P 25: Poster Session- Theory and Modelling

Time: Thursday 16:30–19:00 Location: Empore Lichthof

P 25.1 Thu 16:30 Empore Lichthof

Analytische Lösungen des vereinfachten EMC3 Models — •Jörg Cosfeld[1], Felix Hasenbeck[1], Michael Rack[1] und Yuhe Feng[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung – Plasmaphysik, 52425 Jülich, Germany — [2]Max-Planck-Institute für Plasmaphysik, 17491 Greifswald / 85748 Garching, Germany

Ein Testbed zur Weiterentwicklung des 3D-Monte-Carlo-Code EMC3 [1] wird durch analytische Lösungen der zugrunde liegenden Braginskii-Gleichungen [2] für verschiedene vereinfachte Spezialfälle erstellt. Der EMC3-Code wird in der Beschreibung der Plasmarandschicht von Fusionsexperimenten dazu genutzt, um Teilchen-, Impuls- und Energiebilanzen mit Hilfe eines Monte-Carlo-Algorithmus zu lösen. Approximationen wie die Stationarität und Quasineutralität geben vor, unter welchen Randbedingungen die Braginskii-Gleichungen numerisch ge- löst werden. Ziel dieser Arbeit ist, ein breites Spektrum an analytischen Lösungen zur Code-Verifikation zu erstellen. Aktuell wurden analyti- sche Lösungen für eine approximierte eindimensionale Bewegung des Plasmas hergeleitet. Im ersten Fall wird die Bewegung des Plasmas nur in Richtung des von außen angelegten Magnetfeldes berücksichtigt. Hergeleitet wurden auch vereinfachte Lösungen für die Temperatur und Dichte senkrecht zum angelegten Magnetfeld. Eine entsprechende Überprüfung eindimensionaler Simulationen des EMC3-Codes ist da- mit möglich. Aufbauend auf diesen Ergebnissen sollen nun allgemeine- re analytische Lösungen gefunden werden. [1] Y.Feng. J. Nucl. Mater. 266-269:812-818, 199. [2] S.I. Braginskii. Rev. Plasma Phys. 1:205 (1965).

P 25.2 Thu 16:30 Empore Lichthof

Impact of the Boussinesq approximation on the blob propagation in the scrape-off layer — •Alexander Ross, Andreas Stegmeir, David Coster, and Emanuele Poli — Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany

The investigation of radial transport in the scrape-off layer showed that particles and heat are transported turbulently and mainly via field-aligned filaments, appearing as blobs. These blobs are believed to greatly impact the plasma-wall interaction. Here, we want to further explore the blob transport numerically. Starting from the drift reduced Braginskii equations a two-field full-f fluid model is developed, consisting of the continuity and vorticity equations. We do not make use of the commonly used Boussinesq approximation in the vorticity equation. Instead we present a numerical scheme for the important terms and discuss the impact of the Boussinesq approximation on the transport of blobs, first in a slab geometry. The numerical schemes are implemented in GRILLIX, a plasma turbulence code using the field line map approach, which is able to treat complex geometries, especially the separatrix and X-point of diverted magnetic fusion devices. The final goal is the research of the blob propagation in a realistic geometry.

P 25.3 Thu 16:30 Empore Lichthof

Theory-based modeling of ohmic confinement parameters and impurity transport — •Ivan Erofeev, Emiliano Fable, and Clemente Angioni — Max-Planck-Institut für Plasmaphysik, Garching b. München, Deutschland

In L-mode Ohmic plasmas a transition between linear (LOC) and saturated (SOC) confinement regimes has been regularly observed as the density is raised. It is believed to be caused by a shift of the dominant turbulent mode from TEM to ITG. In some tokamaks, this is also accompanied by a flip in core plasma toroidal rotation direction from co- to counter-current. The value of the density at which this transition occurs was shown to depend on such basic regime parameters as the toroidal field and plasma current, as well as many others. In this work this dependence is studied using the ASTRA transport modeling system, extended with TGLF and NEO codes as modules. Other aspects of LOC-SOC transition including simulated turbulent mode spectra are shown. Another part of the work presented is dedicated to the modeling of the evolution of an impurity blob (on the example of Li pellet) as it penetrates the confinement region in typical deuterium plasma. One of the goals of this whole work is to validate the TGLF code against experiment in LOC-SOC relevance in the first part and on the impurity transport side in the second part, with the aim to arrive to full simulations including plasma rotation.

P 25.4 Thu 16:30 Empore Lichthof

Path integral approach to Stark-broadening of Lyman lines from hydrogen plasmas — •Nacira Bedida, Heidi Reinholz, and Gerd Röpke — University of Rostock, Rostock, Germany

New results for Lyman lines from hydrogen plasmas are presented using the path integral method. Within the path integral approach [1], the time dependent dipole autocorrelation function is obtained in terms of Feynman propagators. Knowing the propagator in comparison to the unperturbed emitter, it is possible to develop a perturbative series. Finally, we obtain a compact formula for the intensity of Lyman lines taking an appropriate ionic micro-field distribution. Good agreement with results obtained within a quantum statistical approach to line profiles [2,3] is found, in particular at high densities and temperatures.

[1] N. Bedida et al. Contrib. Plasma Phys. 54, No 9, 783- 790 (2014); [2] S. Guenter, Habilitation thesis, Rostock University, Germany, 1995; [3] S. Lorenzen et al., Journal of Physics: Conference Series 397, 012021 (2012).

P 25.5 Thu 16:30 Empore Lichthof

Spektral-Kinetische Simulation der Planaren Multipol-Resonanz-Sonde — •Michael Friedrichs[1], Sebastian Wilczek[2], Junbo Gong[2], Ralf Peter Brinkmann[2] und Jens Oberrath[1] — [1]Institut für Produkt- und Prozessinnovation (PPI), Leuphana Universität Lüneburg, Deutschland — [2]Lehrstuhl für Theoretische Elektrotechnik, Ruhr-Universität Bochum, Deutschland

Die Messung von Plasmaparametern wie Elektronendichte und -temperatur während eines Plasmaprozesses ist eine wichtige Voraussetzung für eine Prozesssteuerung oder eine -überwachung. Die aktive Plasma-Resonanzspektroskopie (APRS) stellt eine attraktive Diagnostikmethode für eine solche Überwachung dar, bei der die Eigenschaft von Plasmen, in der Nähe der Plasmafrequenz in Resonanz zu geraten, ausgenutzt wird. Eine spezielle Bauform dieser Diagnostikmethode ist die planare Multipol-Resonanz-Sonde (pMRP). Um mit ihr aus einem gemessenen Spektrum Plasmaparameter zu berechnen, wird eine Relation zwischen Resonanzfrequenzen und Plasmaparametern benötigt. Ein möglicher Ansatz zur Bestimmung der benötigten Relation ist eine spektral-kinetische Simulation der pMRP, die in dieser Arbeit vorgestellt wird. Ähnlich wie bei Particle-In-Cell (PIC) wird bei jedem Zeitschritt aus einer Ladungsverteilung von Superteilchen das Feld und die zugehörige Kraft, sowie anschließend die resultierende Geschwindigkeit und der resultierende Ort der Teilchen berechnet. Der wesentliche Vorteil dieser Methode gegenüber PIC liegt in der gitterfreien Simulation.

P 25.6 Thu 16:30 Empore Lichthof

Electromagnetic resistive-interchange model for type-III-ELM-like limit cycles — •Federico Pesamosca[1,2], Peter Manz[2,3], and Matteo Passoni[1] — [1]Politecnico di Milano, 20133 Milano, Italy — [2]Max- Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [3]Physik-Department E28, Technische Universität München, 85748 Garching, Germany

At the transition from low to high confinement regimes in magnetically confined plasmas regular pulsations in the low kilohertz range occur which are referred to as limit cycles oscillations (LCOs). It is believed that these LCOs are a result of the interaction between zonal fows and drift-wave turbulence whose basis is described by the zero dimensional (0D) Kim-Diamond model. Recent investigations in ASDEX Upgrade have shown that LCOs are not only seen in the magnetic signal, they even show precursor activity identical to type-III ELMs which are believed to be resistive interchange dominated. Also ELMs can be described by 0D-MHD models. To enlighten the role of magnetic fluctuations in the LCO dynamics in general and those of the precursors in particular a model including both zonal fows and MHD is desirable. This has been done by deriving a 0D-model from the 3D electromagnetic turbulence model DALF3. Within the presented model the LCO dynamics has been studied for ASDEX Upgrade conditions.

P 25.7 Thu 16:30 Empore Lichthof

Eigenmode solver for electromagnetic waves in metallic structures — •Sander Coene, Burkhard Plaum, and Thomas Hirth — IGVP, Universität Stuttgart, Germany

To achieve a fusion plasma, a low-pressure gas must first be heated. In order to add energy to the plasma a waveguide and antenna set-up is used to focus an electromagnetic wave into the plasma. If one has knowledge about the eigenmodes in such a waveguide, calculations of wave propagation are immensely simplified in terms of computational time. For standard cross-section shapes (rectangular, circular, ...) analytical solutions exist, but in search of more exotic cross-section shapes that help feed into the fusion plasma, a numerical approach is needed in the form of an eigenmode solver. The development of such a solver can for instance also prove beneficial for designing imaging waveguides with an increased angular range, which are used for fusion plasma diagnostics (e.g. reflectometry and ECE imaging) or for heating (e.g. remote steering).

In these application fields, a high accuracy for the resonance frequencies is of the greatest importance. Therefore we analyze how well-established methods in current high performance computer architecture compare with more modern approaches to obtain the transversal eigenmodes.

P 25.8 Thu 16:30 Empore Lichthof

Zum Einfluss der Elektronenstoßquerschnitte auf die Stoß-Strahlungs-Modellierung eines Ar-Niedertemperaturplasmas[1] — •Jochen Wauer, Jens Harhausen, Rüdiger Foest und Detlef Loffhagen — Leibniz Institut für Plasmaforschung und Technologie, Felix-Hausdorff-Strasse 2, 17489 Greifsweald

Zur Untersuchung von Niedertemperaturplasmen kann die optische Emissionsspektroskopie als etablierter Standard gelten. Neben der technischen Realisierung besteht eine hohe Anforderung an die Modellierung der aufgezeichneten Strahldichte- oder Emissionsdaten, um eine quantitative Interpretation zu ermöglichen. Die Beziehung zwischen optischen Daten und Plasmaparametern wird durch Stoß-Strahlungs-Modelle hergestellt. Hierfür werden u.a. Stoßquerschnitte für die Anregung von Neutralteilchen durch Elektronenstöße benötigt. Diese werden gegenwärtig durch quantenmechanische Berechnungen bestimmt oder aus Schwarmdaten abgeleitet. Vergleicht man Stoßquerschnitte für eine Reaktion aus verschiedenen Quellen, so können diese große Unterschiede aufweisen. Dieser Aspekt wird für einen konkreten Datensatz[2] aus einem Prozess zur plasmagestützten Deposition optischer Schichten (PIAD) untersucht. Dazu verwenden wir ein Stoß-Strahlungs-Modell mit 15 angeregten Ar-Niveaus und betrachten die Sensivität dieses Modells bezüglich der Elektron-Argon-Stoßquerschnitte aus verschiedenen Quellen.

[1]Gefördert durch das BMBF unter dem Förderkennzeichen 13N13213

[2]J. Harhausen et al., J. Phys. D: Appl. Phys. **48** (2015) 045203

P 25.9 Thu 16:30 Empore Lichthof

Fictitious time-evolution for steady state strongly non linear transport equations — •Herbert Oberlin, Marco Restelli, and Omar Maj — Max Planck Institute - IPP/NMPP, Garching bei München, Germany

The solution of nonlinear partial differential equations can pose serious challenges in the development of efficient codes for physics simulations. Standard methods usually rely on iterative schemes that, for time-evolution problems, are nested into time-stepping iterations. In strongly nonlinear cases, the convergence of the iterative nonlinear solver imposes unacceptably small time steps.

In this work, we consider the relaxation to steady-state of strongly non linear problems. In order to mitigate the effects of nonlinearities, we propose a modification of the time evolution of the equations. Through dissipation of certain metrics of the system, we force these strong nonlinear effects to play a lesser role, and induce better convergence to steady-state.

The main envisaged application is the speed up of the computational fluid dynamic kernel of the SOLPS suite of codes which simulate the outer region of the plasma column in tokamak devices.

P 25.10 Thu 16:30 Empore Lichthof

Towards TeV electron acceleration: quasi-stable injection channels in a wakefield accelerator — •Mara Wiltshire-Turkay, John Farmer, and Alexander Pukhov — Heinrich-Heine-Universität Düsseldorf, Germany

Proton-beam-driven plasma-wakefield acceleration is a promising technique to create high-energy electrons. The large accelerating gradients possible in plasma allow the transfer of energy from TeV protons to electrons, potentially increasing achievable energies by two orders of magnitude.

Via theory and simulation, we investigate the dependence of the energy gain on the point of electron injection into the wake. We find previously unobserved complex structure of the the acceptance channels for high-energy acceleration. This result is directly applicable to the optimisation of energy gain for the planned AWAKE project at CERN.

P 25.11 Thu 16:30 Empore Lichthof

Accuracy of fluid and PIC simulations for low pressure ccrf discharges* — •Markus M. Becker[1], Hanno Kählert[2], Anbang Sun[1], Detlef Loffhagen[1], and Michael Bonitz[2] — [1]INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald — [2]ITAP, Christian-Albrechts-Universität zu Kiel, Leibnizstr. 15, 24098 Kiel

Particle-in-Cell (PIC) methods are particularly suited for the theoretical description of low pressure rf discharges [1]. Fluid models are required to reduce the computational cost if plasmas at elevated pressures and/or extended reaction kinetics are to be described. In hybrid models, kinetic and hydrodynamic methods are combined in order to take advantage of the benefits from both approaches. As a preliminary study to the development of novel hybrid models, recently developed PIC and fluid tools are presented and benchmarked against reference results for low pressure rf discharges in helium [1]. In particular, the results obtained from enhanced fluid models [2] are compared with those provided by conventional fluid descriptions and by different PIC simulation codes. It is shown that the accuracy of fluid models can be conserved at low pressures if the electron energy transport and the inertia of ions are adequately described.

This work is partly supported by the DFG via SFB-TRR24 and by the PlasmaShape project from the European Union under grant agreement no 316216.

[1] M. M. Turner *et al.*, *Phys. Plasmas* **20** (2013) 013507

[2] M. M. Becker, D. Loffhagen, *Adv. Pure Math.* **3** (2013) 343–352

*Part of the Kiel research initiative 'The Plasma Interface'.

P 25.12 Thu 16:30 Empore Lichthof

The domino effect of unstable one-dimensional bump-on-tail modes as a test for critical numerical scales — Thomas Hayward and •Philipp Lauber — Max-Planck-Institut für Plasmaphysik (IPP), 85748 Garching, DE

The so-called domino effect [BB95], though which more widely spaced modes can overlap as a result of the overlap of closely spaced modes, can lead to a significant increase in the level of mode saturation in the bump-on-tail system. As this effect depends strongly upon the overlap of fine scale structures, which can lead to the establishment of larger scale structures, it is informative to study how the numerical resolution impacts the result of this system close to the overlap threshold. We perform simulations using both particle [Deng] and grid [Kraus] based methods, investigate numerical convergence, and comment on the differences between the two approaches.

[BB95] Berk, H. L. et al. Nuclear Fusion. Vol. 35, No. 12 (1995)

[Deng] Deng, W. and Fu G.-Y. Computer Physics Communications 185, 96-105 (2014)

[Kraus] Kraus, M. PhD thesis, Technische Universität München (2013)

P 25.13 Thu 16:30 Empore Lichthof

Using IPF-FDMC full wave code as a synthetic reflectometer for studying micro-instabilities computed by ORB5 — •Francesco Carpanese, Alessandro Biancalani, Alf Koehn, and Omar Maj — Max-Planck-Institut für Plasmaphysik Boltzmannstraße 2 D-85748 Garching

The gyro-kinetic codes have reached good maturity in simulating plasma electromagnetic nonlinear micro-instabilities which are responsible for turbulent transport. Validating these codes, such as ORB5, towards experiments requires to be able to reproduce data from diagnostics which detect the micro-instabilities characteristics. The reflectometer in particular is a valuable solution to measure density perturbation and turbulent spectrum near the cut-off of the injected wave [1]. A synthetic reflectometer, to be coupled to the gyro-kinetic code, is therefore needed for simulating and interpreting the experimental diagnostic. A new full-wave code is under development, taking advantage of a novel algorithm. At the same time the 2D finite difference IPF-FDMC code has been coupled to ORB5 to simulate a reflectometer (see also [2]).

[1] Sabot, R, Plasma Phys. Controlled Fusion 48.12B (2006): B421.

[2] Conway, G. D, Plasma Phys. Controlled Fusion44.4 (2002): 451.

P 25.14 Thu 16:30 Empore Lichthof

Transport properties of dense plasma beyond Born approximation — •Sebastian Rosmej, Heidi Reinholz, and Gerd Röpke — Universität Rostock, Rostock, Deutschland

In the generalized linear response theory, transport coefficients are expressed via correlation functions. Especially the static conductivity of dense plasma is investigated. The main contribution due to electron-ion collisions is well known. Further relevant interactions have to be considered, e.g. electron-electron collisions. Within Born approximation, this was done in a recent paper [1] for arbitrary degeneracy. Assuming statically screened Coulomb potentials a correction factor is deduced. Additionally, the treatment of strong collisions is necessary in the warm dense matter regime. In [2] the T matrix effects are considered for electron-ion interactions. A new fit formula for the electron-ion transport cross section is proposed in order to reduce the numerical effort in the low density limit.

In reference to experimental results the treatment of electron-electron collisions in different approximations is evaluated and especially the influence strong collisions via T matrix is shown in more detail.

[1] H. Reinholz, G. Röpke, S. Rosmej, and R. Redmer, Phys. Rev. E 91, 043105 (2015). [2] S. Rosmej, subm. to Contrib. Plasma Phys.

P 25.15 Thu 16:30 Empore Lichthof

Quantum master equation approach for spectral line profiles in a plasma — •Chengliang Lin, Heidi Reinholz, and Gerd Röpke — Universität Rostock, Rostock, Deutschland

Within the framework of the theory of open quantum systems, the behavior of an atom in an interactive environment with particular attention to plasma surroundings is studied. A quantum master equation (QME) is derived to describe the dynamics of the atom in plasma. The contribution of the plasma environment to the QME is represented by its dynamic structure factor. For the application of the QME, the pressure broadening of spectral line profiles in a plasma is investigated. Of particular interest are the Rydberg states of the hydrogen atom. To describe the Rydberg states under the influence of a surrounding plasma, a wave packet description is introduced. The boundary between the quasi-classical and quantum mechanical representation of a bound electron is discussed. In addition, the transition rates between the bound wave packet states are calculated within this method. The resulting transition rates show a better agreement with the experimental data than the pure quantum mechanical calculation. For the further application, the inner-shell transitions (K-alpha line and Auger transition) are discussed by including both transverse and longitudinal component of the photon field as the heat bath of the investigated atom. A systematic approach to investigate the inner-shell transitions in a many-electron atom under the influence of the plasma environment is obtained.

P 25.16 Thu 16:30 Empore Lichthof

Defining and Measuring the Coupling Strength in Coulomb and Yukawa Plasmas — •Torben Ott and Michael Bonitz — Christian-Albrechts-Universität Kiel, Institut für Theoretische Physik und Astrophysik

For strongly coupled plasmas such as dusty plasmas, trapped ions, or ultracold neutral plasmas, the definition and measurement of the correlation or coupling strength is an essential question. However, when precise measurements of charge states and/or temperatures are not feasible or when the interaction between the strongly coupled species is screened, e.g., by electrons, the straightforward use of the Coulomb coupling parameter $\Gamma = Q^2/(ak_BT)$ is problematic.

In this contribution, we present two consistent and mutually compatible approaches for defining and measuring the coupling strength in Coulomb and Yukawa One-Component Plasmas based on the purely structural features of the system, thus removing the need to measure the temperature, the charge state, or the screening length of the plasma to assess its coupling state.

[1] T. Ott, M. Bonitz, Contrib. Plasma Phys. **55**, 243 (2015)
[2] T. Ott, M. Bonitz, L. G. Stanton, M. S. Murillo, Phys. Plasmas **21**, 113704 (2014)

P 25.17 Thu 16:30 Empore Lichthof

Thermodynamic Fermionic Monte Carlo Simulations of Continuous Systems without Fixed Nodes — •Tobias Dornheim, Tim Schoof, Simon Groth, and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel

Path Integral Monte Carlo (PIMC) simulations of correlated fermions at high degeneracy are generally hampered by the fermion sign problem (FSP). Here, we combine two novel methods, the Configuration [1] and Permutation Blocking PIMC [2] approach, which, due to their complementary character of the FSP, allows us to circumvent this issue. Thereby, we are able to present accurate ab initio thermodynamic data for the uniform electron gas [3,4,5] over a broad range of parameters without the need of the fixed node approximation.

[1] T. Schoof *et al.*, Contrib. Plasmas Phys. **51**, 687 (2011)
[2] T. Dornheim *et al.*, New J. Phys. **17**, 073017 (2015)
[3] T. Schoof *et al.*, Phys. Rev. Lett. **115**, 130402 (2015)
[4] T. Dornheim *et al.*, J. Chem. Phys. **143**, 204101 (2015).
[5] S. Groth *et al.*, arXiv:1511.03598 (2015).

P 25.18 Thu 16:30 Empore Lichthof

Konsistente kinetische Simulation von Plasma und Sputtertransport in kapazitiv gekoppelten Plasmen — •Frederik Schmidt, Jan Trieschmann und Thomas Mussenbrock — Ruhr-Universität Bochum, Lehrstuhl für Theoretische Elektrotechnik, Universitätsstraße 150, 44801 Bochum, Deutschland

Sputterplasmen finden breite Anwendung zur Erzeugung funktionaler Schichten (z.B. Härtung, Korrosionsschutz). Diese Prozesse werden häufig bei Gasdrücken < 1 Pa betrieben. Für deren Verständnis – insbesondere der gekoppelten Prozesse – ist eine konsistente Betrachtung des Plasmas und des Transports dadurch gesputterter Teilchen von großer Bedeutung. Wegen großer mittlerer freier Weglängen und der nicht-thermischen gesputterten Spezies, bieten sich zur theoretischen Analyse lediglich kinetische Verfahren an.

Die Particle-in-Cell (PIC) Methode wird zur kinetischen Beschreibung des Plasmas verwendet. Darauf aufbauend wird der Sputtertransport mit Hilfe der Test Multi-Particle Methode (TMPM) bestimmt. Hierzu wird der selbstkonsistent simulierte Ionenfluss über den Fluss gesputterter Teilchen an das Modell des Teilchentransports gekoppelt. Am Beispiel eines kapazitiv gekoppelten Plasmas (CCP) werden die räumlich aufgelösten Dichten und Flüsse aller vorkommenden Spezies und deren Geschwindigkeitverteilung diskutiert. Die Ergebnisse werden ferner mit einem kinetischen Transportmodell der Neutralteilchen verglichen und diskutiert.

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