Upgrade plasmas. These profiles can then be fed into transport codes for the simulation of discharges. Since IDA considers uncertain measurement data from a heterogeneous set of diagnostics but no transport physics, the estimated profiles and their gradients can be in contradiction to the profiles from transport solvers. Using existing transport solvers such as ASTRA and TGLF we have created a loop in which simulated profiles are fed back into IDA as another pseudo-measurement thus providing constraints about the physically reasonable parameter space. This work feeds into a broader effort to make IDA more robust against measurement uncertainties by using multiple transport solvers including machine learning in a multi-fidelity approach.

P 5.11 Mon 16:30 Empore Lichthof

Runaway electron modeling in massive material injection scenarios in ASDEX Upgrade — •Oliver Linder, Emiliano Fable, Frank Jenko, Gergely Papp, Gabriella Pautasso, and the ASDEX Upgrade Team — Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany

In current-carrying fusion devices, the conversion of a large fraction of the plasma current to runaway electrons (RE) following the sudden loss of thermal energy poses a threat to the integrity of the plasma vessel. However, RE formation may be suppressed by massive material injection (MMI); a concept presently being investigated experimentally across various devices. To complement extrapolation to future devices, RE model development and validation is mandatory.

This work reports on simulations of MMI scenarios in ASDEX Upgrade (AUG) with the transport toolset ASTRA-STRAHL, where recently developed (fluid) models for RE generation have been implemented. It is shown, that correct simulation of material penetration and consideration of the impact of partially ionized impurities on RE formation are a prerequisite to capture the RE response in AUG argon injection discharges. Within this framework, edge gas injection simulations for varying impurity amounts and types (such as D, Ne, Ar, Kr) are performed and compared to experimentally observed trends in RE behavior.

P 5.12 Mon 16:30 Empore Lichthof

Fast neural network surrogates for VMEC MHD equilibrium code — •Andrea Merlo, Daniel Böckenhoff, Thomas Sunn Pedersen, and The W7-X Team — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

MHD equilibrium codes, such as VMEC or PIES, are widely used among the fusion community for a variety of applications, ranging from MHD stability to reconstruction of plasma parameters. However, these codes usually require long computing times to converge, ranging from tens to hundreds of seconds per plasma configuration, preventing their adoption in real-time control scenarios or within extensive optimization runs. Data-driven methods for physical simulation codes allow to trade offline computation and memory footprint in favor for improved runtime performance. We are developing two machine-learning methods which act as fast surrogates for the VMEC code. These approaches comprise a Deep Neural Network (DNN) and a Physics-informed Neural Network (PiNN), where physical information regarding the system is provided via learning function. Additionally, to enable efficient training processes, our methods include subspace simulation techniques.

P 5.13 Mon 16:30 Empore Lichthof

Soft X-ray survey of high-performance experiments in Wendelstein 7-X — •Jonathan Schilling, Henning Thomsen, Christian Brandt, Sehyun Kwak, Jakob Svensson, and the W7-X - Team — Max-Planck-Institut für Plasmaphysik

Soft X-ray radiation emitted from a high-temperature plasma can be used to infer local information about the plasma temperature and density. The soft X-ray tomography diagnostic XMCTS in the superconducting stellarator Wendelstein 7-X has been used in the latest operational phases OP1.2a and OP1.2b to measure the soft X-ray radiation from the plasma in one plane of constant toroidal angle. Recent upgrades of the diagnostic model made it possible to compute tomographic inversions of the soft X-ray emissivity throughout the whole available dataset from OP1.2a and OP1.2b, even though significant influence of diagnostic effects have to be modelled along with the tomography. On this poster, a survey of the soft X-ray data focused on the high-performance experiments conducted in Wendelstein 7-X is presented. One aspect of this dataset is the direct measurement of the Shafranov shift due to high plasma pressure and quantitative comparison against theoretical predictions from equilibrium reconstructions.

P 5.14 Mon 16:30 Empore Lichthof

Low frequency fluctuations measured by soft X-ray and Mirnov diagnostic at the Wendelstein 7-X stellarator — •Sara Mendes, Christian Brandt, Kian Rahbarnia, Jonathan Schilling, Henning Thomsen, and Wendelstein 7-X Team — Max-Planck-Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

During the last divertor campaign at the Wendelstein 7-X (W7-X) stellarator fluctuations starting at a few kHz up to about 400 kHz have been observed by various diagnostics. Predominantly lower frequency components (<100 kHz) were found in the soft X-ray (SXR) intensities detected by the SXR tomography system XMCTS, a poloidal camera array with 360 lines-of-sight. Similar and slightly higher magnetic broadband fluctuations have been measured by the Mirnov diagnostic, which consists of 125 individual coils located in four out of five modules of W7-X. Part of the observed frequencies fit well into theoretically predicted gaps in corresponding Alfvén continua, but to ensure a precise analysis of the underlaying mode structures, a complete amplitude and phase calibration including all relevant data acquisition components is necessary, as it is performed for the Mirnov diagnostic. The nature of the observed mode activity specifically for the lower frequency components is discussed.

P 5.15 Mon 16:30 Empore Lichthof

Core plasma density fluctuations in Wendelstein 7-X — •Jan-Peter Bähner[1], Adrian von Stechow[1], Zhouji Huang[2], Jorge Alcuson[1], Eric Edlund[3], Miklos Porkolab[2], Olaf Grulke[1,4], and The W7-X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [2]MIT Plasma Science and Fusion Center, Cambridge, MA, USA — [3]SUNY Cortland, Cortland, NY, USA — [4]Technical University of Denmark, Kongens Lyngby, Denmark

Recent analysis of Wendelstein 7-X experiments have shown that the ion heat diffusion in W7-X is dominated by anomalous transport processes. Consequently, the ion temperature is significantly smaller than expected from neoclassical transport estimates. Ion-scale turbulence is expected to be the main driver for anomalous transport, with the major instabilities on this scale being the ion temperature gradient (ITG) driven mode and the trapped electron mode (TEM).
The Phase Contrast Imaging (PCI) diagnostic provides density fluctuation measurements with temporal and wavenumber resolution spanning the ITG and TEM scales. A recent calibration of the wavelengths and relative fluctuation amplitudes measured by PCI for the majority of W7-X discharges enables a comparison of density fluctuations between a wide range of discharges. Investigations on the impact of magnetic configuration, heating power and density on the density fluctuations are presented, as well as linear growth rate calculations. Core plasma turbulence in W7-X will be characterized by fluctuation level, dominant phase velocity, and wavenumber distribution.

P 5.16 Mon 16:30 Empore Lichthof

Preparation of Triton Burn-Up Studies in Future Deuterium Plasmas of Wendelstein 7-X — •Jan Paul Koschinsky[1], Christoph Biedermann[1], Sergey A. Bozhenkov[1], Monika Koleva[2], G. A. Wurden[3], Andreas Zimbal[4], Robert C. Wolf[1], the W7-X Team[1], and the ASDEX Upgrade Team[2] — [1]Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, D-17491, Greifswald, Germany — [2]IPP, Garching — [3]LANL, US — [4]PTB, Braunschweig

Fast ion confinement is crucial for realizing burning fusion plasmas, both in tokamaks and stellarators. The possible application of a scintillating fiber neutron detector, SciFi, for studying fast ions in future deuterium plasmas of the Wendelstein 7-X stellarator, is investigated here.
In deuterium plasmas, 2.5 MeV neutrons and 1 MeV tritons are generated via two equally probable fusion channels. Depending on confinement and slowing-down processes, the produced tritons will fuse with the surrounding deuterons. This triton burn-up fusion process gives birth to 14 MeV neutrons. Triton burn-up is studied with SciFi, which can discriminate between 14 MeV and 2.5 MeV neutrons.
The characterization of the SciFi detector, utilizing a mono-energetic neutron source at the German National Metrology Institute, PTB Braunschweig, and triton burn-up studies at the ASDEX Upgrade tokamak are presented. An update of a one-dimensional neutron rate estimation for purely ECRH heated W7-X deuterium plasmas is also given.

P 5.17 Mon 16:30 Empore Lichthof

Gyrokinetic investigation of the damping channels of Alfvén modes in ASDEX Upgrade — •Francesco Vannini, Alessandro Biancalani, Alberto Bottino, Thomas Hayward-Schneider, Philipp Lauber, Alexey Mishchenko, Ivan Novikau, Emanuele Poli, and ASDEX Upgrade Team — Max Planck Institute for Plasma Physics, Garching (Germany)

The linear destabilization and nonlinear saturation of energetic-particle driven Alfvénic instabilities in tokamaks strongly depend on the damping channels. In this work, the collisionless damping mechanisms of Alfvénic modes are investigated within a gyrokinetic framework, by means of global simulations with the particle-in-cell code ORB5, and compared with the eigenvalue code LIGKA and reduced models. In particular, the continuum damping and the Landau damping (of ions and electrons) are considered. The electron Landau damping is found to be dominant on the ion Landau damping for experimentally relevant cases. As an application, the linear and nonlinear dynamics of toroidicity induced Alfvén eigenmodes and energetic-particle driven modes in ASDEX Upgrade is investigated theoretically and compared with experimental measurements (see [Vannini-2019], submitted to Physics of Plasmas, arXiv:1910.14489).

P 5.18 Mon 16:30 Empore Lichthof

Fast-ion confinement studies in W7-X using active Balmer-alpha spectroscopy — •Peter Zs. Poloskei[1], Benedikt Geiger[2], Oliver Ford[1], Simppa Äkaslompolo[1], Annabelle Spanier[1], and the W7-X team[1] — [1]Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald, Greifswald, Germany — [2]University of Wisconsin, Madison, USA

Investigation of fast-ion transport in fusion plasmas plays a central role as good fast-particle confinement is essential for burning plasmas. For its recent experimental campaign, the W7-X stellarator was equipped with two neutral hydrogen beam injectors (NBI) which provide fast-particles of our interest and neutral hydrogen particles which make active Balmer-alpha spectroscopy possible.

Due to the complex shape of the measured spectra forward modelling is required for its interpretation. It is done with a code called FIDASIM which takes into account different assumed kinetic plasma profiles, fast-ion densities and information of the beam- and observation geometry.

It was found that most measured spectral components are well reproducible with FIDASIM but the observed active emission, coming from the beam neutral - confined fast-ion charge-exchange reaction (FIDA) cannot fully explain the measured intensities. This suggests that fast-ions in the plasma edge region could interact with the cold neutral population from the plasma vessel, causing additional passive FIDA emission. This needs to be understood in order to address the question of edge charge-exchange fast-ion losses and to infer information on the edge neutral density.

P 5.19 Mon 16:30 Empore Lichthof

Infrared study of CH_4 conversion in a non-equilibrium O_2/He atmospheric pressure plasma jet — •Theresa Urbanietz, Christoph Stewig, Marc Böke, and Achim von Keudell — Experimental Physics II, Ruhr-University Bochum, 44780 Bochum

The dissociation of CH_4 in a non-equilibrium atmospheric pressure O_2/He plasma jet is measured for varying absorbed plasma powers and different CH_4/O_2 ratios. Space resolved measurements are performed and analyzed by Fourier transform infrared spectroscopy. This diagnostic is used to evaluate the products of the reactions which are CH_4, CO_2, CO and H_2O. By comparing the measured spectra with calculated spectra the concentration as well as the rotational and vibrational excitation of the species are determined. It is shown that the CO concentration is independent of the CH_4/O_2 ratio. The consumption of CH_4 is limited by the oxygen admixture.

P 5.20 Mon 16:30 Empore Lichthof

Atmospheric Pressure Plasma for Nano Particle Generation — •Jessica Ruhnke, Sadegh Askari, Judith Golda, and Jan Benedikt — Institute of Experimental and Applied Physics, Kiel University, Germany

Silicon nano particles have a wide range of applications from optoelectronic to photovoltaic and medicine. Atmospheric pressure plasmas are able to generate nano particles and nano crystals with excellent size control from even 1 nm diameter. However, the nano particle growth mechanism and the possible surface modifications are still not well understood and studied.

Here we present the characterization and comparison of two atmospheric pressure plasmas for nano particle generation driven by a radio frequency voltage in a mixture of Ar-He-SiH_4 gas: a smaller capillary source with planar electrodes and a bigger helix jet with specially designed electrodes. Various methods are used for analysis of the sources. Relevant plasma properties are determined by optical emission spectroscopy. The particle size can be analysed *in situ* by a 1 nm scanning mobility particle sizer and *ex situ* by Fourier-transform infrared spectroscopy and transmission electron microscopy.

P 5.21 Mon 16:30 Empore Lichthof

Spatially resolved atomic oxygen densities in the 'COST Reference Microplasma Jet' — •David Steuer, Patrick Preissing, Volker Schulz-von der Gathen, and Marc Böke — Experimental Physics II, Ruhr-University Bochum, Germany

Cold atmospheric pressure plasmas are used for activation of surfaces, etching, coating and biomedical treatments. For these applications, reactive species such as atomic oxygen are produced in the plasma and require monitoring. A non-invasive and less complex method than laser diagnostics (e.g. TALIF) is optical emission spectroscopy (OES), specifically actinometry. The method was applied to a micro-scaled atmospheric pressure plasma jet, namely the COST-Jet [1]. The capacitively coupled 13.56 MHz RF-discharge can be observed through quartz plates. The discharge channel is imaged on a fast, gated intensified CCD camera via electronically tunable filters. This setup allows ns-resolved measurements of oxygen and argon (actinometer gas) transitions, whereby the wavelength (550-1000 nm) can be switched within 100 ms, giving the opportunity to acquire a set of several spectral lines in a few seconds. A spatial resolution is given by a single measurement through the imaging of the complete discharge channel. Typical oxygen densities of 10^{15} cm^{-3} are obtained, which correspond to TALIF measurements.

[1] J. Golda et al., J. Phys. D: Appl. Phys. 49 (2016) 084003.

P 5.22 Mon 16:30 Empore Lichthof

Study of a 2.45 GHz plasma torch for synthesis of fused silica: operation with different $Ar - O_2$ mixtures — •M. Stankov[1], T. Trautvetter[2], H. Baierl[2], R. Methling[1], F. Hempel[1], J. Schäfer[1], M. Baeva[1], R. Foest[1], and D. Loffhagen[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), 17489 Greifswald, Germany — [2]Leibniz Institute of Photonic Technology (IPHT), 07745 Jena, Germany

Simulation analysis and experimental studies of a 2.45 GHz (μW) torch are presented. The device is suitable for the deposition of synthetic fused silica including a simultaneous co-doping with Al-Yb-F. The plasma is generated in a quartz tube positioned in normal direction to a rectangular wave guide R26, at the maximum electric field (TE10). $Ar - O_2$ mixtures are fed through the tube and drive the discharge which develops in the tube outwards through the nozzle where the torch is formed. For investigations on material synthesis, the system can be completed by an external supply for the injection of precursors into the torch and a rotating substrate. The plasma is simulated using a time-dependent, 2D numerical model considering the plasma kinetics, the energy conservation of electrons and heavy particles, the electromagnetic field and the gas flow. The study comprises different gas compositions from pure Ar to pure O_2. The gas temperature is calculated and compared with results from optical emission spectroscopy where OH emissions are exploited to simulate the prevalent gas temperature. The experiments are complemented by IR thermography. (Supported by Leibniz-Gemeinschaft SAW-2017-IPHT-1)

P 5.23 Mon 16:30 Empore Lichthof

Study of the local segregation of multi-component powders during a plasma spray process — •Thorben Kewitz[1], Holger Testrich[1], Antje Quade[1], Katja Fricke[1], Maik Fröhlich[1,2], Rüdiger Foest[1], and Klaus-Dieter Weltmann[1] — [1]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany — [2]University of Applied Sciences Zwickau, Zwickau, Germany

Plasma spraying is an atmospheric pressure coating process. The coatings can be utilized e.g. for wear, corrosion and heat protection or for biomedical applications. The use of powder mixtures consisting of different components allows the extension of specific coating properties. For instance, by addition of a small amount of Cu to TiO2 powder antimicrobial coatings on implant surfaces can be achieved. Our investigations show that the different powders in the mixture can segregate during the plasma spray process on the way from the injection to the substrate. The segregation of the different powders can be ascribed to different material densities and particle sizes (a few tens microns in diameter) of the constituents. The segregation causes gradients in the chemical composition of the coating. During static deposition experiments with mixtures of TiO2 and 3% Cu, a segregation of the resulting profiles of up to 2 cm was observed and verified by XPS analysis. Depth profiles were prepared and analyzed with SEM. The results show that it is important that the particle sizes are selected carefully considering also the material densities as prerequisite for spatially homogeneous coatings. Yet, the segregation can also be used for generating coatings with controlled material gradients.

P 5.24 Mon 16:30 Empore Lichthof

Preliminary investigation of the island divertor configuration by applying 4/1 RMP on the J-TEXT tokamak — •song zhou[1,2], yunfeng liang[1,2,3], nengchao wang[2], bo rao[2], yonghua ding[2], and the j-text team[2] — [1]Institute of Energy and Climate Research, Plasma Physics IEK-4, Forschungszentrum Juelich GmbH, Juelich, Germany — [2]International Joint Research Laboratory of Magnetic Confinement Fusion and Plasma Physics, Huazhong University of Science and Technology, Wuhan, China — [3]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, China

The high heat load on divertor target plate is one of the essential issues for future fusion reactors. The island divertor configuration is a good way to reduce the peaking heat load on the target and also screen the impurity, which is proposed first in 1977 for tokamak but successfully established in various stellarators. In the last campaign of J-TEXT tokamak, an experimental attempt have been made to form an island divertor configuration by using the external resonant magnetic perturbation (RMP) with dominate m/n = 4/1 component. Once the 4/1 locked island has been excited, the radial and poloidal profiles of the floating potential, the intensity of CIII radiation varied significantly. The poloidal profiles of the floating potential measured at the limiters, varied during the formation of 4/1 locked island, indicating the impact of the 4/1 island on the footprints. However, the present RMP is not enough strong to excite a wider edge island, i.e. the width of island is smaller than the critical size. The preliminary design for building a new set of island divertor coils will also be discussed.

P 5.25 Mon 16:30 Empore Lichthof

LEIS Investigation of Cr Segregation in WCrY — •Hans Rudolf Koslowski[1], Janina Schmitz[1,2], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung – Plasmaphysik, 52428 Jülich, Germany — [2]Department of Applied Physics, Ghent University, 9000 Ghent, Belgium

The temperature driven segregation of Cr to the surface of the tungsten-based W-11.4Cr-0.6Y (wt%) alloy is analysed with low energy ion scattering (LEIS) which probes only the composition of the outermost monolayer due to its high surface sensitvity.

The surface concentration of Cr increases slightly when the temperature of the sample is increased up to 700 K and exhibits a much stronger increase when the sample temperature is further raised. At a temperature of 1000 K LEIS detects almost no W atoms on the surface. A segregation enthalpy of 0.7 eV for Cr is obtained from the Langmuir-McLean relation. The modified surface composition due to the segregated Cr stays stable during cool-down of the sample.

Preferential sputtering is investigated using ion bombardment of 250 eV D atoms, resulting in an increase of the W surface density at room temperature. This effect is counteracted at elevated temperatures where segregation replenishes the Cr on the surface and prevents the formation of an all-W surface layer. The flux of segregating Cr atoms towards the surface is evaluated from the equilibrium between sputter erosion and segregation.

P 5.26 Mon 16:30 Empore Lichthof

Phase forming in the Be-Ti system — •Nicola Helfer[1], Jens Bröder[2], Nabi Aghdassi[1], Hans Rudolf Koslowski[1], Daniel Wortmann[2], Stefan Blügel[2], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany — [2]Forschungszentrum Jülich GmbH, Peter Grünberg Institut and Institute for Advanced Simulation, 52425 Jülich, Germany

As a possible blanket material in a future fusion reactor, phase decomposition processes of $Be_{12}Ti$, especially at reactor relevant temperatures, need to be understood. Thin film system are used as model system to elucidate temperature driven surface changes with X-ray photoelectron spectroscopy (XPS). XPS data for Be-Ti intermetallic compounds are lacking, therefore a novel fitting method is developed. Chemical shifts of each chemical environment within a phase unit cell are calculated with DFT (full-potential linearized augmented plane wave method, FLEUR code) and using Voigt profiles artificial pure phase spectra are generated. These pure phase spectra are used as eigenfunctions for the fit of experimental obtained data.

Titanium is evaporated on polycrystalline Beryllium, intermetallic phases form through annealing. At intermediate temperatures (starting at 600 K) mainly Be depleted phases form, with increasing temperature Be rich phases dominate. At high temperatures a metallic Be layer settles at the surfaces, shown by accomplishing angle resolved XPS. Possible mechanisms are segregation and diffusion but also phase decomposition, further measurements are needed to understand this.

P 5.27 Mon 16:30 Empore Lichthof

Production and characterisation of tungsten fiber-reinfoced tungsten (Wf/W) — •Daniel Schwalenberg[1,3], Jan W. Coenen[1], Johann Riesch[2], Leonard Raumann[1], Yiran Mao[1], Alexis Terra[1], Till Höschen[2], Rudolf Neu[2,3], and Christian Linsmeier[1] — [1]Institut für Energie und Klimaforschung, Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Max-Plank-Institut für Plasmaphysik, 85748 Garching bei München — [3]Technische Universität München, 85748 Garching bei München

The divertor of a fusion reactor is used for power and particle exhaust. Extreme conditions are expected in this area, leading to very high demands for material properties. Tungsten (W) satisfies many aspects of the requirements, e.g. excellent thermal properties, high sputter resistance and low hydrogen retention, but lacks mechanical robustness due to its brittleness. To improve the mechanical properties, a fibre reinforced composite material (Wf/W) has been developed. The material consists of ductile W fibres und and a brittle CVD matrix creating a pseudo-ductile behaviour, which prevents the material from failing catastrophically. In order to further characterise the material, larger amounts of Wf/W are being produced. These larger samples will be fabricated with the newly designed setups for chemical vapour deposition. As part of the qualification process of the material, the samples will undergo high heat flux tests at the ion beam facility GLADIS.

P 5.28 Mon 16:30 Empore Lichthof

The effect of Magnetic Geometry on Turbulence in Advanced Divertor Configurations — •Thomas Body, Wladimir Zholobenko, Andreas Stegmeir, David Coster, and Frank Jenko — Max-Planck-Institut für Plasmaphysik, Garching, Deutschland

Advanced Divertor Configurations (ADCs) promise improved control of the plasma exhaust in future fusion power plants such as DEMO. These alternative magnetic configurations modify the magnetic field of the SOL and divertor to achieve higher poloidal flux expansion, increased divertor parallel connection lengths and improved neutral baffling. This work will discuss the relative impact of physical mechanisms which determines the width of the directed heat- and particle-flux channels for fluid-turbulence simulations performed with GRILLIX. The advanced divertor configurations considered by the EUROFusion Work Package DTT1-ADC (namely the Snowflake, X, Super-X, Double-null divertor configurations) are compared to a 'conventional' Single-null divertor configuration. For these cases, "scaled-DEMO" simulations are performed due to computational limits. These simulations have the same magnetic geometry as the full device but have a spatial scale and parameter set similar to the COMPASS device. To investigate the effect of scaling to larger scales, we compare results for the same magnetic configuration run at several machine sizes.

P 5.29 Mon 16:30 Empore Lichthof

Viability of NN-based Predictor-Corrector Schemes for Plasma Simulations — •Robin Greif[1], Frank Jenko[1], and Nils Thuerey[2] — [1]Max-Planck-Institute für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [2]TU Munich, Boltzmannstr. 3, 85748 Garching, Germany

We investigate the viability of using neural network driven simulation methods based on novel predictor-corrector schemes developed for fluid and smoke simulations for turbulence in plasma. The approach builds on top of successful pioneering work on numerical schemes from Mantaflow and its successor, Phi-Flow, a soon to be published data-driven first framework for fluid and smoke simulations. In this project, we extend Phi-Flow to solve the Hasegawa-Wakatani equations as a proof-of-concept of the viability of modern neural-network based numerical simulation techniques for simple plasma models. The use of deep-learning based numerical integration schemes explored here has been shown to provide superior accuracy at coarser grids than classical methods in fluid simulations and is a promising candidate to reduce the computational cost for the next generation of plasma simulations.

P 5.30 Mon 16:30 Empore Lichthof

Hybrid kinetic-MHD simulations using structure-preserving numerical methods — •Florian Holderied[1,2], Stefan Possanner[1,2], Ahmed Ratnani[3], and Xin Wang[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstrasse 2, 85748 Garching, Germany — [2]Technical University of Munich, Arcisstraße 21, 80333 München, Germany — [3]Mohammed VI Polytechnic University, Lot 660, Hay Moulay Rachid Ben Guerir, 43450, Morocco

Classical numerical methods do generally not guarantee anything about the preservation of invariants the simulated model, i.e. the set of partial differential equations, possesses on the continuous level, e.g. conservation of energy or the two divergence constraints arising in electrodynamics, $\nabla\cdot\mathbf{E} = \rho/\epsilon_0$ and $\nabla\cdot\mathbf{B} = 0$. However, as shown by Arnold, Falk and Winther (2010), the preservation of such invariants goes hand in hand with numerical stability. In order to ensure this especially for long-term simulations deep into the nonlinear phase, the preservation of such invariants can be very helpful. The goal of the present work is to explore the usage of numerical methods which are mostly related to finite element exterior calculus (FEEC) with the aim to preserve as many properties of the continuous model as possible. From a physics point of view, the model of interest is the nonlinear coupling of the linearized ideal magnetohydrodynamics (MHD) equations to a kinetic equation (either full-orbit or reduced Vlasov equation). Such hybrid fluid-kinetic models are a suitable way to describe the self-consistent interaction of a thermal fluid bulk plasma with an ensemble of energetic particles, e.g. fusion-born alpha-particles in nuclear fusion devices.

P 5.31 Mon 16:30 Empore Lichthof

Progress towards Gyrokinetic Turbulence in the SOL with GENE-X — •Dominik Michels, Denis Jarema, Andreas Stegmeir, and Frank Jenko — Max-Planck-Institut für Plasmaphysik, Garching, Deutschland

Understanding and predicting the effects of plasma turbulence in the Scrape-Off Layer of a tokamak is a crucial step in the optimisation of confinement for future fusion power plants. Our goal is to develop a new version of the GENE code [1], called GENE-X, to study gyrokinetic SOL turbulence. The Scrape-Off Layer poses several significant problems for gyrokinetic codes. Fluctuations of the plasma in the Scrape-Off Layer are known to be stronger than in the core. As such, nonlinear effects originating from the coupling between fluctuations become important, i.e. a full-f treatment of the underlying equations is necessary. Furthermore, the poloidal magnetic field vanishes at the X-Point of a tokamak – which introduces a coordinate singularity in the commonly used flux-aligned coordinates. We solve this problem by implementing the flux-coordinate independent approach described in [2, 3]. We present first results on simulations with GENE-X in regions of closed field lines and give an outlook on how to expand GENE-X to open field line regions by introducing sheath boundary conditions.

[1] F. Jenko et al., Phys. Plasmas 7 (2000), 1904-1910

[2] F. Hariri et al., Computer Physics Communications, 184:2419 – 2429, 2013

[3] A. Stegmeir et al., Computer Physics Communications, 198:139 – 153, 2016

P 5.32 Mon 16:30 Empore Lichthof

Towards systems code studies for a general class of stellarators — •Jorrit Lion and Felix Warmer — Max Planck Institute for Plasma Physics, D-17491, Greifswald, Germany

Stellarators are attractive candidates for a fusion power plant owing to their inherent steady-state capability and absence of disruptions. A convenient way to study different power plant designs is by applying systems codes, which aspire to model an entire fusion power plant within a single framework. Here, we present general modules for the systems code PROCESS to enlarge the possible configuration space compared to earlier works, focusing on a modular coil model, a support structure model and a bootstrap current model for quasi-axisymmetric stellarators. These models reflect the full 3D geometry of the stellarator coils and are incorporated in PROCESS via scaling laws and fits for specific devices. We further present first results from a modified version of PROCESS using these models, applied on certain stellarator designs with different aspect ratios.

P 5.33 Mon 16:30 Empore Lichthof

Research of the plasma parameters based on CHF3/H2 for etching silicon and glass — •Alena Okhorzina and Norbert Bernhard — 06366, German, Köthen, Bernburger Str. 55

In this work, dry maskless plasma silicon etching was used to reduce light reflection. That method is called "Black silicon" and it is applicable for any type of silicon (mono and multi). By creating a nanostructure on the silicon surface, light reflection was reduced. In this research CHF3-based gas was used because that type of gases has less global warming potential than other gases like SF6-based (standard black silicon process). By manipulating the main parameters of the plasma (flow and amount of gases, CCP and ICP power, pressure in the chamber) the changing of the light reflection and mass of the silicon wafers were observed. It was found that the main factors affecting the etching process in CHF3/H2 are pressure, CCP and ICP powers, and the amount of hydrogen in the gas mixture. The voltage-current characteristics were obtained for plasma etching with the most significant parameters. Langmuir cylindrical probe was used to understand the plasma process. During the experiment, the necessary parameters to hold the process in the etching mode of the plasma (potential, electron temperature, electron/ion current density) were obtained.

P 5.34 Mon 16:30 Empore Lichthof

Minimal invasive extraction and ex situ analysis of nanoparticles synthesized in a reactive plasma — •Maren Dworschak, Franko Greiner, and Oguz Han Asnaz — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel

Plasma systems generating nanometer-sized particles are relevant for a broad range of applications from biomedicine to catalysis and batteries where knowledge about the size of the generated particles and their size distribution is critical. In situ analysis of nanoparticles created in a reactive Ar/C_2H_2-plasma using kinetic Mie-ellipsometry encounters problems when trying to detect particles at both extremes of the size scale. Because it reaches its limits for small (<50 nm, Rayleigh regime) and very large particles (>250 nm, multiple scattering) ex situ analysis has to be done. An optimal particle extractor should (i) not disturb the plasma chemistry, (ii) not change the discharge properties, and (iii) be able to extract several samples during one growth cycle.

We present a device to extract nanoparticles at multiple moments during a single growth cycle, while not disturbing the process itself. The extraction method is based on the thermophoretic force [Godde et al., IEEE Trans. Plas. Sci. (2011)] and allows extracting particles at eight stages of the growth process. During extraction, we monitor the dynamics of the particle cloud with a camera and the particle size via Mie-ellipsometry. The particles are diagnosed ex situ with atomic force, scanning electron, and/or laser microscopy to determine the particle size distribution.

P 5.35 Mon 16:30 Empore Lichthof

TDLAS analysis of the magnetic field strength by Zeeman splitting and gas temperature by Doppler broadening in the linear plasma device PSI-2 — •Marc Sackers, Oleksandr Marchuk, Sven Dickheuer, Stephan Ertmer, and Arkadi Kreter — Forschungszentrum Jülich GmbH - Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany

Tunable diode laser absorption spectroscopy (TDLAS) is a promising technique to estimate the magnetic field strength in a low-density weakly magnetized plasma as well as the temperature of the gas constituents [1]. To obtain this information, the $4s^2 4p^5 (^2P^\circ_{3/2}) 5s$ J=2 –> $4s^2 4p^5 (^2P^\circ_{3/2}) 5p$ J=2 transition from metastable krypton was analyzed. Therefore, the wavelength of a tunable diode laser was tuned to the vacuum transition wavelength of 760.3638 nm and gradually scanned in both directions. A polarization cube was positioned in the optical path in front of the photodiode to detect the π- and σ-components of the transition individually and measure simultaneously. The obtained absorption spectrum of the signal was then used to create a suitable fit with the Doppler broadening and Zeeman splitting as the two dominant contributions to the line broadening.

[1] S. Dickheuer et al. *Atoms* **7(2)**, 48 (2019)

P 5.36 Mon 16:30 Empore Lichthof

A new longitudinal 1D extinction setup for density measurements of nanodusty clouds in low-pressure plasmas — •Alexander Schmitz, Andreas Petersen, Nils Rehbehn, Sebastian Groth, and Franko Greiner — Insitut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel

Clouds of nanometer-sized particles, grown from molecular precursors in reactive low-pressure plasmas, exhibit a wide range of unique characteristics and effects. Hence the detailed knowledge of dust properties is of central importance to understand these complex systems. Methods like computed tomography or 2D extinction measurements are powerful tools to determine the particle densities but come with the downside of usually being time-consuming and requiring full optical access to the system. This significantly limits the possibility of using different diagnostics simultaneously and one must rely on the reproducibility of the investigated phenomena.

Here, we present a new setup that combines 1D extinction measurements with a co-aligned video camera. This makes it possible to reconstruct the dust density profile of a cylindrical nanodust cloud, while only needing access along one optical axis. This leaves enough room for further simultaneous diagnostics. The advantages and drawbacks of the setup will be discussed.

P 5.37 Mon 16:30 Empore Lichthof

On the influence of plasma parameters on particle size — •Sören Wohlfahrt, Niklas Kohlmann, Frank Wieben, Oguz Han Asnaz, Franko Greiner, and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Microparticles are the essential component of a (dusty) complex plasma. The forces affecting these particles, as well as their accumulated charge, depend prominently on their size. Thus, a precise knowledge of the particle size is a key input parameter for a quantitative description and modelling. However, in interaction with the plasma the particle size can change. The size of particles can be determined with very high precision by means of angle- and polarisation-resolved light scattering (ARPLS), which is based on a comparison of experimental data with Lorentz-Mie theory [1]. We will present the size evolution of melamine-formaldehyde (MF) microparticles for various discharge conditions. Especially, variation of rf-power and neutral gas pressure and their effect on the particle size are discussed.

[1] N. Kohlmann, F. Wieben, O. H. Asnaz, D. Block, F. Greiner, Phys. Plasmas 26, 053701 (2019)

P 5.38 Mon 16:30 Empore Lichthof

Numerical investigations of wave propagation in binary complex plasmas — •Lasse Bruhn, Frank Wieben, and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Complex plasmas containing charged dust particles are an ideal model system for research on strong coupling phenomena. In two-dimensional systems waves can be excited either thermally or by external manipulation. The dispersion of waves propagating in monodisperse complex plasmas is well understood. However, the dynamics of waves in binary mixtures, containing two differently sized particle species, are less examined, but an interesting field of research. In this contribution, MD simulations are used to investigate feasible parameter regimes for future experiments.