P 8: Laser Plasmas I - Codes and Modelling I

Zeit: Dienstag 11:00–12:30 Raum: HS 20

P 8.1 Di 11:00 HS 20

Adaptive Multi-Physics Simulations of Collisionless Plasmas — •Simon Lautenbach and Rainer Grauer — Ruhr University Bochum

Collisionless plasmas, mostly present in astrophysical and space environments, often require a kinetic treatment as given by the Vlasov equation. Unfortunately, the six-dimensional Vlasov equation is inherently expensive to compute and thus can only be solved on very small parts of the considered spatial domain. However, in some cases, e.g. magnetic reconnection, it is sufficient to solve the Vlasov equation in a localized domain and solve the remaining domain by appropriate fluid models. We present an adaptive hierarchical treatment of collisionless plasmas ranging from fully kinetic, over a 10-moment fluid model incorporating a simplified treatment of Landau damping, to a 5-moment fluid description. To account for separation of electron and ion physics, hybrid stages of mixed electron and ion models are also allowed. To test this multiphysics approach, the full physics-adaptive hierearchy is applied to the Geospace Environmental Modeling (GEM) challenge of magnetic reconnection.

P 8.2 Di 11:15 HS 20

A new relativistic interaction model for 2D and 3D Wigner crystals in a plasma bubble — •Johannes Thomas, Lars Reichwein, and Alexander Pukhov — Institut für Theoretische Physik 1, Heinrich-Heine-Universität Düsseldorf

The spatial structure of an ultralow-emittance electron bunch in the plasma wakefield bubble regime is studied. The full Liénard-Wiechert potentials are considered for mutual inter-particle interactions in the framework of an equilibrium model. This model uses a quasi-static theory which allows to solve the Liénard-Wiechert potentials without knowledge of the electrons* history. The 2D equilibrium structure we find is similar to already observed hexagonal lattices in [1] and shows more topological defects [2]. These defects reduce the stress onto the lattice, which is important for higher energies since a transition between the hexagonal lattice structure and the parabolic confinement of the external field needs to be made. To calculate the 3D equilibrium structure, we use a Lorentz transformation in propagation direction to model the retarded Coulomb interaction between the electrons inside the bunch. We find three-dimensional filaments in the direction of propagation, while the hexagonal structure in perpendicular direction is preserved. From a physical point of view, it is clear that the scaling originates from different competing structures that minimize the system's energy. [1] Johannes Thomas, Marc M. Günther, and Alexander Pukhov, Phys. Plasmas 24, 013101 (2017) [2] Lars Reichwein, Johannes Thomas, and Alexander Pukhov, Phys. Rev. E 98, 013201 (2018)

P 8.3 Di 11:30 HS 20

Probing the strong-field frontier of quantum electrodynamics — •Christoph Baumann and Alexander Pukhov — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

The success of QED is related to its very precise predictions that are in excellent agreement with experimental data. However, according to Ritus and Narozhny [1] and recently revisited by Fedotov [2], perturbative strong-field QED is conjectured to break down at $\alpha\chi^{2/3} \simeq 1$, thus entering a novel and fully non-perturbative regime of QED for which no reliable theoretical calculations exist so far. Regarding ultra-fast radiation losses in such an extreme environment, this regime is thought to be out of experimental reach. Using the QED-PIC code VLPL [3], the present contribution, however, proposes several setups that might be promising for probing this exotic regime in the not too distant future. All setups have in common that the switching time of the strong background field is significantly shortened to reduce radiation losses. This can be done, for instance, by the collision of two high-current, tightly focused and tightly compressed electron beams [4], by the conversion of an optical laser pulse to an ultra-intense attosecond pulse [5] or by using the fact that the penetration depth in laser-solid interactions is limited to the skin depth [6].

[1] V. I. Ritus, Ann. Phys. 69, 555 (1972); N. B. Narozhny, Phys. Rev. D 21, 1176 (1980); [2] A. Fedotov, J. Phys.: Conf. Ser. 826, 012027 (2017); [3] C. Baumann *et al.*, Phys. Rev. E 94, 063204 (2016); [4] V. Yakimenko *et al.*, arXiv:1807.09271 (2018); [5] C. Baumann *et al.*, arXiv:1811.03990 (2018); [6] C. Baumann *et al.*, in preparation (2018)

P 8.4 Di 11:45 HS 20

Ultra-high energy density physics and ion acceleration in nano- and microstructures — •Vural Kaymak[1], Alexander Pukhov[1], Vyacheslav N. Shlyaptsev[2], Jorge J. Rocca[2,3], Bastian Aurand[4], and Oswald Willi[4] — [1]Institut für Theoretische Physik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany — [2]Department of Electrical Computer Engineering, Colorado State University, Fort Collins, Colorado 80523, USA — [3]Department of Physics, Colorado State University, Fort Collins, Colorado 80513, USA — [4]Institut für Laser- und Plasmaphysik, Heinrich-Heine Universität, 40225 Düsseldorf, Germany

The creation of ultra-high energy density (UHED, $> 1 \cdot 10^8 \mathrm{J/cm^3}$) plasmas in compact laboratory setups enables studies of matter under extreme conditions and can be used for the efficient generation of intense x-ray and neutron pulses. An accessible way to achieve the UHED regime is the irradiation of vertically aligned high-aspect-ratio nanowire arrays with relativistic femtosecond laser pulses. These targets have shown to facilitate near total absorption of laser light several micrometers deep into near-solid-density material. Spherical shaped targets on the microscale have shown to enhance the laser acceleration of proton beams compared to flat targets, making them promising sources for cancer radiotherapy and measurements of magnetic and electric fields with high spatiotemporal resolution. We investigate ways to generate UHED matter in nanowire arrays and the enhanced proton beam acceleration by spherically shaped microstructures.

P 8.5 Di 12:00 HS 20

Investigation of Plasma Expansion on Solid Surfaces Interacting with an Ultrashort Laser Pulse in the Weakly-Relativistic Intensity Regime — •Steffen Mittelmann[1], Götz Lehmann[2], and Georg Pretzler[1] — [1]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf — [2]Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

The dynamics of plasma generation and expansion of a solid surface irradiated by a few-fs, ultra-high contrast weakly-relativistic laser pulse is studied by particle-in-cell simulations. The aim is to observe the onset and the dynamics of plasma expansion on a time-scale less than 100 fs after the main interaction, which is a challenging regime for experimental observations. These dynamics have been previously investigated in the PHASER (Phase-Stabilized Heine Laser) lab in Düsseldorf. A pump-probe experiment was used to detect a spatially structured plasma expansion. Our investigations are made with the simulation code EPOCH and give insight into a potential origin of the observed structured expansion. We are able to identify the plasma behaviour investigated in the experiment and we can show that an important role is attributed to the fact that the used target is a layered system of aluminium coated on a fused quartz substrate.

P 8.6 Di 12:15 HS 20

Laser-driven shock acceleration of ions in the collisional and ultra-relativistic regime — •Shikha Bhadoria, Naveen Kumar, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, Heidelberg

The effect of collisions and quantum electrodynamic effects like radiation reaction and pair production on shock formation and subsequent ion acceleration from laser-plasma interaction are explored by means of particle-in-cell simulations. In this setup, the incident laser pushes the laser-plasma interface inside the plasma target through the holeboring effect and generates hot electrons. The propagation of these hot electrons inside the target excites a return plasma current, leading to filamentary structures caused by the Weibel/filamentation instability. The collisional weakening of the space-charge effects results in the formation of a shock with a higher density jump than in a collisionless plasma. This stronger shock leads to stable quasi-monoenergetic acceleration of ions [1]. In the ultra-relativistic regime, both radiation reaction and pair plasma formation tend to slow down the shock velocity which makes the quasi-monoenergetic ion acceleration lasting on longer timescales. [1] S. Bhadoria, N.Kumar, C.H. Keitel. Stable quasi-monoenergetic ion acceleration from the laser-driven shocks in collisional plasmas ArXiv:1707.03309[physics.plasm-ph]