AKBP 6: New Accelerator Concepts - Models and Experiments

Time: Tuesday 11:00–13:00 Location: E 020

AKBP 6.1 Tue 11:00 E 020

Absolute lanex screen calibration for laser accelerated proton bunch detection — •Joshua Dietrich Schilz[1], Elisabeth Bodenstein[1,2], Florian-Emanuel Brack[1], Martin Rehwald[1], Florian Kroll[1], Jörg Pawelke[1,2], Felix Horst[1,2], Ulrich Schramm[1,3], Karl Zeil[1], and Josefine Metzkes-Ng[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]OncoRay, Dresden, Germany — [3]TUD Dresden, Dresden, Germany

Plasma-based accelerators leverage the robust electromagnetic fields sustained by plasmas for propelling charged particles to elevated energy levels. The creation of accelerating field structures within plasma is achieved through the application of intense laser pulses or charged particle beams. Laser-plasma accelerated (LPA) proton bunches are now applied for research fields ranging from ultra-high dose rate radiobiology to material science. For a long time, multi channel plates (MCP) have been used to characterize these proton bunches in e.g. Thomson parabolas (TPS). It is difficult to asses an absolute proton number calibration from these MCPs due to their nonlinear response. Scintillating lanex screens emerge as a promising and already implemented alternative in LPA facilities for the detection of ions and electrons. This study introduces an absolute proton number calibration for one of the most sensitive screens, the DRZ High (Mitsubishi Chemical Corporation, Duesseldorf, Germany), with the added benefit of seamless transferability to other facilities. Additionally, we delve into the quenching properties of the lanex screen, further enhancing our understanding of its capabilities.

AKBP 6.2 Tue 11:15 E 020

Coulomb-correlated few-electron states from a laser-driven field emitter — •Armin Feist[1,2], Rudolf Haindl[1,2], Till Domröse[1,2], Marcel Möller[1,2], John H. Gaida[1,2], Sergey V. Yalunin[1,2], and Claus Ropers[1,2] — [1]Max Planck Institute for Multidisciplinary Sciences, Göttingen, DE — [2]4th Physical Institute, University of Göttingen, DE

Coulomb repulsion in charged particle beams and pulses is usually considered detrimental due to a stochastic emittance increase. An extreme limit for high-brightness few-electron pulses is the spatially confined femtosecond photoemission from field emitters [1,2] employed in ultrafast electron microscopes [3]. However, ensemble-averaged detection usually prevents studying correlations in free-electron beams.

Here, we use event-based electron microscopy to characterize laser-triggered few-electron pulses generated at a Schottky field emitter [4]. We find strong Coulomb-correlations and field-controllable antibunching in electron pair, triple, and quadruple states, with a characteristic energy scale of 2 eV. State-sorted beam caustics show a discrete increase in virtual source size and longitudinal source shift.

Inducing such few-electron Coulomb correlations facilitates non-Poissonian electron pulse statistics and single-electron heralding, and promises applications in free-electron quantum optics.

[1] P. Hommelhoff *et al.*, Phys. Rev. Lett. **96**, 077401 (2006).
[2] C. Ropers *et al.*, Phys. Rev. Lett. **98**, 043907 (2007).
[3] A. Feist *et al.*, Ultramicroscopy **176**, 63-73 (2017).
[4] R. Haindl *et al.*, Nature Physics **19**, 1410-1417 (2023).

AKBP 6.3 Tue 11:30 E 020

Enhancing the Efficiency of Laser-Based Heavy Ion Acceleration by Radiative Target Heating — •Veronika Kratzer, Laura D. Geulig, Erin G. Fitzpatrick, Runjia Guo, Ming-Yang Hsu, Vitus Magin, Maximilian J. Weiser, and Peter G. Thirolf — Ludwig-Maximilians-Universität München, Munich, Germany

The efficient acceleration of heavy ions to kinetic energies above ca. 7 MeV/u is crucial to investigate the properties of heavy, neutron-rich nuclei in the novel fission-fusion nuclear reaction scheme [1]. This necessitates the acceleration of heavy ions with an intense laser pulse yielding bunches of multiple ion species of several charge states and with a continuous energy spectrum up to a characteristic cutoff-energy. Previously, it was found that the acceleration of (in our case) Au ions from thin foil targets can significantly be enhanced by evaporating surface contaminants and thus suppressing the acceleration of namely protons and C ions [2,3]. At the Centre for Advanced Laser Applications, we successfully accelerate highly charged Au ions from targets which are radiatively heated. Additionally, we record the thermal spectrum of the target and determine the surface temperature by fitting Plancks radiation law which allows a quantitative analysis [4]. The heating behavior of gold foils in vacuum and air is compared. Further, targets of different manufacturing processes and with different foil thicknesses are studied. [1] D. Habs et al., Appl. Phys. B 103, 471-484 (2011) [2] F. H. Lindner et al., Phys. Plasm. Contr. Fusion 61, 055002 (2019) [3] F. H. Lindner et al., Sci Rep 12, 4784 (2022) [4] M. J. Weiser, Master Thesis, LMU Munich, 2021

AKBP 6.4 Tue 11:45 E 020

Influence of laser intensity ramps on proton acceleration of solid density targets in PIC simulations — •Franziska Paschke-Bruehl, Thomas Kluge, and Ilja Göthel — HZDR (Helmholtz-Zenrum Dresden-Rossendorf), Dresden, Germany

We present a study that investigates the influence of an exponential laser intensity ramp (pre main pulse) on the proton acceleration from an ultra-thin Hydrogen target at plastic-density in 1D PIC (particle in cell) simulations. We find that laser ramp constellations with long scale lengths, i.e. shallow slope for energy deposition, and less energy in the ramp, about 2-8 % of total energy in pulse, are optimal for high proton energies due to a shock appearing in the expanding plasma on the rear side of the target. Protons of the pre plasma experience reflection from the shock and additional acceleration when traveling down the density gradient, these particles gain significant velocity and overtake the expanding TNSA protons.

By varying parameters such as a0, target thickness and density, we tested the robustness of the mentioned dynamics and found the same trends for a number of setups.

AKBP 6.5 Tue 12:00 E 020

Predicting Atomic States in Laser Plasma Accelerators — •Brian Edward Marré[1], Axel Huebl[2], Sergei Bastrakov[1], Michael Bussman[1,3], René Widera[1], Thomas Cowan[1], Ulrich Schramm[1], and Thomas Kluge[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Berkley National Lab — [3]CASUS-Center for Advanced System Understanding

Standard atomic physics models in Particle-in-Cell(PIC) simulations either neglect excited states, predict atomic state population in post processing only, or assume quasi-thermal plasma conditions.

This is not sufficient for high-intensity short-pulse laser generated plasmas, due to their non-equilibrium, transient and non-thermal plasma conditions, which are now becoming accessible in XFEL experiments at HIBEF (EuropeanXFEL), SACLA (Japan) or at MEC (LCLS/SLAC).

To remedy this we have developed FLYonPIC, an extension of the PIC code PIConGPU, modelling excited atomic states population dynamics in transient plasmas and without assuming a specific spectrum or temperature for electrons. This extension is based on an atomic state super configuration model, solved explicitly in time and with feedback to PIC, enabling full self consistency.

We will present an efficient implementation and discuss statistical analysis for validation of our model.

AKBP 6.6 Tue 12:15 E 020

Searching for non-thermal acoustic pulses emitted from laser-produced plasmas in water — •Timo Pohle, Anna-Katharina Schmidt, Julia Liese, and Jörg Schreiber — Fakultät für Physik, Ludwig-Maximilians-Universität München, Am Coulombwall 1, 85748 Garching

Laser acceleration in plasmas can yield short, very dense bunches of protons and heavier ions, which complicates diagnosing them. We use water as a detector medium where the ions deposit their energy when slowing down without the risk of destroying the detector. The rapid change in energy density results in an acoustic wave that provides a way of characterizing each ion bunch individually. Modeling the process commonly relies on the thermoacoustic approach, that is water thermally expands due to local heating. Surprisingly, heating by ions creates an additional, non-thermoacoustic, signal component which becomes observable close to the temperature where water has its highest density. In contrast, heating due to linear absorption of light behaves thermally [1]. We are now measuring the acoustic signal created by a laser produced plasma and by ions depositing their energy using water of around 4°C. This suppresses the thermoacoustic contribution and enables us to investigate the origin of the non-thermal signal. In my talk I will present first experimental results of the plasma-acoustic experiments.

[1] R. Lahmann et al. Astropart. Phys. 65, 69 (2015).

AKBP 6.7 Tue 12:30 E 020

Transverse Plasma Density Redistribution in Discharge Capillaries — •Advait Kanekar, Judita Beinortaite, Jonas Björklund Svensson, Lewis Boulton, Matthew James Garland, Harry Jones, Gregor Loisch, Mathis Mewis, Felipe Peña, Sarah Schröder, Maxence Thévenet, Stephan Wesch, Matthew Wing, and Richard D'Arcy — Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

Plasma-wakefield accelerators provide acceleration gradients several orders of magnitude higher than radio-frequency accelerators and therefore represent a promising technology for reducing the footprint of future particle accelerators. Detailed knowledge of plasma dynamics, both spatially and temporally, is crucial to be able to mature the technology for application to linear colliders and free-electron lasers. FLASHForward is a beam-driven plasma-wakefield accelerator experiment at DESY. Using discharge capillaries as its plasma source, FLASHForward acts as a test bench to develop technologies to accelerate electron beams with high quality and high average power. In this contribution we present investigations into the temporal evolution of transverse plasma-density distributions at FLASHForward. Beam-based measurements are compared to hydrodynamic simulations for the first time.

AKBP 6.8 Tue 12:45 E 020

Visualizing Plasmons and Ultrafast Kinetic Instabilities in Laser-Driven Solids using X-ray Scattering — •Paweł Ordyna[1,2], Ulrich Schramm[1,2], Thomas Cowan[1,2], and Thomas Kluge[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Technical University Dresden

Ultra-intense lasers that ionize and accelerate electrons in solids to near the speed of light can lead to kinetic instabilities that alter the laser absorption and subsequent electron transport, isochoric heating, and ion acceleration. These instabilities can be difficult to characterize, but a novel approach using X-ray scattering at keV photon energies allows for their visualization with femtosecond temporal resolution on the few nanometer mesoscale.

The scattering signal can be predicted from Particle-in-cell simulations. We present here combined experimental and synthetic results from laser-driven flat silicon membranes that show development of periodic structures in the plasma electron density. Our Particle-in-cell simulations confirm that the observed signals are due to an oblique two-stream filamentation instability.

These findings provide new insight into ultra-fast instability and heating processes in solids under extreme conditions at the nanometer level with possible implications for laser particle acceleration, inertial confinement fusion, and laboratory astrophysics.