P 27: Theory of nonideal Plasmas

Time: Friday 10:30–13:00 Location: SPA HS201

Invited Talk P 27.1 Fri 10:30 SPA HS201

Production and Diagnostics of dense matter — •Erik Brambrink[1], Alessandra Benuzzi-Mounaix[1], Tommaso Vinci[1], Norou Amadou[1], Gael Huser[2], Guillaume Morard[3], Francois Guyot[3], Thibaut de Resseguier[4], Stephane Mazevet[6], Norimasa Ozaki[5], Michel Koenig[1], and Kohei Miyanishi[5] — [1]LULI UMR7605 CNRS - CEA - Ecole Polytechnique - Université Pierre et Marie Curie, Palaiseau, France — [2]CEA,DAM,DIF, F-91297 Arpajon — [3]Université Paris Diderot. IMPMC. IPGP. CNRS. Université Pierre et Marie-Curie, Paris, France — [4]Institut PPrime. CNRS. ENSMA. Université de Poitiers, Poitiers, France — [5]Graduate school of engineering, Osaka university, Suita, Osaka 565-0871, Japan — [6]LUTH, UMR 8102 Observatoire de Paris, CNRS Université Paris Diderot, Meudon, France

High energy lasers are a unique tool to create high pressure states above 10 Mbar at ns time scales, which allow to study materials under these extreme conditions. These conditions are, for example, comparable with planetary cores, where material properties play in important role for the properties and evolution of a planet. The rapid compression allows also to study dynamic effects of phase transitions.

We will present recent results of laser compression of iron reaching conditions of so called super-Earth cores. A description of the compression schemes as well as present and future diagnostics is presented.

P 27.2 Fri 11:00 SPA HS201

Relativistic Frequency Synthesis of Light Fields — •Christian Rödel[1,2], Erich Eckner[1], Jana Bierbach[1,2], Mark Yeung[2,3], Brendan Dromey[3], Thomas Hahn[4], Silvio Fuchs[1,2], Arpa Galestian[1], Martin Wünsche[1], Stephan Kuschel[1,2], Dirk Hemmers[4], Georg Pretzler[4], Matthew Zepf[2,3], and Gerhard Paulus[1,2] — [1]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität, Jena — [2]Helmholtz-Institut Jena — [3]Centre for Plasma Physics, Queen's University Belfast, United Kingdom — [4]Institut für Laser- und Plasmaphysik, Universität Düsseldorf

High harmonic generation from relativistically oscillating plasma surfaces typically exhibits a shallow, but generally decaying, spectral slope. We observed, however, an enhanced emission of particular harmonics for extremely steep plasma gradients approaching a step-like plasma density ramp. Numerical simulations reproduce the observations when matching the plasma conditions to those in the experiment and reveal a strong excitation of the surface plasma mode with the plasma frequency. A simple model of nonlinear frequency synthesis is able to explain the measured harmonic spectrum when relativistic nonlinear effects are taken into account. This novel type of relativistic nonlinearity may lead to a tunable, coherent XUV source of high efficiency.

P 27.3 Fri 11:15 SPA HS201

Using XFELs for Probing of Complex Interaction Dynamics of Ultra-Intense Lasers with Solid Matter — •Thomas Kluge[1], Christian Gutt[2], Lingen Huang[1], Malte Zachias[1], Ulrich Schramm[1], Michael Bussmann[1], and Thomas E. Cowan[1] — [1]Helmholtzzentrum Dresden-Rossendorf — [2]Universität Siegen

We demonstrate the potential of X-ray free-electron lasers (XFEL) to advancethe understanding of complex plasma dynamics by allowing for the first time nanometer and femtosecond resolution at the same time in plasma diagnostics. Plasma phenomena on such short timescales are of high relevance for many fields of physics, in particular in the ultra-intense ultra-short laser interaction with matter. Highly relevant yet only partially understood phenomena may become directly accessible in experiment. These include relativistic laser absorption at solid targets, creation of energetic electrons and electron transport in warm dense matter, including the seeding and development of surface and beam instabilities, ambipolar expansion, shock formation, and dynamics at the surfaces or at buried layers. We demonstrate the potentials of XFEL plasma probing for high power laser matter interactions using exemplary the small angle X-ray scattering, resonant coherent X-ray diffraction imaging and photon correlation spectroscopy, focusing on general considerations for XFEL probing.

Invited Talk P 27.4 Fri 11:30 SPA HS201

Theory of high energy density matter — •Jan Vorberger — Max-Planck-Institut für die Physik komplexer Systeme, Dresden, Germany

High energy density matter naturally occurs in the interior of planets. It is created in laboratories to experiment on fusion for energy production and to study these novel states in detail. Densities for this state of matter routinely exceed those of known solid materials but there is a lack of long range order in the ionic subsystem. The electrons are partially degenerate and contribute the main part of the pressure of the system. Ionization is a very dynamic phenomenon and is controlled by a complex interplay of temperature and pressure ionization, and changing electronic states. Here, it is shown how a body of knowledge for this state of matter was generated by a combination of new experimental capabilities and new theoretical methods over the last 10 years. It is demonstrated, how a precise modelling of the electronic structure factor leads to an unprecedented accuracy of measurements of the ion structure, the equation of state, and energy relaxation properties. Such possibilities then lead to new and exciting ways to test the latest heoretical predictions. These rely heavily on finite temperature density functional molecular dynamic simulations, a widely employed tool, as well as on more traditional quantum statistics methods. Their advantages and shortcomings are discussed and possibilities of the new x-ray free electron lasers are sketched to advance the theoretical modelling of high energy density matter.

P 27.5 Fri 12:00 SPA HS201

Scaling of Optical Free-Electron Lasers in Traveling-Wave Geometries — •Klaus Steiniger, Alexander Debus, Michael Bussmann, and Roland Sauerbrey — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Optical free electron lasers in the X-ray range using high power lasers are difficult to realize in the standard head-on Thomson-scattering geometry. Problems arise from the nonlinear Thomson intensity threshold and the Rayleigh-length limiting the interaction distance which prevent the SASE process to occur.

These limits can be circumvented in a Travelling-wave Thomson-scattering (TWTS) geometry, in which ultrashort and narrow-band light pulses in the X-Ray region of the spectrum are created by scattering high intensity laser pulses from relativistic electron bunches. TWTS uses lasers with a pulse front tilt in a sidescattering geometry to scale the interaction length into the centimeter to meter range with undulator periods in the region of one hundred to a few hundred micrometer.

Starting from a fully 3D, wave-optical representation of the TWTS pulse, including its dispersion properties, we present a self-consistent 1.5D FEL-theory which accounts for the coupling of the obliquely incident laser pulse to the electron dynamics. Furthermore, we give scaling laws on the interaction geometry and FEL-amplification with respect to incidence angle and electron beam parameters. Using these findings we discuss possible experimental scenarios and its requirements on laser pulses and electron beams.

P 27.6 Fri 12:15 SPA HS201

Adaptive-Particle-Refinement for PIC Simulations — •Nils Moschüring and Hartmut Ruhl — Ludwig-Maximilians-Universität, Munich, Germany

Particle-in-cell (PIC) codes commonly employ a finite element method in order to solve Vlasov's equation and a finite-difference-time-domain method to solve Maxwell's equations. The number of employed quasi-elements in the finite element solver is significant for the reliability of the obtained results. In most cases it is also the defining property when evaluating the computational demands of a given simulation. Thus it is regarded to be very useful to dynamically adapt this number. We have developed an adaptive-particle-refinement (APR) algorithm which dynamically adapts the number of quasi-particles during a simulation while conserving the total momentum, total energy and total charge. It introduces no unphysical divergence in the electromagnetic fields. It can either increase the number of quasi-particles by splitting them or decrease the number by merging them. This can be useful in various situations: 1. The number of quasi-particles is an important property which determines the signal-to-noise ratio for various derived quantities. 2. In cases where the charge density is not conserved, numerical algorithms can lead to a steep increase in quasi-particles and thus computational demand. Quasi-particle merging can counteract this. 3. When performing Monte-Carlo-Collisional (MCC) simulations it is imperative to have quasi-particles with comparable or equal weight in order to achieve statistical significance. 4. It represents an important step in order to implement Adaptive-Mesh-Refinement-PIC (AMR-PIC).

P 27.7 Fri 12:30 SPA HS201

Kinetic simulations of plasma instabilities — •Benedikt Steinbusch[1,2], Paul Gibbon[1,3], and Richard Sydora[4] — [1]Institute for Advanced Simulation, JSC, Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Institut für Laser- und Plasmaphysik, Heinrich Heine Universität Düsseldorf, 40225 Düsseldorf — [3]Centre for Mathematical Plasma Astrophysics, Department of Mathematics, Katholieke Universiteit Leuven, Belgium — [4]Department of Physics, University of Alberta, Edmonton, Alberta T6G2E1, Canada

Magnetically confined plasmas can be subject to the Kelvin-Helmholtz (KH) instability when an inhomogeneous electric field is crossed with the confining magnetic field, creating a sheared drift velocity. We investigate this instability in the kinetic, high-frequency regime where the ion cyclotron radius is comparable to or larger than the characteristic width of the shear flow.

First, we perform kinetic simulations of a conventional KH setup with a homogeneous plasma density using our mesh-free treecode PEPC. We compare our results to both analytic fluid theory for the linear growth phase and previous computations performed with a Particle-in-Cell simulation.

Having established the validity of the mesh-free technique, we proceed to study the more complex case of a plasma-vacuum interface, where a sheared electric field arises naturally due to a difference in larmor radii of different species. Here, we also compare the treecode to PIC simulations, focussing on the long-term, non-linear evolution of the system.

P 27.8 Fri 12:45 SPA HS201

Unleashing PFlop/s for Plasma Science with PIConGPU — •Axel Huebl[1], René Widera[1], Heiko Burau[1], Felix Schmitt[2], Richard Pausch[1], Benjamin Schneider[1], Guido Juckeland[2], and Michael Bussmann[1] — [1]Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Deutschland — [2]Zentrum für Informationsdienste und Hochleistungsrechnen, TU Dresden, Deutschland

PIConGPU is a massively parallel open source particle-in-cell (PIC) code written for CUDA capable graphics cards (GPUs). PIC codes are used to model fully relativistic electro-magnetic interactions between particles and discrete mesh points (fields) in a self-consistent manner. That allows for ab-intio simulations ranging from astrophysical scenarios like emerging plasma instabilities to modern laser-driven particle accelerators like the laser-wakefield accelerator (LWFA).

In this talk, we will present the strategy to port a non-trivial algorithm to a modern, massively parallel hardware architecture like GPUs. We give a short introduction in our free multi-GPU framework libPMacc for general mesh and particle based simulations. Based on that, scalings up to 18,000 GPUs on the Titan supercomputer (Oak Ridge National Lab) will be discussed.

Applications will include results of in-situ far field radiation diagnostics for the relativistic Kelvin-Helmholtz-Instability (KHI) by evolving billions of electrons and calculating their individual Liénard-Wiechert potential for arbitrary directions and frequencies on the fly.