AKBP 1: New Accelerator Concepts I

Time: Monday 15:00–18:00 Location: MOL 213

AKBP 1.1 Mon 15:00 MOL 213

LUX Beamline for Laser-Plasma Driven Undulator Radiation — •Andreas R. Maier[1], Niels Delbos[1], Irene Dornmair[1], Henning Groth[1], Sören Jalas[1], Spencer Jolly[1,2], Manuel Kirchen[1], Vincent Leroux[1,2], Philiip Messner[1], Kevin Peters[1], Matthias Schnepp[1], Maximilian Trunk[1], Christian Werle[1], and Paul Winkler[1] — [1]Center for Free-Electron Laser Science & Department of Physics, University of Hamburg, 22761 Hamburg, Germany — [2]ELI Beamlines, Dolní Břežany, Czech Republic

Plasma-based accelerators promise ultra-compact sources of highly relativistic electron beams, especially suited for driving novel x-ray light sources. Within the LAOLA Collaboration, the University of Hamburg and DESY work closely together, combining university research with the expertise of a large and well-established accelerator facility, to enhance the performance of plasma accelerators for applications. Here, we will discuss and show first results from the so-called LUX beamline for plasma-driven undulator radiation and provide an overview of our group activities.

AKBP 1.2 Mon 15:15 MOL 213

Control and propagation effects of the wavefront quality for a high-power laser system — •Vincent Leroux[1,2], Spencer W. Jolly[1,2], Matthias Schnepp[1], and Andreas R. Maier[1] — [1]Center for Free-Electron Laser Science & Department of Physics, University of Hamburg, 22761 Hamburg — [2]ELI Beamlines, Dolní Břežany, Czech Republic

Laser-Plasma Wakefield Accelerators showed promising results in the past few years, generating high-energy electron beam over cm-distances. Nevertheless, the quality and shot-to-shot stability of such beams have not yet reached the level of conventional accelerators. One of the crucial factors is the driver laser beam quality, which needs to be focused close to the diffraction limit. To achieve the highest electron beam quality, the laser wavefront has to be controlled via a closed loop including a deformable mirror and a wavefront sensor. The LUX beamline, built in collaboration between ELI-Beamlines, the University of Hamburg and DESY, aims to generate and study plasma-driven undulator radiation. It is driven by the 200 TW ANGUS laser system which includes such adaptive optics. In this talk, I will present results on the wavefront control of the high power laser beam, including effects of the wavefront propagation through the 35 meters long transport beamline and wavefront-based alignment of the focusing parabolic mirror. The quality of the focal spot is investigated as the final figure of merit.

AKBP 1.3 Mon 15:30 MOL 213

Pre-target characterization of the ANGUS laser at the LUX plasma accelerator and online diagnostics of the laser system — •Matthias Schnepp[1], Niels Matthias Delbos[1], Irene Dornmair[1], Sören Jalas[1], Spencer Windhorst Jolly[1,3], Manuel Kirchen[1], Vincent Leroux[1,3], Phillip Messner[1,4], Kevin Peters[1], Maximilian Trunk[1], Christian Markus Werle[1], Paul Winkler[1,2], and Andreas R. Maier[1] — [1]Center for Free-Electron Laser Science and Department of Physics,University of Hamburg, 22761 Hamburg, Germany — [2]DESY, Hamburg, Germany — [3]ELI Beamlines, Dolní Břežany, Czech Republic — [4]International Max Planck Research School for Ultrafast Imaging and Structural Dynamics, Hamburg, Germany

Laser-plasma based acceleration has matured into a technique providing high-energy electron beams able to drive undulator-based x-ray light sources. The LUX beamline, currently built up in a collaboration between University of Hamburg, DESY and ELI-Beamlines, is designed to be such a light source. The plasma acceleration stage is driven by the 5 Hz 200 TW laser system ANGUS. Recently first accelerated electrons have been shown. In this presentation the ANGUS laser system and its transport beamline will be briefly introduced. First measurements of pre-target diagnostic will be presented as well as the implementation of online diagnostics at the laser repetition rate.

AKBP 1.4 Mon 15:45 MOL 213

Research activities and capabilities at the DRACO laser system — Florian Brack[1,2], Lennart Gaus[1,2], Alexander Jahn[1,2], Thomas Kluge[1], Stephan Kraft[1], Florian Kroll[1,2], Josefine Metzkes[1], Lieselotte Obst[1,2], Martin Rehwald[1,2], •Hans-Peter Schlenvoigt[1], Karl Zeil[1], Tim Ziegler[1,2], and Ulrich Schramm[1,2] — [1]Helmholtz-Zentrum Dresden – Rossendorf, Institute of Radiation Physics, Bautzner Landstr. 400, 01328 Dresden, Germany — [2]Technische Universität Dresden, 01062 Dresden, Germany

Since 2014, the DRACO laser system of HZDR got back into operation with both its original 150 TW beam and the new 1 PW beam. Its main goal is to study novel, laser-driven, plasma-based acceleration concepts and their potential to medical applications. Highlight experiments for ion acceleration were using a cryogenic hydrogen jet as pure proton, near-critical-density target with high repetition rate capability (collaboration with SLAC and European XFEL), ultra-thin liquid-film targets in combination with a laser pulse contrast cleaning technique (collaboration with Ohio State University), the implementation of a pulsed-solenoid-based proton beamline for in-vivo cell irradiation experiments as well as the first shots with a full PW laser beam.

AKBP 1.5 Mon 16:00 MOL 213

Development and In Situ - Characterization of Ultra-Thin Laser Targets for the Acceleration of Protons and Ions at the DRACO Laser with Ultra-High Pulse Contrast — •Alexander Jahn[1,2], Joshua Gössel[1,2], Stephan Kraft[1], Lieselotte Obst[1,2], Hans-Peter Schlenvoigt[1], Karl Zeil[1], and Ulrich Schramm[1,2] — [1]HZDR, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany

High-intensity laser-plasma ion generation is promising as a compact, low-cost proton source for applications like ion beam therapy. To reach the performance of conventional and already existing systems there is still a lot to optimize. One way to characterize the ion acceleration performance for given laser parameters can be performed using thickness scans and hence the determination of the optical target thickness. We present the development of an ultra-thin foil target system (range of 10–1000 nm) including reliable thickness measurement. These targets will be applied for measurements at 600 TW Draco laser at the HZDR with ultra-high contrast. The foils are made of formvar (aka polyvinyl formal) or polysterene powder which has to be solved and put on a water surface to generate a thin film structure. To measure the thickness of the produced targets a F20 reflectometry system by Filmetrics is established. The reflectometer calculates the thickness of the measured sample out of the reflection spectrum based on the phenomenon of thin-film interference. The main advantage of this technique is the possibility to characterize the target thickness directly before the high power laser shot at the interaction point in the vacuum chamber.

AKBP 1.6 Mon 16:15 MOL 213

Probing of ultra-high contrast laser-plasma interaction from condensed hydrogen jet — •Tim Ziegler[1,2], Karl Zeil[1], Lieselotte Obst[1,2], Martin Rehwald[1,2], Florian Brack[1,2], Josefine Metzkes[1], Stephan Kraft[1], Hans-Peter Schlenvoigt[1], Sebastian Goede[3], Maxence Gauthier[3], Christian Roedel[3], Chandra Curry[3], Siegfried Glenzer[3], and Ulrich Schramm[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]TU Dresden, Dresden, Germany — [3]SLAC National Accelerator Laboratory, Stanford, United States

To advance the development of laser proton accelerators for highly demanding applications like cancer treatment a stable source of energetic particles at high repetition rates is required. During our last experimental campaign at the Helmholtz-Zentrum Dresden-Rossendorf we therefore employed a pure condensed hydrogen jet as a renewable target for the 100TW Draco laser. Draco is a ultra-high power Ti:Sa laser system which delivers pulses of 30fs and 3J on target at 800nm with a repetition rate of 10Hz. A recollimating single plasma mirror results in an improved temporal contrast represented by an ASE level of 10^{-13}. The expanding jet was monitored on-shot with a separate phase locked diode-pumped ps-laser at a wavelength of 515 nm. By that over-exposure of the CCD resulting from strong plasma self-emission which had been observed in earlier experiments to be at the harmonics of the pump laser, could be avoided. The probe beam was split in two parts oriented perpendicular and parallel with respect to the pump laser axis in order to precisely determine the jet position and its density profile.

15 min. break

AKBP 1.7 Mon 16:45 MOL 213

Plasma targets for the Laser-plasma driven Undulator X-ray source LUX — •Philipp Messner[1,2], Niels Delbos[1], and Andreas R. Maier[1] — [1]Center for Free-Electron Laser Science & Department of Physics, University of Hamburg, 22761 Hamburg, Germany — [2]International Max Planck Research School for Ultrafast Imaging & Structural Dynamics, 22761 Hamburg, Germany

Laser-plasma accelerator are promising candidates to provide ultra-relativistic electron beams for compact light sources. However, the generation of stable, high quality electron beams which are necessary to drive such a compact light source is challenging. The main determining factors are thereby the plasma properties which are given by the structure of the cm-scaled plasma target itself.

Here, we present the design process of the LUX plasma targets. Based on computational fluid dynamic simulations, targets were produced allowing to control the plasma properties and to set stable, repeatable conditions. Raman spectroscopy measurements of the gas density in the target confirm these simulations. Furthermore, results from target machining in sapphire crystals using a femtosecond laser system with KHZ repetition rate are presented and compared to the machining with state of the art milling machines.

AKBP 1.8 Mon 17:00 MOL 213

LUX Electron Optic — •Paul Winkler[1,2], Christian Werle[2], Niels Delbos[2], Max Trunk[2], Philipp Messner[2,4], Manuel Kirchen[2], Sören Jalas[2], Spencer Jolly[2,3], Vincent Leroux[2,3], Matthias Schnepp[2], Dariusz Kocoň[3], Alexander Molodozhentsev[3], Přibyl Lukáš[3], and Andreas R. Maier[2] — [1]DESY, Hamburg, Germany — [2]Center for Free-Electron Laser Science & Department of Physics, University of Hamburg, 22761 Hamburg, Germany — [3]ELI Beamlines, Dolní Břežany, Czech Republic — [4]International Max Planck Research School for Ultrafast Imaging & Structural Dynamics, 22761 Hamburg, Germany

The LUX experiment, built and operated by the LUX Junior Research Group of the University of Hamburg in close cooperation with DESY, produces laser-plasma electron bunches with 5 Hz repetition and is currently upgraded towards the generation of undulator radiation. In this talk we present a beam optic for electron energies of 100-400 MeV with a modified, compact electro quadrupole doublet. The magnets feature a gap size as small as 12 mm, resulting in field gradients of up to 150 T/m, which allows capturing the beam 10cm behind the target and focusing it into a 5mm period undulator or an electron spectrometer, respectively. Special care was taken in the beam pipe design to ensure clip-free laser transport to the post target diagnostics.

AKBP 1.9 Mon 17:15 MOL 213

Studying a new LWFA scheme that produces electron bunches of several hundred picocoulombs using PIConGPU — •Richard Pausch[1,2], Alexander Debus[1], Klaus Steiniger[1,2], Marco Garten[1,2], Jurjen Couperus[1,2], Alexander Köhler[1,2], Heiko Burau[1,2], Axel Huebl[1,2], Arie Irman[1], Ulrich Schramm[1,2], and Michael Bussmann[1] — [1]Helmholtz-Zentrum Dresden - Rossendorf — [2]Technische Universität Dresden

We present recent simulation studies of laser wakefield acceleration that match experiments performed at HZDR which produce quasi mono-energetic electron bunches of several hundred picocoulombs charge. The talk focuses on the dynamics of this new acceleration scheme and required code improvements to study it using the 3D3V particle-in-cell code PIConGPU. We discuss in detail the influence of various ionization mechanisms and laser implementations on the plasma dynamics. Furthermore, we present computation constrains and implementation challenges that these new methods entail. On top of discussing the acceleration scheme, we predict experimental observables using PIConGPU's in-situ synthetic radiation diagnostics. It allows predicting spectra from infrared to x-rays and provides the capability to determine the temporal and spatial origin of the radiation. These radiation simulations give valuable spectral signatures that allow conclusions on the micrometer femtosecond electron dynamics occurring in experiments. As an example of such a signature, simulated betatron spectra will be compared to experimentally measured spectra in order to determine the spatial extent of the electron bunch.

AKBP 1.10 Mon 17:30 MOL 213

Studying laser ion acceleration with overdense hydrogen ribbon targets by PIC code simulation — •João Branco[1,2], Karl Zeil[1], Lieselotte Obst[1,2], Ulrich Schramm[1,2], Thomas Kluge[1], and Michael Bussmann[1] — [1]Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Deutschland — [2]Technische Universität Dresden, Dresden, Deutschland

We present simulation results on laser ion acceleration using hydrogen ribbon targets irradiated by ultra-intense, ultra-short laser pulses. These targets promise to produce pure proton beams applicable for cancer therapy at high repetition rates. We address critical issues concerning the acceleration process that potentially hinders the application of these beams in a clinical scenario.

For achieving proton energies suitable for the treatment of deep seated tumors it is important to increase the laser intensity. At high laser intensities, plasma instabilities both at the target surfaces and target bulk can create electron filaments which result in non-uniform proton beams, detrimental for delivering uniform dose distributions.

By varying the laser contrast it is possible to change the preplasma scale length to influence the formation of instabilities. Other means of controlling proton beams are either changing target geometry (e.g. going from planar ribbon targets to spherical droplet targets) or the polarization. We present results of 2D3V particle-in-cell simulations at realistic densities that show the influence on the plasma dynamics and final beam properties and discuss their relevance regarding applications of solid hydrogen targets for laser-driven proton tumor therapy.

AKBP 1.11 Mon 17:45 MOL 213

Optimization of the lateral and depth dose profile in the course of a small animal irradiation with laser-accelerated protons — •L. Gaus[1,3], E. Beyreuther[1], F.-E. Brack[1,3], L. Karsch[2], S. Kraft[1], F. Kroll[1,3], J. Metzkes[1], J. Pawelke[1,2], H.-P. Schlenvoigt[1], M. Schürer[2], K. Zeil[1], and U. Schramm[1,3] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Oncoray, National Center for Radiation Research in Oncology, Dresden — [3]Technische Universität Dresden

Laser-driven ion acceleration has been considered a potential alternative for conventional accelerators and thus could provide a more compact and cost-efficient particle therapy solution. The beam properties of laser accelerated beams strongly differ from quasi-continuous beams. They exhibit fs to ps bunch length, carry up to 10^13 particles with broad energy spectrum and are highly divergent.

The current driving question is whether pulsed proton beams obtain an equivalent biological efficacy compared to quasi-continuous beams in the case that a living organism is irradiated. Therefore, a small animal irradiation will be undertaken. That requires a homogeneous lateral and depth dose distribution, proton energies in the range of 25 MeV and dose rates in the order of Gy/min with a high degree of reproducibility. The experiment will be performed with the 600 TW beam of the Dresden laser acceleration source Draco.

This talk focuses on the characterization and optimization of the depth dose distribution as well as on the optimization of the target alignment procedure to provide the necessary dose rate.