P 15: Helmholtz Graduate School II

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

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

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

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

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

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

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

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

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

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

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

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Doppler Coherence Imaging of impurity ion flows in the ASDEX-Upgrade divertor and plasma flows in VINETA.II — •Dorothea Gradic[1], Oliver Ford[1], Tilmann Lunt[2], Robert Wolf[1], and ASDEX-Upgrade Team[2] — [1]Max-Planck-Institut für Plasmaphysik, D-17491 Greifswald, Germany — [2]Max-Planck-Institut für Plasmaphysik, D-85748 Garching, Germany

In magnetically confining plasma experiments, measurement of ion dynamics is of great importance to study the plasma behavior in magnetic fields such as the exhaust particle flows in the divertor areas. The Doppler coherence imaging spectroscopy (CIS) is a relatively new technique for the observation of plasma bulk ion flows. It is a passive optical diagnostic which produces 2D images of line-integrated measurements of the ion flow or ion temperature.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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An aligned discontinuous Galerkin method for a non-coercive elliptic operator — •Benedict Dingfelder[1], Florian Hindenlang[1], Ralf Kleiber[2], Axel Könies[2], and Eric Sonnendrücker[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Deutschland — [2]Max-Planck-Institut für Plasmaphysik, Greifswald, Deutschland

Due to the anisotropy introduced by the magnetic field, the equations of ideal MHD show poor convergence properties if they are straightforwardly discretized by finite elements (FE). In their simplest form, they collapse to a heterogeneous anisotropic diffusion equation with a semidefinite diffusion tensor. The form we consider is given by

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

for the two-dimensional periodic domain Ω and direction of the magnetic field b. Despite of its simplicity, the equation reproduces the relevant poor convergence behaviour. A discontinuous Galerkin (DG) method with locally aligned cells and basis is presented which improves the numerical accuracy by roughly four digits in comparison to existing methods with the same computational complexity. The results can be used in more complex applications.

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

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

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

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

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

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

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

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

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

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

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

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

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

One of the aims of Wendelstein 7-X,an advanced stellarator in Greifswald,is the investigation of quasi-steady state operation of magnetic fusion devices,for which power exhaust is a very important issue. The predominant fraction of the energy lost from the confined plasma region will be removed by 10 so-called island divertors,which can sustain up to 10 MW/m2. In order to protect the divertor elements from overheating and to monitor power depositions,infrared endoscopes will be installed and real-time system is designed for online analysis. Important prerequisite for safe operation of a steady-state device is automatic detection of the hot spots and other abnormal events. The earlier algorithm designed for early detection of defects e.g. hotspots, surface layers and delaminations during the discharge is improved to be compatible with the real time system acquiring the images. It enables automatic detection of the critical events and broadcast them to the main Discharge Control System. This allows dynamic control of the scenario of the discharge in order to assure safe operation of W7-X. The initial tests of the overall system was conducted in GLADIS.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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Progression of the tungsten-fibre reinforced tungsten com-

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

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

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

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

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