AKBP 7: Novel Accelerator Concepts II and FELs

Time: Wednesday 16:15–18:15 Location: ZHG004

AKBP 7.1 Wed 16:15 ZHG004

Considerations for high repetition rate plasma accelerator sources — •Juan Pablo Diaz, Stephan Wesch, and Jonathan Wood for the FLASHForward-Collaboration — Deutsches Elektronen-Synchrotron DESY

Electron-bunch-driven plasma-wakefield accelerators promise to revolutionize particle acceleration by providing compact and cost-effective energy boosters for electron linacs which could, for example, significantly enhance the photon energies produced by free-electron lasers. The FLASHForward facility at DESY has made substantial progress, demonstrating that accelerated electron bunches can maintain their charge, energy spread, and emittance during plasma acceleration. A major challenge remains in achieving high-repetition-rate operation, as is common in conventional radiofrequency accelerators.

To match the bunch patterns of superconducting RF linacs, identical plasma acceleration events must take place at MHz frequencies. This presents two challenges: how to maintain the same plasma density over these timescales, and how to deal with the high heat load in the plasma and its containment device. In this contribution we will first outline plans and recent results to measure the density evolution of discharge-initiated plasmas with high temporal and spatial resolution. Secondly, we will report on the long-term heating of the plasma cell from repeated plasma creation events with a view towards implementing mitigation strategies

AKBP 7.2 Wed 16:30 ZHG004

New radiation-based method for diagnosing driver dynamics in plasma wakefield accelerators — •Nico Wrobel[1], Alexander Debus[1], Arie Irman[1], Maxwell La Berge[1], Susanne Schöbel[1], Ulrich Schramm[1], Klaus Steiniger[2], Jessica Tiebel[1], Patrick Ufer[1], and Richard Pausch[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf: Dresden, Sachsen, DE — [2]Center for Advanced Systems Understanding: Görlitz, DE

Plasma Wakefield accelerators (PWFA) are a novel concept to build compact particle accelerators while improving beam quality compared to Laser Wakefield accelerators (LWFA). The precise dynamics of the driver in a PWFA are subject of interest, as they determine the created fields and therefore the capabilities to accelerate particles in the wake. One issue in improving PWFA is understanding these driver beam dynamics in the plasma, since it cannot be observed directly in experiments.

Here, we present a novel diagnostic method to overcome this problem by using the measurement of radiation emitted by the driver electrons. This method can reconstruct transversal and longitudinal dynamics of the driver. To develop this method, the many-GPU particle-in-cell code PIConGPU was used to model the ab-initio plasma dynamics. In addition, we computed the spectrally and directionally resolved far field radiation in-situ. We also developed an analytical description to explain the complex driver dynamics, such as the oscillation and degradation patterns observed in the plasma simulations, and directly related them to the infrared radiation signatures.

AKBP 7.3 Wed 16:45 ZHG004

Hydrodynamic simulations of plasma sources for wakefield acceleration — •Mathis Mewes[1], Gregory Boyle[2], Harry Jones[1], Rob Shalloo[1], and Maxence Thévenet[1] — [1]DESY, Hamburg, Germany — [2]James Cook University, Townsville, Australia

With the recent advancements in plasma wakefield acceleration (PWA), it becomes more important to fully understand the dynamics of plasma sources. Some of the critical questions surround discharge control, laser guiding and cooling. Numerical simulations can provide detailed insight into the relevant dynamics.

Particle in Cell simulations work well in the kinetic regime of a wakefield, which occurs on femtosecond time scale, but they are impractical for long term plasma evolution. Instead, (Magneto-)Hydrodynamic simulations can describe thermalized plasma at viable computational costs.

In this work, we propose a quasi-neutral single-fluid plasma model for plasma sources. It uses two temperatures and evolves the composition via collisional reactions and diffusion. The model is implemented in the COMSOL multiphysics software.

We will present and examine simulation results and benchmarks for laser ionized and discharge plasma sources utilized in plasma wakefield accelerators.

AKBP 7.4 Wed 17:00 ZHG004

A virtual spectral diagnostic for plasma accelerated bunches at FLASHForward — •Philipp Burghart[1,2], Lewis Boulton[1], and Jonathan Wood[1] for the FLASHForward-Collaboration — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]University of Hamburg, Germany

Plasma-wakefield acceleration (PWFA) promises to reduce the size of future machines significantly by providing multi-GeV/m acceleration gradients, orders of magnitude higher than conventional RF accelerators. However, PWFA is a process with many non-linear dependencies, making it difficult to understand the influence of input parameters. Moreover, measurements of e.g. energy spectra are destructive, preventing the output beam from being used for applications whilst only allowing for the diagnosis of one bunch in a bunch train simultaneously. Neural networks trained on non-destructive measurements can be used to predict the properties of accelerated bunches, which would provide more insight into sources of variability and potential shot-to-shot, non-destructive measurements for whole bunch trains. Using experimental data collected at FLASHForward - a beam-driven plasma acceleration experiment at DESY, Hamburg - a neural network-based virtual diagnostic predicting the spectral properties of plasma accelerated bunches is being investigated. In this contribution, we present first results from this project.

AKBP 7.5 Wed 17:15 ZHG004

Plasma Afterglow Metrology for Laser-Wakefield Accelerators — •Nils Hanold, Marc Osenberg, Paula Sedlatschek, Kamil Naczynski, Edgar Hartmann, Onur Bilen, Natascha Thomas, Jesko Wrobel, Andrew Sutherland, Mirela Cerchez, Constantin Aniculaesei, Thomas Heinemann, and Bernhard Hidding — Institute of Laser- and Plasmaphysics, Heinrich Heine University Düsseldorf

Characterizing the plasma light emitted upon the interaction of a high-power laser with a gas target aims for the development of a non-invasive metrology technique for the complex processes in laser-wakefield accelerators (LWFAs). While integrating the emitted afterglow temporally and spectrally allows obtaining top level information about the interaction, resolving it spectrally and temporally allows extracting further information such as involved ionization levels, laser-plasma interaction strength, dynamics and evolution, to identify and quantify ionization processes along the laser propagation axis, and markers of injection events.

AKBP 7.6 Wed 17:30 ZHG004

Status of THz FEL activities at PITZ — •Namra Aftab, Xiangkun Li, and Mikhail Krasilnikov — Deutsches Elektronen-Synchrotron DESY, Platanenallee 6, 15738 Zeuthen, Germany

A single-pass THz free-electron laser (FEL) at the Photo Injector Test facility at DESY in Zeuthen (PITZ) was designed and implemented for a proof-of-principle experiment on a tunable high-power THz source for pump-probe experiments at the European XFEL. THz pulses are generated at a radiation wavelength of 100 μm within a 3.5 m long, strongly focusing planar LCLS-I undulator. High gain is achieved by driving the FEL with high brightness beams from the PITZ photoinjector at 17 MeV and a bunch charge of up to several nC. Simulations have been carried out to understand the experimental results. THz diagnostics are focused in particular in order to accurately characterize the radiation pulse energy, spectrum and temporal profile.

AKBP 7.7 Wed 17:45 ZHG004

High-gain high-efficiency tapered FEL oscillator — •Margarit Asatrian[1], Eugenio Ferrari[2], Andrew Fisher[3], Georgia Paraskaki[2], Pietro Musumeci[3], and Wolfgang Hillert[1] — [1]University of Hamburg, Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [3]University of California at Los Angeles, Los Angeles, California, USA

Free Electron Lasers (FELs) are unique light sources capable of producing intense, high-brightness radiation in the XUV and X-ray regimes. The growing demands of experimental science are pushing FELs to their performance limits in terms of radiation quality and output power. To meet these challenges, it is crucial to explore ways of improving the energy conversion efficiency between the electron beam and the FEL output. Enhanced efficiency could either expand the achievable power range of FELs or enable more compact infrastructures.

The TESSA (Tapering-Enhanced Stimulated Superradiant Amplification) scheme offers a promising solution, with efficiencies more than an order of magnitude higher than those of conventional FELs. This approach employs a strongly tapered undulator and a high-power seed to extract energy from a pre-bunched electron beam. At short wavelengths, however, the absence of suitable high-power seed laser sources calls for the use of cavity-based FELs to generate the required seed. Here, we present FEL simulations that illustrate the power buildup and steady-state regime of such a TESSA-based high-gain FEL oscillator in the XUV wavelength range.

AKBP 7.8 Wed 18:00 ZHG004

Beam-by-design pulse shaping for seeded Free-Electron Laser — •Andreas Thiel[1], Skirmantas Alisauskas[2], Margarit Asatrian[1], Giovanni Cirmi[2], Eugenio Ferrari[2], Ingmar Hartl[2], Wolfgang Hillert[1], Nhat-Phi Hoang[2], Tino Lang[2], Pardis Niknejadi[2], Lucas Schaper[2], and Jiaan Zheng[2] — [1]Universität Hamburg, Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron, Hamburg, Germany

External seeding offers significant improvements in the pulse properties of Free-Electron Lasers (FELs) compared to Self-Amplified Spontaneous Emission (SASE) FELs. Seeding techniques such as High-Gain Harmonic Generation (HGHG) and Echo-Enabled Harmonic Generation (EEHG) utilize seed lasers and dispersive beamline elements to structure the longitudinal phase space of the electron beam. This process creates a density modulation that initiates the FEL process. The coherence properties of the seed are transferred to the FEL output, enabling the production of fully coherent, narrowband radiation with enhanced stability at shorter wavelengths. At the FEL facility FLASH (DESY), the ongoing FLASH2020+ upgrade project includes the integration of external seeding at high repetition rates. A key component of this upgrade is the development of an advanced laser system (SLASH) to act as the seed source. We explore the use of pulse shaping on the seed laser to control the characteristics of the seeded FEL output. Here, we present initial results from a test of the pulse shaper on our laser system, along with numerical simulations that investigate the potential and limitations of generating custom-tailored FEL pulses.