P 14: Poster Session - Theory and Modelling

Time: Tuesday 16:30–18:30 Location: SPA Foyer

P 14.1 Tue 16:30 SPA Foyer

Filamentary Plasma Eruptions in Tokamaks — •Sophia I. Henneberg and Howard R. Wilson — York Plasma Institute, Department of Physics, University of York, Heslington, York, YO10 5DD, UK

The early stages as well as the crash of explosive, filamentary eruptions in magnetised plasmas, such as Edge Localised Modes (ELMs) in tokamaks, are investigated by modelling the ballooning mode envelope equation which can be derived from non-linear ideal MHD [1,2]. The ballooning mode envelope equation describes the growth of a plasma filament amplitude; however it is not generally analytically tractable. Wilson and Cowley [3] derived this equation for tokamak-like geometry, and provided numerical solutions for the two-dimensional non-linear differential equation, which can involve fractional temporal derivatives, but is often second order in time and space. We have extended those simulations to evolve through linear marginal stability instead of starting with a highly unstable state. This enables one to explore more realistic scenarios of these explosive events. Building on this, we have developed a new heuristic approach for the energy ejected in the plasma eruptions that could form the basis for a first-principle ELM model for tokamaks and, indeed, plasma eruption events in other plasma systems. If successfully benchmarked against tokamak data (future work), this method would help to make confident predictions for ELMs in ITER.

[1] S.C. Cowley et al., Phys. Plasmas 3, 1848 (1996)
[2] O.A. Hurricane et al., Phys. Plasmas, 4, 3565 (1997)
[3] H.R. Wilson and S.C. Cowley, Phys Rev Letts, 92, 175006 (2004)

P 14.2 Tue 16:30 SPA Foyer

Modellierung von geschichteten Filamenten in einem RF-Plasmajet — •Florian Sigeneger und Detlef Loffhagen — INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald

Der Plasmajet arbeitet bei Atmosphärendruck und besteht aus zwei konzentrischen Kapillaren und zwei ringförmigen Elektroden, die um die äußere Kapillare gewickelt sind. Im aktiven Volumen zwischen den Elektroden wird ein filamentiertes Argon-Plasma durch eine RF-Spannung bei 27.12 MHz erzeugt. Je nach Entladungsbedingungen werden ein oder mehrere Filamente experimentell beobachtet.

Ein einzelnes Filament wurde mit Hilfe eines räumlich zweidimensionalen Fluidmodells theoretisch untersucht. Das axialsymmetrische Modell umfasst Kontinuitätsgleichungen für Elektronen und die wichtigsten Argonteilchen, die Elektronenenergiebilanz, die Poisson-Gleichung und eine Gleichung für die Oberflächenladung an den Wänden der Kapillaren. Außerdem wird die Wärmebilanzgleichung gelöst, um die Gastemperatur zu ermitteln. Die Transporteigenschaften der Elektronen sowie ihre Stoßratenkoeffizienten wurden durch Lösung der Elektronen-Boltzmanngleichung als Funktion der mittleren Elektronenenergie und des Ionisationsgrades bestimmt.

Die Ergebnisse zeigen eine deutliche Separation zwischen dem kontrahierten Filament im Bulkplasma und den Elektrodenregionen. Außerdem wurden ausgeprägte Schichtungen entlang des Filaments mit Modulationsgraden bis zu 90% gefunden.

Diese Arbeit wurde durch die Deutsche Forschungsgemeinschaft im Rahmen des SFB TRR 24 unterstützt.

P 14.3 Tue 16:30 SPA Foyer

Reaktionskinetik von HMDSO im Atmosphärendruckplasmajet in Argon — •Detlef Loffhagen, Markus M. Becker, Rüdiger Foest und Florian Sigeneger — INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald

Hexamethyldisiloxan (HMDSO) ist eine siliziumorganische Verbindung, die häufig als Präkursor bei der Dünnschichtabscheidung mittels plasmagestützter chemischer Gasphasenabscheidung (PECVD) Anwendung findet. Um das physikalische Verständnis der Beschichtungsprozesse besser zu verstehen, werden im Rahmen des Forschungsclusters „Optimierung der Gasausnutzung bei Atmosphärendruck-Plasmaprozessen“ (www.ogaplas.de) grundlegende Untersuchungen zur Aufdeckung der plasmachemischen Reaktionspfade von HMDSO und ihrer Wirkung auf die Zusammensetzung und Struktur der abgeschiedenen Schicht durchgeführt. Der vorliegende Beitrag stellt die wesentlichen primären und sekundären plasmachemischen Prozesse und deren Reaktionsprodukte im Effluenten eines Argonplasmajets bei Atmosphärendruck vor. Die verfügbaren Daten und die Bedeutung der verschiedenen Elektronen- und Schwerteilchenstoßprozesse werden diskutiert. Ergebnisse von hydrodynamischer Modellierung des Plasmajets deuten daraufhin, dass die Fragmentierung von HMDSO durch Stöße mit Argonmolekülionen initiiert wird, während Penningprozesse für die Reaktionskinetik im Effluenten eine untergeordnete Rolle spielen.

Die Arbeiten werden durch die Deutsche Forschungsgemeinschaft unter dem Geschäftszeichen LO 623/3-1 unterstützt.

P 14.4 Tue 16:30 SPA Foyer

Growth of axisymmetric instabilities in ASDEX Upgrade — •Till Sehmer[1], Karl Lackner[1], Erika Strumberger[1], Emiliano Fable[1], Patrick McCarthy[2], and Otto Kardaun[1] — [1]Max-Planck-Institut für Plasma-Physik, EURATOM Association Boltzmannstraße 2, 85748 Garching, Germany — [2]University College Cork, Ireland

Modern poloidal divertor tokamaks, such as ASDEX Upgrade (AUG), produce elongated plasmas, which are unstable against vertical displacement. The growth rate of this 2D instability in the presence of stabilizing passive conductors (PSL) with finite resistivity was calculated for 5416 AUG typical equilibria. For this, a general ideal MHD code package (NEMEC, CAS3DN, STARWALL) was used, which is able to take into account also the 3D structure of the PSL. The comparison of the resulting growth rates with the previously used rigid displacement model (movement only in z-direction, no skin effect for PSL considered, no induced surface currents) shows that the latter simplified model gives a consistently lower limit for typical AUG parameters (elongation, triangularity, current profile and axis position in radial direction). A statistical analysis of the results of the rigid displacement model shows the expected dependencies except for the triangularity, which has a stabilizing effect in this model. Based on results of our present, more general model, we conclude that a rigid displacement model gives an over-optimistic result regarding the effect of triangularity, in line with the experimental observation on AUG of an increasing discrepancy between previously predicted and observed growth rates for strongly triangular plasmas.

P 14.5 Tue 16:30 SPA Foyer

Numerische Simulation von kalten und heißen Gasströmungen in einem Mikrowellen-Plasmabrenner — •Sandra Gaiser, Martina Leins, Andreas Schulz, Matthias Walker und Thomas Hirth — Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie, Universität Stuttgart, Pfaffenwaldring 31, 70569 Stuttgart

Eine entscheidende Rolle bei der Optimierung eines Mikrowellen-Plasmabrenners spielt das Gasmanagement. Heiße Gasströmungen müssen kontrolliert und empfindliche Bereiche im Brenner davor geschützt werden. Da eine rein empirische Untersuchung solcher Strömungsprozesse für deren Verständnis unzureichend ist, werden numerische Simulationen mit COMSOL Multiphysics® durchgeführt.

In einem ersten Schritt wurde das Verhalten kalter Gasströmungen in einem Glasrohr betrachtet, in dem später das Plasma betrieben wird. Mit Hilfe einer tangentialen Anordnung der Gaseinlässe kann eine Rotationsströmung entlang der Rohrwand erzielt werden, die einen Einschluss des heißen Plasmas ermöglicht. Es zeigt sich, dass eine größere Anzahl von Gaseinlässen eine gleichmäßigere Hüllströmung und somit eine bessere Stabilisierung des Plasmas gewährleistet. Andererseits sind hohe Einlassgeschwindigkeiten eine Voraussetzung für die Erhaltung der Rotationsströmung über den gesamten Plasmabereich.

Da es im Plasmabrenner zu einem Aufheizen des Gases kommt, wurde dieser Einfluss untersucht. Dazu wurde zunächst eine konstante Heizquelle in das Strömungsmodell eingebracht. Die sich daraus ergebenden Temperaturprofile zeigen bereits eine gute Übereinstimmung mit gemessenen Werten.

P 14.6 Tue 16:30 SPA Foyer

Stabilization of finite-element methods for shock wave problems in Comsol Multiphysics — •Marina Lisnyak, Markus M. Becker, Sergej Gorchakov, Detlef Loffhagen, and Klaus-Dieter Weltmann — INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald

It is well known that in arc plasmas shock waves can occur. Therefore, numerical methods used for modelling of arc plasmas have to be robust

and able to describe discontinuities. Sudden jumps of plasma properties such as temperature and pressure lead to shock wave initiation. During the last decades large effort for the development of numerical methods for the accurate description of shock waves in gases have been made. However, more general methods are still required for modelling of arc plasmas since different phenomena have to be described at the same time. In the present contribution the capabilities of the commercial software package Comsol Multiphysics for modelling of strong shock waves are evaluated. Different techniques for stabilization of the implemented finite-element methods are compared with the example of known test cases, like Sod's shock tube problem and Lax' problem. The results demonstrate that the streamline upwind Petrov-Galerkin (SUPG) stabilization gives satisfactory results and allows to remove instabilities, except narrow regions near discontinuities.

P 14.7 Tue 16:30 SPA Foyer

"Collisionless absorption, hot electron generation and intensity scaling in relativistic laser plasma interaction — •Tatyana Liseykina[1] and Peter Mulser[2] — [1]Institut für Physik, Universität Rostock, Germany — [2]Institut für Angewandte Physik, Technische Universität Darmstadt, Germany

The essence of collisionless absorption of intense laser beams in solid targets and the generation of fast electrons is described. From one-dimensional particle-in-cell simulations the main absorption mechanism is extracted as a function of intensity in the relativistic domain. Degree of absorption and hot electron production is shown to undergo a minimum which is attributed to the back holding effect of the radiation pressure. The variation of the electron spectrum with intensity is analyzed and scaling laws are presented. A critical comparison with existing modelling and experiments is given.

P 14.8 Tue 16:30 SPA Foyer

Simulation of nanocolumn formation in low-temperature plasmas — •Jan Willem Abraham, Lasse Rosenthal, and Michael Bonitz — Institut für theor. Physik und Astrophysik, CAU Kiel

Metal-polymer nanocomposites are of growing interest in many fields because the diverse physical features of their constituents allow for the production of materials with interesting novel properties. Recent experiments [1] and simulations [2] have shown that co-evaporation of the metallic and organic components in a simple single-step process can give rise to the formation of ultrahigh-density Fe-Ni-Co nanocolumnar structures embedded in a fluoropolymer matrix. Accompanying upcoming experiments, we show new results from kinetic Monte Carlo simulations that are expected to answer the question whether similar structures can also be produced in a plasma environment.

[1] Greve et al. Appl. Phys. Lett. **88**, 123103 (2006) [2] L. Rosenthal et al. J. Appl. Phys. **144**, 044305 (2013)

P 14.9 Tue 16:30 SPA Foyer

Configuration path integral Monte Carlo - Theory — •Simon Groth, Tim Schoof, David Hochstuhl, Alex Filinov, and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts Universität zu Kiel, Germany

The worm algorithm for configuration path integral Monte Carlo (CPIMC), based on the expansion of the one-particle Green function in a basis of (anti-)symmetrized N-particle states (configurations of occupation numbers), has been successfully applied to lattice models of bosonic systems in equilibrium [1]. Here, we present a generalization to correlated, fermionic many-particle systems with arbitrary pair interactions in continuous space at finite temperatures. The method does not rely on any approximations yielding exact results. Further, the sign problem of the presented method is complementary to that of the standard Direct fermionic path integral Monte Carlo (PIMC) [2] and thus allows for calculations of highly degenerate systems which are not accessible with PIMC. The algorithm including all Monte Carlo steps sufficient to ensure ergodicity is explained in detail. In an accompanying poster by Schoof et al., the application of the method is investigated for a test system of degenerate, Coulomb-interacting fermions in a two dimensional trap.

[1] N. V. Prokof'ev, B. V. Svistunov, and I. S. Tupitsyn, J. Exp. Theor. Phys. 87, 310 (1998)
[2] T. Schoof, M. Bonitz, A. Filinov, D. Hochstuhl, and J. Dufty, Contrib. Plasma Phys. 51, 687 (2011)

P 14.10 Tue 16:30 SPA Foyer

Configuration path integral Monte Carlo simulation of correlated fermions - Application — •Tim Schoof, Simon Groth, David Hochstuhl, Alex Filinov, and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts Universität zu Kiel, Germany

The configuration path integral Monte Carlo (CPIMC) method allows for efficient ab-initio simulations of highly degenerate, moderately coupled systems with arbitrary pair interactions in a continuous space at finite temperatures [1,2]. Using the worm algorithm [3] gives direct acces to the one-particle Green-function and related off-diagonal quantities. Results for degenerate, Coulomb-interacting fermions in a two dimensional trap are presented and the efficiency of the method (fermion sign problem) is investigated and compared to standard Direct fermionic path integral Monte Carlo (PIMC) and an exact diagonalization method. The details of the algorithm are given in an accompanying poster.

[1] T. Schoof, M. Bonitz, A. Filinov, D. Hochstuhl, and J. Dufty, Contrib. Plasma Phys. 51, 687 (2011)
[2] T. Schoof, S. Groth and M. Bonitz in "Complex Plasmas: Scientific Challenges and Technological Opportunities", edited by M. Bonitz, K. Becker, J. Lopez and H. Thomsen Springer, to be published 2013.
[3] N. V. Prokof'ev, B. V. Svistunov, and I. S. Tupitsyn, J. Exp. Theor. Phys. 87, 310 (1998)

P 14.11 Tue 16:30 SPA Foyer

Numerical simulations of drift wave-zonal flow turbulence — •Ole Meyer[1], Odd Erik Garcia[2], Ralph Kube[2], and Alexander Kendl[1] — [1]University of Innsbruck, Institute for Ion Physics and Applied Physics, A-6020 Innsbruck, Austria — [2]University of Tromsø, Department of Physics and Technology, N-9037 Tromsø, Norway

In the edge of magnetically confined plasmas one experimentally observes long-range correlations in time series of fluctuating plasma parameters. This is believed to be indirect evidence of self- organized criticality behavior of the radial particle flux. A well established model that describes plasma edge dynamics is given by the Hasegawa Wakatani equations (HW). The HW model can be modified (MHW) to allow for self-consistent formation of zonal structures from the underlying drift-wave turbulence. A Fourier-Galerkin method is used to solve the MHW equations in a two-dimensional slab geometry, assuming a uniform and constant magnetic field. Simulations of the quasi-adiabatic regime of the MHW model have been performed well into the non-linearly saturated state. Time series from these simulations are analysed statistically using rescaled range (R/S) analysis and temporal structure functions. Probability distributions (PDFs) of fluctuating quantities are essentially Gaussian for coupling- parameter C = 0.1 and C = 0.2 whereas increased adiabacity (C = 1) yields exponential tails in PDFs. R/S and temporal structure function analysis computes Hurst exponents close to 0.5. Non-linear scaling exponents in structure functions give evidence of multi-fractal behavior in fluctuating quantities.

P 14.12 Tue 16:30 SPA Foyer

Kinetic Monte Carlo Simulations of Cluster Growth in a Plasma — •Kenji Fujioka, Sebastian Wolf, and Michael Bonitz — ITAP University of Kiel, Germany

Cluster growth in low-temperature plasmas is of increasing importance as modern technologies utilize these systems in the fabrication of unique and novel materials. In order to model the complex interplay of the physical processes involved, kinetic Monte Carlo (kMC) simulations are efficient and well suited [1]. Here we present an improvement to the standard *first reaction* method of kMC that is based on simulations of astrophysical polarization maps [2]. This algorithm limits the total number of calls for random number generation while allowing for fluctuating rates and arbitrarily distributed processes. We show some test cases of the algorithm itself, but focus on simulation results for cluster size and velocity distributions and compare them with recent experiments [3]. [1] M. Bonitz et al, Contrib. Plasma Phys. 52, No. 10, 804 (2012). [2] O. Fischer et al, Astron. Astrophys., 284, 187 (1994). [3] M. Ganeva et al, Plasma Sources Sci. Technol. 22, 045011 (2013).

P 14.13 Tue 16:30 SPA Foyer

Estimation of critical parameters for the Super-FRS target at FAIR — •Claudia-Veronika Meister and Dieter H.H. Hoffmann — Technische Universität Darmstadt, Institut für Kernphysik, Schlossgartenstr. 9, 64289 - Darmstadt

In the Super-FRS target and in the beam catchers at GSI stress waves

are generated by intense, fast-extracted ion beams which deposit a high amount of energy within a very short time into target material. This may cause material damage. In this connection, measurements of thermal parameters and eddy-currents resistivity are planned as monitoring techniques. At the same time, to understand the physics of the destruction processes in more detail, also a comprehensive theoretical study of thermal parameters such as heat capacity and coefficient of thermal expansion as well as transport coefficients in warm dense matter is necessary. Here, latest experimetal and theoretical results for the critical parameters of the Super-FRS target are compared.

P 14.14 Tue 16:30 SPA Foyer

Thermal Simulation of a Radio Frequency Ion Thruster — •Waldemar Gärtner and Bruno Meyer — I Physikalisches Institut Justus Liebig Universität, Giessen, Germany

Common missions have a high requirement on the power consumption of all parts of a spacecraft. Since the thermal behavior of the thruster play a great role for the power absorption it is necessary to optimize the thermal design. For the thermal modeling the program COMSOL Multiphysics is used. To investigate the power losses in the thruster an electromagnetic simulation was built up. And then to describe the thermal behavior a 3D thermal model was produced. The thermal simulation considers the thermal radiation between the thruster surfaces and radiation to the test facility walls. We also include in the model thermal conductance of the parts and between the parts.

In current work results of thermal modeling for the small RIT will be presented. Comparison between simulation and experimental data will be given.

Evaluation of the discharge plasma parameters can be done with using of reverse thermal simulation. It seems to be interested for future investigation on non-contact plasma diagnostic.

P 14.15 Tue 16:30 SPA Foyer

Einfluss von Elektron-Elektron-Stößen auf die Leitfähigkeit warmer dichter Materie — Gerd Röpke, Heidi Reinholz, •Sebastian Rosmej und Ronald Redmer — Universität Rostock, Institut für Physik, 18051 Rostock, Deutschland

Die Frage nach dem Einfluss von Elektron-Elektron-Stößen auf die dynamische Leitfähigkeit der dichten Plasmen wird diskutiert. Insbesondere wird die Gleichstromleitfähigkeit untersucht. Bei geringen Dichten im nichtentarteten Grenzfall ist das Verhalten bekannt. Mit zunehmender Entartung nimmt die Rolle der Elektron-Elektron-Stöße ab. Es wird ein "Korrekturfaktor" vorgeschlagen, der die Berücksichtigung der Elektron-Elektron-Stöße bei der Behandlung der Leitfähigkeit auf der Grundlage der Kubo-Greenwood Formel möglich macht. Beispielrechnungen zu Aluminium werden vorgestellt.

P 14.16 Tue 16:30 SPA Foyer

Cluster virial expansion for partially ionized plasmas — •Niels-Uwe Friedrich Bastian[1], Yultuz Omarbarkiyeva[2], Gerd Röpke[1], and Heidi Reinholz[1] — [1]INSTITUT FÜR PHYSIK | Universität Rostock, Universitätsplatz 3 | Rostock, Germany — [2]SECTION OF PHYSICS | International IT University, Dzhandosov 8a | Almaty, Kazakhstan

The chemical picture serves as an intuitive concept to treat the low-density limit of many-particle systems forming clusters (bound states). Systematic quantum statistical approaches allow to combine the mass ac- tion law with mean-field concepts. Within a generalized Beth-Uhlenbeck approach, the quasi particle virial expansion and the suppression of correlations due to screening and Pauli blocking is formulated. This approach is generalized to include arbitrary clusters, where special attention must be paid to avoid inconsis- tencies such as double counting. The contribution of the continuum to the virial coefficients can be reduced considering separately excited states and quasiparticle energies. The cluster-virial expansion connects known benchmarks at low densities as well as at high densities. In detail the electron, proton and atom system is considered.

P 14.17 Tue 16:30 SPA Foyer

Laser Plasma Acceleration: amplification of a laser induced plasma wave and electron trapping — •Saltanat Sadykova[1], Anri Rukhadze[2], Stepan Andreev[2], and Paul Gibbon[1] — [1]Forschungszentrum Jülich - Jülich Supercomputing Centre (JSC) — [2]Prokhorov General Physics Institute, Russian Academy of Sciences, Vavilov Street 38, Moscow, 119991, Russia

The idea to accelerate the charged particles in a plasma medium using collective plasma fields belongs to Budker, Veksler, and Fainberg. Later on, another acceleration schemes were proposed including the laser plasma acceleration. In our earlier work we studied the possibility of employment of ultrarelativistic monoenergetic electron and proton bunches for generation of high plasma wakefields in dense plasmas due to Cherenkov resonance plasma- bunch interaction. We estimated various paramaters at which the maximum amplitude can be generated at the given plasma and bunch parameters [1]. In our present work, we discuss another scheme of amplification of a plasma wave using a laser at the qualitative level. Namely, we make an estimation of plasma, injected electron bunch parameters, maximum amplitude of the generated electric field, determine condition for the electron trapping by the laser-induced plasma wave at which the maximum electron acceleration energy can be gained. As the basis parameters we use those set in plasma acceleration experiment at SPARC_LAB facility of INFN-LNF, Frascati, Italy, with external electron Injection [2]. [1] A. A. Rukhadze and S. P. Sadykova, Phys. Rev. ST Accel. Beams 15, 041302 (2012); [2] A. R. Rossi, et al.,Proceedings of IPAC2012, USA,WEEPPB002

P 14.18 Tue 16:30 SPA Foyer

Laser Plasma Acceleration: amplification of a laser induced plasma wave and electron trapping — •Saltanat Sadykova[1], Anri Rukhadze[2], Stepan Andreev[2], and Paul Gibbon[1] — [1]Forschungszentrum Jülich - Jülich Supercomputing Centre (JSC) — [2]Prokhorov General Physics Institute, Russian Academy of Sciences, Vavilov Street 38, Moscow, 119991, Russia

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P 14.19 Tue 16:30 SPA Foyer

Laser-ion density modulations by ultrafast electron filamentation — •Thomas Kluge[1], Josefine Metzkes[1], Karl Zeil[1], Thomas E. Cowan[1,2], Ulrich Schramm[1,2], and Michael Bussmann[1] — [1]Helmholtzzentrum Dresden-Rossendorf — [2]Technische Universität Dresden

The interaction of ultra-intense lasers with solid foils can be used to accelerate ions to high energies well exceeding 60 MeV. The non-linear relativistic motion of electrons in the intense laser radiation leads to their acceleration and later to the acceleration of ions. Ions can be accelerated from the front surface, the foil interior region, and the foil rear surface (TNSA, most widely used), or the foil may be accelerated as a whole if sufficiently thin (RPA).

Here, we focus on the most widely used mechanism for laser ion-acceleration of TNSA. Starting from perfectly flat foils we show by simulations how electron filamentation at or inside the solid leads to a spatial modulations in the ions. The exact dynamics depend very sensitively on the chosen initial parameters which has a tremendous effect on electron dynamics.

For the first time the two-plasmon decay of plasma oscillations is considered as a source of small-scalelength modulations and evidence for its existence in utrashort laser irradiation of steep denity gradients is presented.