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EUROPEAN NETWORK FOR NOVEL ACCELERATORS

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Book of Abstracts

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Poster Session / 3

Acceleration of spin-polarized proton beams from a dual-laser pulse scheme

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Particle beams of high energy and spin-polarization are necessary for various experiments, i.a. in order to test the Standard Model of particle physics. Over the last few years, several setups for spin-polarized electron and proton beams from laser-plasma interaction have been proposed. We present a mechanism based on magnetic vortex acceleration, where the interaction of a single laser pulse with a plasma delivers high spin-polarization of the final beam. In our new scheme, we consider two laser pulses propagating in parallel with a carrier envelope phase difference of π, forming two separate plasma channels. Besides the proton filaments created in each channel, a third in the space between the pulses is formed. Our particle-in-cell simulations show that for a normalized laser vector potential of $a_0 = 100$ proton energies > 100 MeV can be obtained. Compared to single-pulse MVA, our scheme exhibits better spin polarization (~80%) of the final proton beam since the third filament is better shielded from the prevalent electromagnetic fields.

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GeV-scale low-emittance positron beams from a laser-wakefield accelerator

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We report on the first direct and comprehensive characterisation of the spatial and spectral properties of near-GeV positron beams generated in a fully laser-driven configuration, using a 100 TW-class laser system.

More than 10^5 positrons are generated within 5% of energies exceeding 500 MeV, and isolated using an energy selection system. The beam exhibited a normalised emittance at 600 MeV of 18 micron, a source size of 5 micron, and a longitudinal length < 15 micron.

We propose that positron beams with these characteristics will enable the experimental study and optimisation of plasma-based positron accelerators.

Special Topic / 6

Direct laser acceleration of positrons with intense pulses

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Plasma-based alternatives to conventional accelerators are largely investigated for electrons, whereas there are extremely few studies dedicated to positrons. Indeed, positrons are difficult to create and guide in the self-generated fields of laser-plasma interaction. Landmark studies demonstrated that positron beams created by conventional accelerators can be further accelerated in plasma wakefields.

In this work, we prove that direct laser acceleration of positrons in a plasma channel is possible. Positrons are created through the Breit-Wheeler process as an intense pulse interacts with a relativistic electron beam propagating at 90 degrees of incidence [1]. We first evaluate precisely from theory the number of positrons created in this geometry. We then demonstrate that only a few percent of positrons are deflected by the laser in its propagation direction. Finally, we prove that positrons are guided along the channel's main axis due to a high-charge self-loaded electron beam. This proposal opens a path toward direct laser acceleration of positrons with high-intensity lasers.

[1] B. Martinez et al, arXiv:2207.08728 (2022)

This work is supported by the European Research Council (ERC-2015-AdG Grant
695088), the FCT grant CEECIND/01906/2018 and PTDC/FIS-PLA/3800/2021. We also acknowledge PRACE for awarding access to MareNostrum based in BSC, Spain.

Poster Session / 7

WAKEFIELD CALCULATION AND HIGH ORDER MODES ANALYSIS USING HOMEN MODEL IN ENERGY RECOVERY LINAC

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Energy-recovery linac (ERL) light sources facilities based on superconducting (SC) cavities are deemed as ones of the most promising techniques in the future of accelerator physics. Running in a continuous wave (CW) mode with a high repetition rate, the ERL we are addressing in this study exploits a two-pass two-way mechanism, where the energy endures in the beam after being used, then recovered to accelerate other particles. The aim of our studies is to simulate the possible effects of high order modes (HOMs) on beam dynamics (BD) based on wakefield calculation to attain beam quality and stability, considering a high average current of the machine. Therefore, we have developed a mathematical model based on energy budget which represent the major philosophy behind our approaches.

Poster Session / 8

Gas cell target development for laser-plasma electron injector using OpenFOAM fluid dynamics solver and dedicated test bench

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Laser plasma acceleration [1] provides several advantages compared to conventional radio-frequency accelerators for electron source injectors: high accelerating gradients up to hundreds of gigavolts per meter (compactness) and short duration electron beams. However, the control of quality and stability of the produced electron bunches remains a challenge.

In this report we focus on the target design studies for the PALLAS project which aims to achieve reliability of conventional RF accelerators producing 150-200 MeV electron bunches in the injector stage, with a charge of 15-30 pC, at 10Hz with less than 5% energy spread. The laser pulse is provided by the LaseriX laser driver, yielding a 35fs laser pulse with 50TW peak field.

We present a two-chamber plasma cell design (N2-doped Helium and pure Helium) inspired from previous project [2] with electronic density in the range of 10^18cm-3. Optical measurements of the plasma channel and pressure measurements on a dedicated test bench are performed and compared with OpenFOAM [3] simulation results to validate our model. We then discuss our ability to confine the N2-dopant in the cell first chamber and the laser ablation lifetime. Finally, a review of the design in comparison with other laboratories experiments [4,5,6] is presented.

Poster Session / **9**

Laser Wakefield Acceleration to Energies in the GeV Regime

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For the creation of matter-antimatter pairs from the quantum vacuum via the Breit-Wheeler effect, an intense laser and energetic γ-rays need to interact. At the Stanford Linear Accelerator Center the Breit-Wheeler experiment in the perturbative regime has been accomplished in 1997 but was never implemented in the non-perturbative regime. At the moment, this experiment is in preparation in a fully laser-driven set-up using Laser Wakefield Acceleration (LWFA) at the Ludwig-Maximilian-Universität München. In the experiment an initial multi-GeV electron beam will be sent onto a Bremsstrahlung-converter to generate γ-rays. LWFA has been improved to reach multi-GeV electron energies in recent years. However, building a reliable, stable source with quasi-monoenergetic bunches over 2 GeV, showing low divergence and pointing jitter, still holds challenges. Essential is the careful design of gas targets. These have to provide homogeneous densities over a few centimetres. In preparation for this, Computational Fluid Dynamic simulations were conducted to design centimetre-long gas nozzles. First LWFA results can be shown with energies reaching over 1.5 GeV using these nozzles and energies reaching over 2 GeV with a gas cell. Moreover, different injection techniques using these targets were tested with the goal to obtain quasi-monoenergetic electron bunches in the GeV regime.

Poster Session / **10**

Galilean PIC code: towards real-time wake field simulations

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We use Galilean transformation to the co-moving coordinates s=x, ξ=x−ct. This allows to overcome the huge scale disparity otherwise present in wake field simulations. Different from the standard quasi-static codes, the new Galilean PIC code accurately simulates the laser pulse wave structure, because the full set of Maxwell's equations is solved. The code treats all numerical macroparticles uniformly and does not distinguish between "beam" and "background" or "jet" particles. This allows to incorporate the self-trapping process in a natural way. In addition, the code uses flexible gridding, so that even short wavelength radiation can be resolved at a particular location within the large scale simulation domain.

Special Topic / **11**

External injections of electrons into a laser-driven plasma wakefield at CLARA

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External injection of high quality, low energy electron bunches into a laser driven plasma wakefield has been proposed as a method to improve the quality and stability of the accelerated electrons. Simulations have shown the preservation of emittance and energy spread of injected bunches but there has been only one experiment to date demonstrating successful injection and acceleration. We report the results of a new experiment at the Daresbury Laboratory, UK, to study the acceleration of 35MeV electons from the CLARA linear accelerator injected into a laser plasma wakefield.

Poster Session / **12**

Monochromatic shadowgraphy and mid-infrared probing of LWFA

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Ultrafast shadowgraphy with transverse few-cycle probe pulses has enabled the observation of details of the laser-plasma interactions with unprecedented temporal (fs) and spatial (μm) resolution. However, in previous studies, probe pulses spanning a broad frequency spectrum have been commonly used to achieve an acceptable signal-to-noise ratio because of the limit of probe pulse energy. Recently, ultrafast monochromatic shadowgraphic images of laser-generated wakefields became feasible due to an increased probe pulse energy. Narrow-band shadowgraphic images are shown in this poster, which were taken with 10 nm (FWHM) bandpass filters at different center wavelengths. Nevertheless, in previous pump-probe studies, the probe pulses were split off from the main pulses, which means that the probe spectrum is closely related to the pump spectrum, particularly its central wavelength. This sets a low-density limit ($< 5\times10^{18}$ cm^{-3}) for the investigation of LWFAs. In the future, a separate 1 kHz Ti: sapphire laser will be synchronized to the pump laser to generate the probe pulses, with a relative timing jitter of < 20 fs (RMS). With the help of nonlinear optics processes, the central wavelength of the probe pulses can be tuned into the mid-infrared regime, which will allow the direct observation of LWFAs in the low-density regime.

Poster Session / 13

QED Effects at Grazing Incidence on Solid-State-Targets

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New laser facilities will reach intensities of 10^{23}W cm^{-2}. This advance enables novel experimental setups in the study of laser-plasma interaction. In these setups with extreme fields quantum electrodynamic (QED) effects like photon emission via non-linear Compton scattering and Breit-Wheeler pair production become important.

We study high-intensity lasers grazing the surface of a solid-state target by two-dimensional particle-in-cell simulations with QED effects included. The two laser beams collide at the target surface at a grazing angle. Due to the fields near the target surface electrons are extracted and accelerated. Finally, the extracted electrons collide with the counter-propagating laser, which triggers many QED effects and leads to a QED cascade under a sufficient laser intensity. Here, the processes are studied for various laser intensities and angle of incidence and finally compared to a seeded vacuum cascade. Our results show that the proposed target can yield many order of magnitude more secondary particles and develop a QED cascade at lower laser intensities than the seeded vacuum alone.

Special Topic / 14

Design of plasma sources for compact accelerators

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In recent years, great progress to achieve extreme gradients preserving high quality of beams in compact plasma-based accelerating structures have been done, both by using laser-driven (LWFA) and particle-driven (PWFA) techniques. This research activity is strictly related to the design of dedicated devices to produce and confine plasmas in order to optimize the interaction with particle beams, which represent the main component of plasma-based accelerators. Such a research field involves efforts from several scientist teams devoted to improve plasma formation techniques with the aim to control its properties in terms of stability, uniformity and reproducibility. In this work, a summary overview of current solutions and future perspectives coming from experts in plasma technology and accelerator physics for producing plasma accelerating modules has been presented.

Special Topic / 15

ARES at DESY, with femtosecond synchronization and high stability infrastructures towards advanced accelerator applications.

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The generation and acceleration of ultra-short, high quality electron beams has attracted more and more interest in accelerator science. Electron bunches with these properties and highest stability are necessary to operate and test novel diagnostics and advanced high gradient accelerating schemes.
The dedicated R&D linac ARES at DESY (Deutsches Elektronen-Synchrotron) is now fully operational and able to produce these electron beams at the nominal energy of 155 MeV and deliver it to users.
This talk will describe i.a. the fs synchronization at ARES and the infrastructure required to reach highest stability.

Poster Session / 16

Energy Compression and Stabilization of Laser-Plasma Accelerators

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Laser-plasma accelerators (LPAs) outperform current radiofrequency technology in acceleration strength by orders of magnitude. Yet, enabling them to deliver competitive beam quality for demanding applications, particularly in terms of energy spread and stability, remains a major challenge. Here, we report on a recently published method that combines bunch decompression and active plasma dechirping for drastically improving the energy profile and stability of beams from LPAs. Realistic start-to-end simulations demonstrate the potential of these post-acceleration phase-space manipulations for simultaneously reducing an initial energy spread and energy jitter of ~1–2 % to ⊠0.1 %, closing the beam-quality gap to conventional acceleration schemes.

Poster Session / 17

Multitask optimization of laser-plasma accelerators using simulation codes with different fidelities

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Laser-plasma accelerators can generate GeV electron beams in an ultra-compact, cm-scale setup, but have yet to demonstrate sufficient beam quality and stability for demanding applications. To overcome this challenge, broad optimization of the accelerator design with numerical simulations is essential. However, due to the high computational cost of general particle-in-cell simulations, optimization over a large parameter space is prohibitively expensive. Here, we show that cheaper simulations based on reduced physical models can be effectively incorporated into an optimization to strongly reduce the need for fully-detailed simulations. This is enabled by a Bayesian optimization algorithm using a multitask Gaussian process, where two tasks corresponding to the output of each simulation code are defined. The algorithm identifies correlations between both tasks, allowing it to learn from inexpensive evaluations and perform only a few, well-targeted simulations of high fidelity. By means of a proof-of-principle study combining the FBPIC and Wake-T codes, we demonstrate an order-of-magnitude reduction in computing time and cost, paving the way towards cost-effective optimization over wide parameter spaces.

Poster Session / 18

Precise intensity tagging for ultrashort high-power lasers

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The LUXE (Laser Und XFEL Experiment) project at DESY Hamburg aims to measure processes in the strong-field quantum electrodynamics regime with high precision by colliding electrons or a high-energy photon beam with a high-power, tightly focused laser beam at a repetition rate of 1Hz. Simulations [LUXE CDR, arXiv:2102.02032 [hep-ex]] predict that the probability of pair production responds highly non-linearly to the laser strength parameter. Consequently, small variations in the laser intensity lead to significant variations in the experimental observables. The required precision will be achieved by intensity tagging through precise measurements on the relative variation of intensity on a shot-by-shot basis, with an ultimate aim to monitor the shot-to-shot fluctuations with a precision below 1%. We present the results of a non-linear intensity tagging method, which provides a measure of the laser intensity by comparing the fundamental to a non-linear copy of the laser focal spot from a thin non-linear crystal. This method provides a reference to crosscheck the intensity fluctuations derived from independent measurements of energy, duration and fluence.
ACKNOWLEDGEMENT - This poster presentation has received support from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 101004730.

Poster Session / 19

Hot Electron Jets from a Relativistic Laser Interaction with Wavelength-Scale Rods

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Over the past decade, many experiments showed that interactions of relativistic laser pulses with targets whose geometrical features are comparable to the laser wavelength can result in increased energy coupling between the laser field and the target electrons.

Several different models were suggested to explain this phenomenon. However, unveiling the details of these interactions through parametric studies was so-far hindered by stringent requirements on laser contrast, the need for sophisticated targets, and the realization of an efficient way to deliver targets to the focus of the laser.

I will present our results on the interaction of relativistic laser pulses with free-standing micrometric gold rods varying from smaller- to larger-than the laser wavelength. Hot electrons were found to be emitted in two jets of MeV electrons with an opening angle of a few degrees that depends on the rod's lateral extent. Particle-in-cell simulations show that hot electrons are generated via a 3 step process that extends the well-established Brunel model for vacuum acceleration.

Special Topic / 20

Plasma Acceleration at EPAC

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The Extreme Photonics Applications Centre, a new 10Hz Petawatt laser facility under construction will be a state-of-the art centre for laser-driven plasma accelerator research and its applications. I will give a brief update about the project

Poster Session / 21

Numerical simulation study of the propagation of a short electron bunch and a long proton bunch in a plasma ramp

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A particle bunch propagating through plasma will induce a non-linear response when $n_b \gg n_{e0}$ [1]. A positively charged bunch will attract plasma electrons, which will flow-in to the propagation axis, creating a filament [2]. This will sustain defocusing fields for negatively charged particles.

In the Advanced Wakefield Experiment (AWAKE) [3], in which a long proton bunch drives high amplitude wakefields
for electron acceleration through self-modulation [4], there is a plasma density ramp at the entrance and exit of the plasma [5].
The density in the plasma ramp can be up to five orders of magnitude lower than that of the long plasma. In such a low
density, the proton bunch drives a plasma electron filament on axis. We present a numerical study performed with the particle-in-cell code LCODE [6] using parameters similar to those of the experiments. We show that the plasma ramp would have a detrimental effect, in terms of charge reduction or emittance growth, both for a seed electron bunch placed inside of the proton bunch and for an electron bunch injected in a second plasma for acceleration [7], if that plasma had a density ramp at the entrance.

Poster Session / **22**

Effect of driver charge on wakefield characteristics in a plasma accelerator probed by femtosecond shadowgraphy

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Recent experiments have shown the capability of Laser wakefield accelerated (LWFA) electron beams to be suitable driver beams for a particle driven wakefield acceleration (PWFA) stage. The high peak current and short duration of such beams open up the possibility of operating the PWFA stage at density ranges in the order of $10^{18}\mathrm{cm}^{-3}$. Here, femtosecond optical probing of the acceleration process can be used for the insight view into the plasma wave dynamics during the propagation of the driver. We report the results of this investigation, showing pronounced differences in the morphology of beam driven plasma waves when surrounded by either neutral gas or a broad pre-generated plasma channel. Furthermore an elongation of the first cavity is measured, which becomes stronger with increasing driver beam charge. This observation is supported by 3D particle-in-cell simulations performed with PIConGPU. This work can be extended for the investigation of driver depletion by probing at different propagation distances inside the plasma, which is essential for the development of high energy efficiency PWFAs.

Poster Session / 23

Alternating phase focusing and approaching large net energy gain in photonic chip-based particle acceleration

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Building small scale particle accelerators on a photonic chip may lead to revolutionary applications of particle accelerators, including new minimally invasive beam irradiation tools for physicians. All individual elements required for particle accelerators on a chip have been demonstrated, but a beam confinement scheme matched to the nano- and micrometer size was needed. By alternately focusing and defocusing the electrons in the transverse and longitudinal directions, the alternating phase focusing (APF) allows, in principle, lossless transport over extended distances [1]. In accordance with particle tracking predictions, we have experimentally demonstrated this low-loss electron transport through a silicon-based nanostructure measuring 77.7 micrometers in length [2,3]. On this poster, we show these results and the current status of the experiment to demonstrate particle acceleration over extended distances and with a significant energy gain.

[1] Niedermayer, U., Egenolf, T., Boine-Frankenheim, O., Hommelhoff, P., Phys. Rev. Lett. 121, 214801 (2018).

[2] Shiloh, R., Illmer, J., Chlouba, T., Yousefi, P., Schönenberger, N., Niedermayer, U., Mittelbach, A., Hommelhoff, P., Nature 597, 498–502 (2021).

[3] Shiloh, R., Chlouba, T., Hommelhoff, P., Journal of Vacuum Science & Technology B 40, 010602 (2022).

Poster Session / 24

FLASH radiotherapy: from RF-based to laser plasma accelerators

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FLASH Therapy, an innovative technique in radiation therapy, has shown to dramatically spare normal tissue toxicities in multiple organs maintaining the efficiency as conventional irradiation to inhibit tumor growth. The therapy has been successfully tested using microsecond pulses of low energy electrons, using intrapulse dose rate in the range 106–107 Gy/s, time-averaged dose rate >100 Gy/s, and duty time < 100 ms. FLASH-RT has already translated to the clinic, yet the underlying radiobiological basis of the FLASH effect remains to be demonstrated. We will discuss the genesis of this methodology and its implementation based on different technologies, such as RF-based and Laser-plasma accelerators.

Poster Session / **25**

Large energy depletion of a beam driver in a plasma-wakefield accelerator

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Beam-driven plasma-wakefield acceleration has the potential to reduce the building cost of accelerator facilities, with large accelerating fields that are orders of magnitude greater than those of radio-frequency cavities. Sustaining strong decelerating fields for the driver and strong accelerating fields for the trailing bunch across long plasma stages will be key to demonstrating high energy efficiency in this scheme, which is necessary to keep the running costs low for such a facility. We show first measurements at FLASHForward with a 500 MeV drive bunch depositing approximately half of its energy into a 20 cm long plasma.

Special Sub-Session / **29**

Discussion

Specific questions, technical aspects, scaling

Poster Session / **32**

6-D Phase Space Optimization of DLA, Preserving MeV Energy Gain

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Dielectric laser accelerator (DLA) has emerged as a miniaturised and cost-effective tool for particle acceleration. DLAs have proved to be a promising candidate for GeV/m acceleration gradient within the damage threshold of the materials used. However, the emittance growth and energy spread increase at higher particle energies and limit the realistic applications. Here we present the numerical simulations of a mm scale DLA, operated by a THz laser, with various injection schemes for an electron bunch created externally. We show that at a particular focusing scheme for electron bunch inside the structures, the emittance growth and energy spread are mitigated while the energy gain remains above MeV.

Poster Session / 33

Surrogate modelling of laser-plasma acceleration

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Laser-plasma acceleration (LPA) promises compact sources of high-brightness electron beams for science and industry. However, transforming LPA into a technology to drive real-world applications remains a challenge. Machine learning techniques could prove decisive in further understanding and improving the performance of these machines. Here, we discuss the application of supervised learning to create surrogate models of the LPA process at LUX. Using simulated and experimental data, we train artificial neural networks to predict the electron beam quality as a function of the drive laser properties. Of the many potential applications of such models, we emphasize their use to study the influence of laser fluctuations on the electron beam stability.

Poster Session / 34

Bayesian Optimization of Laser-Plasma Accelerators

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Laser-plasma accelerators (LPA) are one the verge of becoming drivers for real-world science applications. However, in order to be considered serious alternatives to conventional machines they need to be able to provide competitive quality and versatility of the electron beam parameters as requested by potential applications. As shown by numerous experiments in the past LPAs are in principle capable of doing so. However, specifically finding the configuration of machine parameters to satisfy the demands of an application remains a complex task that involves the optimization of a single or multiple, oftentimes competing, objectives. Bayesian optimization provides a framework that can help to efficiently tune a machine to provide beams individually tailored for each intended application.
Here we show our latest results on optimization of plasma accelerators both in the design phase using simulation and in real time at the LUX experiment and show a perspective of efficiently tuning the experiment to suit various applications.

Special Topic / 35

Stability of ionization-injection-based laser-plasma accelerators

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Laser-plasma acceleration (LPA) is a compact technique to accelerate electron bunches to highly relativistic energies, making it a promising candidate to power radiation sources for industrial or medical applications. However, further improvements in terms of repetition rate and stability are required for LPAs to compete with already existing technologies. We report on the generation of electron beams from an 80 MeV-level LPA setup based on ionization injection (II) over a duration of 8 hours at a repetition rate of 2.5 Hz, resulting in 72,000 consecutive shots with charge injection and acceleration. During this time, the moving average of the total beam charge of 14.5 pC stayed constant. Using correlations of our final beam parameters to the experimental conditions, we identified the plasma density as our largest source of shot-to-shot jitter in the beam charge. This is supported by particle-in-cell simulations, which show that stronger laser self-focusing in higher density plasmas significantly increased the ionized charge along with the emittance of the beam. The nonlinearity of this process imposes tight constraints on the reproducibility of the laser-plasma conditions required for a low jitter II-LPA as desired for future applications.

Poster Session / 36

Radiation safety for high power laser applications

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With the development of chirped-pulse amplification ultra-short lasers with femtosecond pulse durations have become readily available and are used in numerous applications such as material processing or plasma-based accelerators. In most cases, these lasers are focused to small spot sizes, exceeding intensities of $10^{13}\ W/cm^2$ and thus the ionization threshold in most materials. As this can lead to the production of x-rays, national law in Germany made it mandatory to monitor the dose rate from all laser setups exceeding this intensity threshold. At Deutsches Elektronen-Synchrotron DESY, research has now started to further investigate and understand the production of x-rays in different materials and gases to enable safe working conditions and compliance with the legal framework while maintaining the flexible workflow required at universities and research institutes. This poster gives an overview of studies already conducted on this topic, shows plans for the research at DESY and invites to discuss implications for future work in the development of plasma accelerators.

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Special Sub-Session / 39

Solutions and challenges for a multi-stage plasma accelerator

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Particle physics requires high energies, beyond what is possible in a single plasma-accelerator stage. Coupling of stages is, however, very challenging due to chromatic aberrations and tight tolerances on synchronization. A new beam-optics scheme is proposed, based on nonlinear plasma lenses, promising to enable compact staging without degrading emittance, as well as improving tolerances on synchronization via a self-stabilization mechanism. We discuss the implications of this concept, the challenges ahead, and propose new test facilities to overcome them.

Poster Session / 40

Plasma Wakefield Acceleration: a parametric model for fast beam dynamics integration.

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The state of the art in terms of Plasma Wakefield Acceleration simulation accuracy are Particle in Cell (PIC) codes, based on a kinetic model which requires hard numerical integration and execution times of hundreds of hours on processors clusters for centimetre-long simulations. During my Master's thesis a computationally lighter model was developed, able to accurately reproduce the most significant aspects of the process in shorter execution times, setting a starting line for identification of work points and optimal beam injection conditions. The code lays on a multi-fluid superposition plasma model (Lu, Dalichaouch et al.): charge density and currents are calculated via continuity equation through a semi-empirical parametrization of fluid regions ratios, tuned by fit on PIC simulation results. Under quasi-static approximation, plasma response and wakefields are calculated at each time step for a given beam profile and used to compute beam slices evolution. Beam energy, emittance and energy spread evolution were validated on PIC simulation results, featuring high accuracy and showing model ability to reproduce nonlinearities and to range in different plasma response regimes. The code is able to run on a laptop, giving execution times four orders of magnitude shorter than a PIC code executed on a processors cluster.

Special Topic / 41

Laser-plasma acceleration at ELI-Beamlines

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ELI-Beamlines, located near Prague in Czech Republic, is one the pillar of the pan-European Extreme Light Infrastructure (ELI) project. The specific nature of the ELI-Beamlines facility is its multi-discipline features, opening wide opportunities for the worldwide user community to cultivate secondary radiation and particle sources for revolutionary applications. The ELI-Beamlines development, has two major aspects: enhancing capabilities and versatility of laser systems and subsequently using improved lasers for novel applications, including compact free-electron lasers and high-energy physics. In the frame of this report, we overview the current status of the lasers development and main experimental achievements in the laser-plasma acceleration at ELI-Beamlines.

Special Topic / 42

Examples of PIC code limit and potential for the simulation of wakefield acceleration and accelerator applications

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Beam- and laser-driven wakefield acceleration is now routinely simulated with Particle-In-Cell (PIC) codes. Due to their increasingly wide use in our community, these tools tend to be considered as highly trustworthy under any circumstances. However, some numerical errors can significantly affect the acceleration process and alter the simulated beam properties. One example is the Numerical Cherenkov Radiation (NCR) and Instability (NCI) that may degrade the beam divergence and emittance among other spurious effects. Solving the NCR/NCI issue in a PIC code is still challenging, but different recent numerical schemes able to remove or reduce NCR and NCI will be presented.

PIC codes can also be unique tools to simulate diverse applications of electron accelerators. We will show how the development of new modules in PIC code can allow us to study various radiation sources with a broad range of photon energies, ultrarelativistic beam-plasma instabilities that are relevant to beam propagation in plasma and to astrophysical scenarios, or the nearly unexplored strong-field QED regime.

Poster Session / 43

ARIA, a VUV beamline for EuPRAXIA@SPARC_LAB

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EuPRAXIA@SPARC_LAB is a new Free Electron Laser (FEL) facility that is currently under construction at the Laboratori Nazionali di Frascati of the INFN. The electron beam driving the FEL will be delivered by an X-band normal conducting LINAC followed by a plasma wakefield acceleration stage. It will be characterized by a small footprint and include two different plasma-driven photon beamlines. In addition to the soft-X-ray beamline, named AQUA and delivering ultra-bright photon pulses for experiments in the water window to the user community, a second beamline, named ARIA, has been recently proposed and included in the project.
ARIA is a seeded FEL line in the High Gain Harmonic Generation configuration and generates coherent and tunable photon pulses in the range between 50 and 180 nm.
Here we present the potentiality of the FEL radiation source in this low energy range, by illustrating both the layout of the FEL generation scheme and simulations of its performances.

Special Topic / 44

Thin-Disk Amplifiers and Nonlinear Pulse Compression

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Applications such as high harmonic generation, laser plasma X-ray sources, inverse Compton scattering, electron acceleration and laser-driven neutron sources demand for always higher pulse energies and peak intensities at higher repetition rates
With significant progress in high-power laser technology during the past decade, new concepts of laser driver sources are rapidly emerging for compact linear accelerators and x-ray sources. Diode-pumped ytterbium thin-disk based systems have immensely increased their performance in recent years, making them particularly appealing in conjunction with nonlinear broadening in gas-filled multipass cells. This approach overcomes the laser gain bandwidth limitation, while maintaining high optical efficiency with limited impact on the beam quality even at high average powers. Lately, we broadened the 180 mJ output of Dira 1000-5 system inside a Herriott cell to generate ~40 fs pulses at 5 kHz. Our ongoing work seeks to increase the peak power of our high-energy systems (500 mJ, 1 kHz, <600 fs) via nonlinear pulse compression and reach 400 mJ with <50 fs pulse duration. While the available driver sources of TRUMPF Scientific Lasers (1J, 1kHz, 600fs) might be already directly used to accelerate neutrons, the post compressed pulses can be implemented for laser wakefield acceleration of electrons.

Poster Session / 45

Simultaneous space-time focusing with radially-chirped laser pulses for ionization injection in LWFAs

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Simultaneous space-time focusing occurs when a transversely-chirped ultrashort laser pulse is focused using a conventional lens. Before the lens different frequencies are separated radially so that at any point on the transverse plane the local bandwidth is relatively low. These frequencies are brought together downstream of the lens as they approach the focus. As the spatial overlap between different frequency components increases, so does the local bandwidth, thereby reducing the pulse

duration to its minimum at the focus. This reduces the space-time volume of the region in which the intensity is high. This may have potential advantages towards reducing the phase-space volume of electrons injected in a wakefield accelerator by optical ionisation injection.

The focusing of a radially-chirped laser pulse is studied both analytically and numerically. Decomposing any arbitrarily chirped input laser pulse as a superposition of Laguerre-Gaussian modes allows for an exact expression of the electric field at any longitudinal position of the focusing beam. A numerical investigation is also performed using Collins' method: a diffraction integral based on ray-matrices. It is investigated whether the radial chirp gives enhanced intensity roll-off in space and time over conventional focusing.

Poster Session / 46

Resonant wakefield excitation observed in long plasma channels

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The multi-pulse laser wakefield acceleration (MP-LWFA) scheme provides a route for GeV-scale accelerators operating at kilohertz-repetition-rates driven by picosecond-duration laser pulses, such as those available from thin-disk lasers, which are modulated to be resonant with the plasma wave. We recently published theoretical work proposing a new scheme of GeV accelerator based on MP-LWFA. In this scheme, trains of pulses are generated from a long, high-energy drive pulse via the spectral modulation caused by a low amplitude wakefield driven by a leading short, low-energy seed pulse. Our simulations show that temporal compression of the modulated drive pulse yields a pulse train that can resonantly drive a wakefield, allowing for acceleration of a test electron bunch to 0.65 GeV in a 100 mm-long plasma channel.
In this study, we present the preliminary results of recent experiments with the Astra-Gemini TA3 laser at the Central Laser Facility which are relevant to the accelerator stage of this novel scheme. We demonstrate, for the first time, guiding of 2.5 J pulse trains in a 100 mm long all-optical plasma channel. Measurements of the spectrum of the transmitted laser pulse train suggest that a wakefield was resonantly excited in the plasma channel.

Special Topic / 47

Stable and high quality electron beams from staged laser and plasma wakefield accelerators

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Using Laser-wakefield accelerated (LWFA) electron beams to drive a plasma-wakefield accelerator (PWFA) has been at the center of a multi-partner collaboration during the last few years. The motivation for doing so is two-fold: Firstly, current LWFA beams achieve peak currents beyond the capabilities of most dedicated PWFA facilites (with the exception of FACET-II), therefore our approach can act as a scalable, easily accessible toy model for high-current PWFA research. Secondly, while LWFA can yield >nC total charge beams with energy conversion factors >10 percent, but due to dephasing and the heating of the plasma electrons by the laser field their emittance is too large e.g. for driving an FEL. If the LWFA beam energy can by coverted efficiently in a cold PWFA stage to a high-quality beam, this will bring us a step closer to the dream of a compact ultralow-emittance beams source. We will show latest experimental results on the stability limits and potential emittance improvement for such a staged wakefield accelerator scenario, as well as laying out the next steps for the collaboration.

Special Topic / **48**

High-Resolution Diagnostics for Laser Wakefield Accelerators – a Tool for Detailed Insights into the Interaction

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Relativistic plasmas generated by high-power laser pulses are promising candidates for future compact particle accelerators. In a laser wakefield accelerator for electrons, a driving laser pulse generates a high-amplitude plasma wave forming an electric field structure (the "wakefield"), which can trap and accelerate electrons to several GeV energies over few-centimeter distances only. The properties of the generated electron pulses (energy, duration, lateral dimensions) strongly depend on the parameters and the evolution of the wakefield.
Therefore, a complete understanding of the physical phenomena underlying the acceleration process is mandatory to improve the controllability of the electron pulses, which will determine their suitability for future applications. This presentation will discuss transverse optical probing as a diagnostic tool for laser-wakefield electron accelerators and present experimental results on the characterization and evolution of the electron pulses, the plasma wave and the driving laser pulse.

Poster Session / **49**

Early dynamics of the self-modulation instability growth rate

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The self-modulation instability (SMI) is instrumental for single-stage plasma wakefield accelerator concepts with long, high-energy drive bunches such as the AWAKE experiment. It provides a self-consistent mechanism to reach high-amplitude wakefields despite the driver's length, which would otherwise not excite the plasma resonantly.
In recent demonstrations of acceleration with a self-modulated proton driver, the use of a linear plasma density gradient has been a key factor in maximising the energy gain [1]. It is known that a density gradient effectively delays or hastens the growth of the SMI, though this effect has been discussed in the context of asymptotic models that assume small gradients [2], or of the saturation phase of the SMI [3].
We present a new framework for understanding the onset of the SMI, and show that its growth rate varies according to the frequency of the seed (a beam radius perturbation), which can be tuned by varying the plasma density. This may have implications for the control of the SMI's growth and the associated acceleration process.
[1] AWAKE Collaboration, Nature **561**, 363-367 (2018)
[2] C. B. Schroeder, *et al.*, Phys. Plasmas **19**, 010703 (2012)
[3] F. Braunmüller, *et. al.* (AWAKE Collaboration), Phys. Rev. Lett. **125**, 264801 (2020)

Special Topic / **50**

Mitigation of the onset of hosing in the linear regime through plasma frequency detuning

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The hosing instability poses a feasibility risk for plasma-based accelerator concepts. Though potential mitigation methods have been discussed extensively in the blow-out regime, less attention has been devoted to hosing in the long-beam, linear wakefield regime [1,2], which is relevant for PWFA concepts geared towards high-energy physics applications, such as the AWAKE experiment.
We show that the growth rate for hosing in this regime is a function of the centroid perturbation wavelength. We demonstrate how this property can be used to damp centroid oscillations by detuning the plasma response sufficiently early in the development of the instability. We also develop a new theoretical model for the early evolution of hosing.
[1] C. B. Schroeder *et al.*, Phys. Rev. E **86**, 026402 (2012)
[2] J. Vieira *et al.*, Phys. Rev. Lett. **112**, 205001 (2014)

Special Sub-Session / **51**

Plasma accelerator demonstration facility at intermediate energy

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It is envisioned that a future energy-frontier lepton collider would require a center-of-mass energy beyond 10 TeV. Plasma accelerators are a leading candidate technology to reach these beam energies, owing to their ability to produce gradients on the order of 10 GV/m, leading to compact accelerator structures. To realize a future plasma-based collider, intermediate facilities are required to test the technology and demonstrate key subsystems. A 20-100 GeV center-of-mass energy plasma-based lepton collider is a possible candidate for an intermediate test facility. In addition to the utility as a test beam facility for accelerator and detector studies, a collider at intermediate energies can provide opportunities for particle physics studies using fixed targets, precision quantum chromodynamics, beyond standard model physics measurements, and investigation of charged particle interactions with extreme electromagnetic fields. Gamma-gamma and electron-ion collider designs may also be considered for such an intermediate energy facility.

Special Topic / 52

The Cool Copper Collider

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A new concept for a low cost high efficiency linear collider based on LN2 cooled copper accelerator structures will be described. The collider is expected to have a performance similar to ILC with higher gradients allowing for the potential of higher energy reach at a substantially lower cost per GeV. The R&D status, expected performance, and future plans will be described.

Special Sub-Session / 53

First SASE and Seeded FEL Lasing based on a beam driven wakefield accelerator

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The breakthrough provided by plasma-based accelerators enabled unprecedented accelerating fields by boosting electron beams to GeV energies within few cm.
This enables the realization of table-top accelerators able to drive a Free-Electron Laser (FEL), a formidable tool to investigate matter at sub-atomic level by generating X-UV coherent light pulses with fs and sub-fs durations.
So far, short wavelength FELs had to rely on the use of conventional large-size radio-frequency accelerators due to the limited accelerating fields provided by such a technology.
Here we report the experimental evidence of an FEL driven by a compact plasma accelerator. The accelerated beams are characterized in the six-dimensional phase-space and have a quality, comparable with state-of-the-art accelerators. This allowed the observation of amplified SASE radiation in the infrared range with typical pulse energy exponential growth, reaching tens of nJ over six consecutive undulators.
On the basis of these first amplification results starting from spontaneous emission (SASE), we upgraded the setup by seeding the amplifier with an external laser. Compared to SASE, the seeded FEL pulses are characterized by higher pulse energy, two orders of magnitude larger (up to about 1 uJ) and an enhanced reproducibility (up to about 90%) resulting in higher shot-to-shot stability.

Poster Session / 54

Hybrid LWFA-PWFA: A stability and beam-quality booster for laser-generated electron beams

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Laser-wakefield acceleration (LWFA) has been investigated as a possible route towards a compact, high-gradient replacement for current RF-based accelerator technology. LWFAs recently made huge progress in terms of achievable energy (multi-GeV), charge (~nC), current (up to 100 kA) and spectral charge density (up to 20pC/MeV). However, due to the sensitive dependence on driver fluctuations and heating by the laser, it remains extremely challenging to generate stable and low emittance electron bunches in LWFA.
In particle driven wakefield acceleration (PWFA) some of these problems can be attributed. So far, however, such research was only possible on a few large-scale accelerator facilities. In past experiments we showed that also high current LWFA-generated electron bunches from 100-TW-class laser facilities are suited as drive beams for PWFA – demonstrating wakefield generation and the injection and acceleration of witness beams.
This contribution summarizes our recent experiments, demonstrating the insensitivity of PWFA to fluctuations in driver energy, making the hybrid scheme comparable or even more stable than pure LWFA. Moreover, due to the high energy transfer efficiency and cold witness injection in our PWFA, the spectro-spatial charge density of our witness beams exceeds that of the LWFA-generated drive beam, giving a real-world performance boost to LWFAs.

Poster Session / 55

openPMD – F.A.I.R. and open scientific I/O at the Exascale Era

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This poster presents openPMD, an open and F.A.I.R. standard for particle-mesh data, and its impact in heterogeneous scientific workflows.
Particle accelerator codes need to span various time and length scales, leading to data processing pipelines consisting of multiple heterogeneous codes.
Standardization of physical data helps bridging the different models with a commonly-understood markup, creating interoperable and flexible workflows.

The openPMD standard is made accessible to scientific software via the openPMD-api, a library for the description of scientific data.
The backend implementations of the openPMD-api are based on established I/O framworks such as HDF5 and ADIOS2, and also include a scalable streaming backend for HPC workflows, provided by ADIOS2.
The poster gives an insight into the existing ecosystem of openPMD and describes the basic concepts of the data markup.

It shortly illuminates recent trends in large-scale I/O and their impact on scientific compute workflows. While traditional attempts at counteracting such trends, e.g. through compression, remain available in the openPMD-api, we propose loose coupling and online analysis via streaming workflows as a sustainable solution that avoids parallel filesystem bottlenecks.

Poster Session / 56

Investigating novel hybrid LPWFA accelerators using start-to-end PIConGPU simulations

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The use of accelerated electrons from a laser wakefield accelerator (LWFA) as drivers of a plasma wakefield stage (PWFA) provides compact PWFAs that can serve as a test bed for the efficient investigation and optimization of PWFAs and their development into brightness boosters. Such hybrid accelerators have been experimentally realized at HZDR and LMU to study novel injection schemes. To better understand the microscopic, nonlinear dynamic of these accelerators, the experiments were accompanied by 3D3V particle-in-cell simulations using PIConGPU.

Here, we present the latest results from these numerical studies, covering injections due to hydrodynamic shocks, beam self-modulation and breakup, and cavity elongation - all accompanied by synthetic diagnostic methods that allow direct comparison with experimental measurements.
Challenges such as parasitic injections, shock injections, and non-ideal driver beam dynamics will be discussed. Recent technical advances in PIConGPU that enabled the execution of these large-scale simulation campaigns are briefly covered, as well as new synthetic in situ shadowgraph and radiation diagnostics.

Special Topic / 57

openPMD – F.A.I.R. and open scientific I/O at the Exascale Era

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This talk presents openPMD, an open and F.A.I.R. standard for particle-mesh data, and its impact in heterogeneous scientific workflows.
Particle accelerator codes need to span various time and length scales, leading to data processing pipelines consisting of multiple heterogeneous codes.
Standardization of physical data helps bridging the different models with a commonly-understood markup, creating interoperable and flexible workflows.

The openPMD standard is made accessible to scientific software via the openPMD-api, a library for the description of scientific data.
The backend implementations of the openPMD-api are based on established I/O framworks such as HDF5 and ADIOS2, and also include a scalable streaming backend for HPC workflows, provided by ADIOS2.
The talk gives an insight into the existing ecosystem of openPMD and describes the basic concepts of the data markup.

It shortly illuminates recent trends in large-scale I/O and their impact on scientific compute workflows. While traditional attempts at counteracting such trends, e.g. through compression, remain available in the openPMD-api, we propose loose coupling and online analysis via streaming workflows as a sustainable solution that avoids parallel filesystem bottlenecks.

Special Topic / 58

Establishing Laser Accelerated Proton Beam Performance for Dose Controlled Irradiation Studies and Beyond

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Applications of laser plasma accelerated proton beams in cancer therapy were discussed almost since the first demonstration of compact plasma accelerators. In-vitro studies to investigate the radiobiology of these intense particle bunches were performed, in particular with respect to dose rate related phenomena. With the recently reported FLASH effect, observed to reduce radiation toxicity in normal tissue, the field has regained significant interest as provision of high single pulse dose rate is inherent to plasma accelerators. Yet, for the translation to in-vivo studies laser accelerated protons not only lacked sufficient energy to penetrate the required volume but often reproducibility to ensure the provision of a dose distribution in a prescribed way. This presentation focuses on developments at the Petawatt laser DRACO at HZDR that enabled dose controlled irradiation of tumors in mice. Details on acceleration mechanisms and strategies to increase stability and energy well beyond the 60 MeV range are discussed – and expanded to recent explorations of the near critical density regime – as well as beam transport by means of a dedicated pulsed solenoid beamline to a secondary target together with online metrology and dosimetry.

F. Kroll, et al., Nature Physics 18, 316 (2022)

Poster Session / 59

Lattice Boltzmann simulations of Plasma Wakefield Acceleration

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We explore a novel simulation route for Plasma Wakefield Acceleration (PWFA) by using the computational method known as the Lattice Boltzmann Method (LBM). LBM is based on a discretization of the continuum kinetic theory while assuring the convergence towards hydrodynamics for coarse-grained fields (i.e., density, velocity, etc.). LBM is an established numerical analysis tool in computational fluid dynamics, able to efficiently bridge between kinetic theory and hydrodynamics, but its application in the context of PWFA has never been investigated so far. Our work takes a step forward to fill this gap. Results of LBM simulations for PWFA are discussed and compared with those of a code (Architect) implementing a Cold Fluid model for the plasma. In the hydrodynamic framework, we discuss the importance of regularization effects related to diffusion properties intrinsic of the LBM, allowing to go beyond the Cold Fluid approximations.

Poster Session / 60

A plasma-based acceleration method suitable for non-relativistic muons

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The past years have seen a growing interest in plasma-based accelerator technology since it provides a route to more compact, ecological yet powerful accelerators. However, even well-established acceleration techniques are only effective with particles traveling at speeds close to the speed of light (relativistic particles), leading to the exclusion of heavier particles, e.g. muons from the acceleration process.
Recently, cutting-edge methods for shaping the spatio-temporal spectrum of electromagnetic wave-packets that produce pulses with variable group velocities have been devised [1]. These pulses can propagate with subluminal group velocities, making them suitable candidates to drive acceleration wakes for slower particles. Furthermore, if carefully crafted, they can also increase their group velocity while propagating [2].
In this work, we present the ongoing research on a plasma-based acceleration method for non-relativistic particles using pulses with increasing subluminal group velocities as drivers. The method suggested has been first studied analytically and then tested using 2D particle-in-cell simulations with the code OSIRIS [3].

[1] H. Kondakci„ Y. F. Abouraddy, Nature Communications 10, 929 (2019).
[2] M. Yessenov and Y. F. Abouraddy, Phys. Rev. Lett. 125, 244901 (2020).
[3] R.A. Fonseca et al., Phys. Plasmas Control. Fusion 55, 124011 (2013).

Poster Session / 61

Paving the way for CW kHz operation of a discharge capillary in the DESY ADVANCE lab

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Discharge capillaries are an essential plasma-source for a wealth of different applications in plasma-based accelerators. The long, uniform plasma profiles have been pivotal in both LWFA and PWFA experiments alike. The repetition rate of such sources has been limited to 1-10 Hz, far below the required 10 kHz to MHz of a plasma-based collider or FEL. Development of high repetition rate discharge capillaries is imperative for these and other future applications and is currently being performed in the ADVANCE laboratory at DESY. Our initial goal is to achieve the milestone of continuous, stable, 1 kHz operation from which higher repetition rates might be achieved. A summary of the work being performed towards this goal is presented here.

Poster Session / 62

Few-cycle probing of laser and electron driven plasma wakefield accelerator experiments

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Laser and plasma wakefield acceleration is a two-stage process. Electron bunches are accelerated to relativistic velocities and then tailored to specific characteristics. In depth understanding and control of the involved acceleration mechanisms is crucial. Femtosecond probing gives insight into plasma dynamics during acceleration. Spectrally broadened and compressed probe pulses with a length of a few optical cycles are capturing high resolution shadowgrams showing the interaction between gas and laser or electron beam. The plasma oscillations, periodic modulations of the electron density, are captured for the laser and electron driven wakefields. The wavelength of these oscillations relates directly to the local density and is a valuable parameter for online diagnostics. It is extracted easily via Fourier transform. Applying a continuous wavelet transform determines the local densities along the propagation axis. Besides this longitudinal resolution, the shadowgrams, which are phase contrast images, also allow reconstruction of a quasi-3D, quantitative density distribution. From shadowgrams taken in multiple image planes the accumulated phase is calculated. Assuming rotational symmetry, a reverse transformation reveals the local refractive index, which is proportional to the density. Various probe beam diagnostics have been integrated and the first data shots were taken with a multiplane and multispectral imaging system.

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Beam driven wakefield characteristics probed by femtosecond-scale shadowgraphy

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High peak current electron beams from laser wakefield accelerators (LWFA) are capable to drive a particle driven wakefield (PWFA) in a subsequent stage. The intrinsic short duration of these driver beams opens the possibility for PWFA studies in a higher density regime of the order of $10^{18} \cdot \mathrm{cm}^{-3}$. Since optical probing provides a reasonable contrast at this density range, direct insight into the particle-driven wakefields is possible. Here we present the results of femtosecond optical probing of such beam driven wakefields, showing pronounced differences in the morphology of beam driven plasma waves when surrounded by either neutral gas or a broad pre-generated plasma channel. Moreover, the shape and size of the first cavity of the wakefields correlates with the driver beam charge. The experimental results are supported by 3D particle-in-cell simulations performed with PIConGPU. This method can be extended to a detailed study of driver charge depletion by probing the evolution of the wakefield as it propagates through the plasma. This is an important step for further understanding and optimization of high energy efficiency PWFAs.

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Plasma-Modulated Plasma Accelerator (P-MoPA)

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The drivers for laser plasma accelerators (LPA) are typically based on Ti:Sa technology, which is limited to repetition rates in the lower Hz range for high energies and to average powers of ~100 W. In contrast, modern Yb:YAG thin disk laser technology offers a magnitude higher average powers and repetition rates in the kHz range, combined with a high electrical-to-optical efficiency. The bottleneck of this technology is the typically picosecond long pulse duration, which forbids an efficient drive of a plasma wave.
Here, we present a new, three-stage approach for converting a picosecond long pulse of a modern Yb:YAG thin disk laser into a train of femtosecond-class pulses, which can then be used to resonantly drive a GeV-scale, multi-kHz LPA. To experimentally prove the approach and to explore its potential, we are using two state-of-the-art Yb:YAG laser systems located at the CALA facility of the Ludwig-Maximilians-Universität München (LMU). This allows us to scan for a wide range of parameters, with repetition rates of 1 kHz or 10 Hz, pulse energies from 120 mJ to 4 J, and pulse durations between 37 fs and 1 ps.

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Opening of Workshop

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European Network for Novel Accelerators (IFAST-WP6)

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Beam-driven Plasma Accelerators with focus on proton-driven

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Simulation tools and roadmap

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Laser Technology and LWFA Results (e-, p+, ion)

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Distributed Plasma Accelerator Landscape in Europe and Technical Progress towards Applications (EuPRAXIA ESFRI and others)

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Talks and discussion on plasma-based FEL experiments

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Particle physics plasma test facility (multi-stage, 10's of GeV)

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EuroNNAc Student and Young Researher Program - Posters, prizes, …

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International Landscape: Facilities, projects, initiatives

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Structure-based accelerators (e.g. ACHIP) and advanced radiation generation schemes

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Towards milestone report MS21 for EuroNNAc in May 2023

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Demonstration of Trojan horse injection in a hybrid LWFA-driven PWFA

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In a hybrid LWFA-driven PWFA (LPWFA) electron beams from a laser wakefield acceleration (LWFA) stage are utilized to drive a plasma wave in a subsequent plasma wakefield acceleration (PWFA) stage for acceleration of witness electron bunches to high energies. This concept allows for the exploration of PWFA-physics in a compact setup and harnessing the advantages of both plasma acceleration schemes in order to generate high-quality electron beams. Here we present results of Trojan horse injection in this hybrid plasma acceleration configuration. The DRACO laser is focused onto a gas target (LWFA stage), creating a plasma wakefield to accelerate a high peak current electron bunch. While such a beam is propagating in the second gas jet (PWFA stage), consisting of a mixture of high and low ionization threshold gas, an auxiliary low energy laser pulse intercepts the generated wakefield perpendicularly to release electrons from the highest ionization level in the first cavity. The generated witness beams show improved beam quality, such as lower energy spread compared to the drive electron beam. The realization of Trojan horse injection in LPWFA is a further step towards applications based on high brightness electron beams such as free electron lasers.

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Summary - Beam-driven Plasma Accelerators with focus on proton-driven

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Summary - Simulation tools and roadmap

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Summary - Laser Technology and LWFA Results (e-, p+, ion)

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Summary - Distributed Plasma Accelerator Landscape in Europe and Technical Progress towards Applications (EuPRAXIA ESFRI and others)

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Summary - Talks and discussion on plasma-based FEL experiments

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Summary - Particle physics plasma test facility (multi-stage, 10's of GeV)

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Special Sub-Session / 84

High-quality electron beams and free electron lasing based on a laser wakefield accelerator at SIOM

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Laser wakefield accelerators (LWFAs) are capable of generating ultra-high accelerating gradient up to 100 GV/m, and hold a great potential as a candidate for driving compact free electron lasers (FELs). However, the stability and insufficient beam quality, in terms of energy spread, large initial divergence, present a substantial obstacle to the realization of high-gain FELs. With the in-house developed 200-TW laser system with a repetition rate of 1-5 Hz and a well-designed gas target, a stable and high quality LWFA has been experimentally obtained. Here, we present an experimental demonstration of undulator radiation amplification in the exponential-gain regime. The amplified undulator radiation, typically centered at the 27 nanometers, has a maximum radiation energy of approximate 150 nJ. The maximum gain was estimated to be 100-fold in the third of the three undulators with the orbit kick method, indicating an undoubtable exponential gain. Such a proof-of-principle experiment will expedite the development of future compact facilities with broad applications.

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Summary - EuroNNAc Student and Young Researher Program - Posters, prizes, …

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Summary - International Landscape: Facilities, projects, initiatives

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Summary - Structure-based accelerators (e.g. ACHIP) and advanced radiation generation schemes

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Workshop Closure

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Special Sub-Session / 89

Seeded FEL lasing of the COXINEL beamline driven by the HZDR plasma accelerator

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Laser Plasma Accelerator (LPA) capabilities of producing high peak current, low emittance and GeV electron beams within a cm scale of accelerating distance paved the way for the realization of future compact light sources. With the continuous developments on LPA stability and electron beam properties, free electron laser (FEL) amplification had been recently demonstrated.
We report here on the commissioning of the COXINEL experiment at HZDR, combining the DRACO 150 TW ultra-short pulse laser and the COXINEL manipulation beamline, with the aim of achieving FEL amplification in the seeded configuration at 270 nm.
LPA-based FEL amplification requires a refined characterization of the electron beam phase space along the beamline before reaching the undulator.
The 10 meter long COXINEL beamline transport is designed to mitigate the chromatic emittance, reduce the slice energy spread and implement the supermatching optics, in addition to beam pointing alignment compensation allowing for position and dispersion control.
As for diagnostics, five imaging systems are installed along the line for electron beam optimization, a streak camera for temporal alignment and a UV spectrometer to measure the FEL signal. Furthermore, measurements are cross-checked with simulations, ELEGANT for beam optics and GENESIS for FEL.

Special Topic / 90

Electron injector system for AWAKE Run 2

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The proton driven plasma Wakefield acceleration experiment AWAKE at CERN demonstrated basic electron capturing and acceleration using a rather long electron bunch spreading out over several plasma wavelengths. For the second phase of the experiment called Run 2, the aim is to inject a short electron bunch with appropriate emittance and charge to achieve full capture and emittance preservation of the injected electron bunch. Therefore, a new electron injector and beam delivery system has been designed to fulfil the requirements. At the plasma entrance a bunch length of 200 fs and a charge of 100 pC is needed, the electron beam has to be focused down to a beam size of 5 um to realize a complete blow out which enables emittance preservation. The design of the injector consisting of an S-band RF-gun and X-band acceleration and velocity bunching will be presented as well as the design of the transfer line into the plasma. The status of the prototyping work will be discussed as well.

Special Topic / 91

Roadmap at Amplitude for high average power PW system

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Amplitude is involved in the increase of the average power of high energy system since 10 years. In the frame of ELI ALPS, we have already reached the level of 100W of average power on a 500TW at 10Hz (20fs) and we should be above 300W in the next 2 years. This results are possible thanks to the development of a new range of pump laser based on Nd:YAG liquid cooled disk laser head.
Today using flashlamp pumping we have already demonstrated pump laser generating 500W (50J/10Hz) in the green (Premiumlite product).
In the next few years, the use of diode pumping will allow us to further increase the repetition rate while keeping high energy per pulse. This new development has started in Amplitude in 2022 we will present our roadmap with to goal to reach more than 2kW pump laser in the green at 100Hz
In parallel to this roadmap we are also working on important topics that are needed to manufacture a high repetition rate multi 100's of TW TiSa laser with the level of reliability and ease of use needed for plasma accelerator.

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Discussion

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Poster Session / 93

Mechanisms to control laser-plasma coupling in laser wakefield electron acceleration

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A laser wakefield experiment was performed at the Lund Laser Centre with the support of ARIES Transnational Access programme. In the context of the EuPRAXIA project it aimed to explore possible control mechanisms over laser-plasma coupling and the resulting trapping and acceleration dynamics of the produced electron bunches. Three main experimental parameters which have a large impact on the accelerated electrons properties were varied: the density downramp before plasma exit, the focal position of the laser within the plasma and the laser energy distribution through focus. Experimental results are in good agreement with particle-in-cell simulation results using realistic laser energy, phase distribution, and temporal envelope, allowing for accurate predictions of difficult to model parameters, such as total charge and spatial properties of the electron bunches, opening the way for more accurate modelling for the design of plasma-based accelerators.

Special Topic / 94

Proton and deuteron acceleration with few-cycle, relativistic intensity laser pulses

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According to recent theories, ion acceleration is predicted to achieve high efficiency with the use of single-cycle laser pulses. Few-cycle, high-repetition-rate laser systems with modest energy (10s of mJ) have been developed recently with remarkable stability. With the use of adaptive optics, such laser pulses can be focused down to relativistic intensities, providing a platform for exploring the laser-plasma interactions with very few cycle pulses. Here we present an experimental study of proton and deuteron acceleration in both forward and backward directions with 12 fs laser pulses, providing ~10^19W/cm^2 intensity on target.
Protons were accelerated on thin foils made of various materials, with thicknesses ranging from 5 nm to 9 microns. The highest cut-off energy and conversion efficiency was 1.5 MeV, and 1.5%, respectively, with a beam emittance as small as 0.00032π-mm-mrad. Deuterons were accelerated close to MeV by irradiating homemade 200 nm thin deuterated polyethylene foils. Dependence of the cut-off energy and the conversion efficiency on the dispersion of the pulses have been also measured. The demonstration of MeV deuterium ions can lead to the production of bright neutron flux via D-D reaction, which could be a pathway to drive a sub-critical reactor for transmutation of spent nuclear fuel.

Poster Presentation Session / 95

Simon van der Meer Early Career Award in Novel Accelerators

Authors: Bernhard Holzer[1]; Roman Walczak[2]

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Poster Presentation Session / 96

Poster Prizes

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Poster Presentation Session / 97

Poster Presentations

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Poster Session / 98

Computational fluid dynamics simulations of discharge capillary waveguides at FLASHForward for high-repetition-rate plasma-wakefield accleration

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Plasma-wakefield accelerators provide acceleration gradients several orders of magnitude larger than conventional accelerators and as such, represent a promising technology for reducing the footprint of future particle accelerators. The luminosity in colliders and the brilliance in free-electron lasers, scales with the repetition rate at which the accelerator operates. Therefore, repetition rate is a crucial parameter to consider when developing plasma-based accelerators for these applications. FLASHForward is an experimental, beam-driven, plasma-accelerator facility at DESY that is unique in the field due to it's ability to probe high-repetition-rate operation. To fully realise FLASHForward's potential it is crucial to develop a plasma source capable of providing consistent plasma properties at megahertz repetition rates. To do this we must gain a better understanding of the plasma dynamics inside the existing discharge-capillary waveguides used at FLASHForward with the aim of improving the designs in the future. The first step required is to optimise the gas flow in the capillaries to achieve repeatable plasma conditions at high repetition rate. In this contribution, computational fluid dynamics simulations in discharge capillaries are presented, revealing both a better understanding of gas flow in existing designs as well as hints as to how designs may be optimised in the future.

Poster Session / 99

Phase manipulation through plasma density modulation

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A Laser-Wakefield Accelerator can produce electrons in the MeV range just over a few millimetres. However, due to their finite energy spread and divergence the applications of these electrons become limited. By tailoring the plasma density, the phase can be manipulated and hence gaining control of the bunch energy spread and divergence. Here, the properties of 100 MeV shock-assisted ionisation injected electrons after propagation through two supersonic gas jets is presented.

Poster Session / 100

Modelling of laser distribution as input for simulations of Laser wakefield acceleration

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The optimisation of electron beams accelerated by laser driven wakefield in plasma relies on the identification of the optimum plasma and laser properties for a specific regime of acceleration. The influence of laser symmetry around focus on the electron properties was investigated to understand recent experimental results in the case of ionisation injection in gas cells.

In order to simulate accurately laser plasma coupling for 100 TW to 1 PW class lasers drivers such as Apollon F2 beam, we implemented a Gerchberg-Saxton-like Algorithm (GSA) to efficiently fit measured asymmetric laser fluences using bases of orthogonal functions (Hermite-Gauss & Laguerre-Gauss). This GSA process allows us to retrieve a 2D phase-map associated to a collection of fluence images measured in vacuum through laser focus by minimising the integrated error on the fit. Due to the high dimensionality of the fit parameters space used within the algorithm, we employed a Bayesian Optimisation method to retrieve the optimal set of inputs for our fit functions.

We discuss the major steps, the numerical constraints and the overall accuracy of this best-fit algorithm and how it is implemented in PIC simulations using the quasi-3D cylindrical FBPIC code.

Poster Session / 101

Demonstration of divergence reduction of laser driven wakefield accelerated electron beams using a compact plasma lens generator

Authors: Alexander Debus[1]; Amin Ghaith[2]; Arie Irman[3]; Yen-Yu Chang[3]; Jurjen Couperus Cabadag[3]; Klaus Steiniger[1]; Max LaBerge[4]; Patrick Ufer[1]; Richard Pausch[5]; Susanne Schoebel[1]; Ulrich Schramm[1]

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We demonstrate the divergence reduction of laser driven wakefield accelerated electron beams using a compact plasma lens in a single stage setup. We modify the gas density profile of a super sonic gas

jet and create a shallow second density bump, which serves as a passive plasma lens, using a small ($< 1\text{cm}^3$) metal wedge. The plasma lens decreases the electron beam divergence from averaged 2.1 down to 0.98 mrad (r.m.s.), while at the same time, the changing of the peak energy and the charge of the beam with or without the plasma lens is within the error bar. As a result, the plasma lens preserves the peak current ($\sim$ 10kA) of the electron beam and drastically increases the peak charge density from averaged 1.8 to 4.7 pC/(MeV*mrad). This new technique unlocks the possibility of generating arbitrary gas density in a simple and compact setup, which is essential for achieving adiabatic focusing or staging acceleration.

Poster Session / 102

Edge-Pumped Tm:Lu2O3 disk broadband laser amplifier design at 1 kHz

Authors: Gianluca Cellamare[1]; Federica Baffigi[2]; Luca Labate[3]; Daniele Palla[4]; Leonida Antonio Gizzi[5]

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We report on the conceptual design of an amplification chain based on Tm-doped gain medium [1], for solid-state, ultra-short CPA laser pulses, aiming at high-efficiency, kHz repetition rate, high peak power and kW-scale average power, with emission wavelength around 2 μm. A multi-pass configuration is presented, with three stages, with 4% doped Tm:Lu2O3 ceramic thin discs, lateral (edge) [3] pumping (EPDL) scheme with an output energy of >500mJ from an input energy pulse of 1 mJ. The modelling of multipass extraction (at the 1kHz rep rate) and thermal load is also studied and discussed.

[1] D.A.Copeland et al., "Wide-Bandwidth Tm-Based Amplifier for Laser Acceleration Driver",Proc. of SPIE Vol. 9729, 97290I, (2015)· doi: 10.1117/12.2220010
[2] E.V. Ivakin et al., "Laser ceramics Tm:Lu2O3. Thermal, thermo-optical, and spectroscopic properties", Optical Materials 35 499–503 (2013). doi:10.1016/j.optmat.2012.10.002
[3] J. Vetrovec, et al., "2-micron lasing in Tm:Lu2O3 ceramic:initial operation", Proc. SPIE 10511, 1051103 (2018); doi:10.1117/ 12.2291380

Special Topic / 103

Applications of machine learning to plasma-based acceleration

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This talk will review recent applications of machine learning techniques to plasma-based acceleration, both for simulation workflows and for real-time control of experiments. I will briefly describe the working principle of some of these techniques, and discuss how plasma-based accelerators could take advantage of them. I will also discuss some of the recent applications of machine learning to conventional accelerators, and how these advances could carry over to plasma-based accelerators.

Special Topic / 104

Electron bunch seeding of the self-modulation instability in plasma

Author: Livio Verra[1]

Co-authors: Giovanni Zevi Della Porta ; Edda Gschwendtner [1]; Michele Bergamaschi [2]; Tatiana Nechaeva [3]; Jan Pucek [4]; Patric Muggli [5]

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We show experimentally that the self-modulation instability of a long 400 GeV proton bunch can be seeded by a preceding short 18 MeV electron bunch. We prove that the timing of the self-modulation is reproducible from event to event, and that it is controlled by the timing of the seed bunch.We show that the amplitude of the seed wakefields depends on the parameters of the seed electron bunch, and that the growth rate of the self-modulation depends on those of the proton bunch.
The electron bunch seeding of the self-modulation in plasma is an important milestone on the path towards proton driven plasma wakefield acceleration of electron bunches, with quality and energy suitable for high-energy physics application, such as in the AWAKE experiment.

Special Topic / 105

AWAKE RUN 2: Program and plans

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Poster Session / 106

Fast models for collective effects in linear accelerators

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The applications envisioned for advanced linear accelerator-based facilities rely on the production of intense particle beams delivered at high repetition rates. Indeed, the demanding brightness and luminosity foreseen by electron driven radiation sources and linear colliders, respectively, imply the coexistence of high peak currents and small transverse emittances. The acceleration of such beams in high gradient machines exposes charged particles to a mutual parasitic interaction which is caused by the excitation of wakefields acting either within the same bunch or among different bunches. Moreover, electron beams produced by rf-photoinjectors enter the main linac with energies in the 4-6 MeV range which implies a non-negligible sensitivity to space-charge effects. The presence of the aforementioned self-induced fields may dilute the phase space quality and, thus, their effect has to be investigated carefully in order to ensure the design performance. Beam dynamics studies including collective effects typically require significant numerical resources and, therefore, we present here reliable methods to describe such processes by means of quasi-analytical approaches that simplify the computation. Such models are embedded in a custom tracking code that provides a fast simulation tool for the dynamics of electron linacs in presence of space charge forces and wakefield effects.

Special Topic / 107

GeV-scale accelerators driven by plasma-modulated pulses from kilohertz lasers.

Authors: Aimee Ross[None]; Alexander Picksley[1]; David McMahon[1]; Emily Archer[None]; Oscar Jakobsson[1]; Roman Walczak[2]; James Chappell[2]; James Cowley[1]; Johannes van de Wetering[2]; Linus Feder[None]; Simon Hooker[2]; Warren Wang[2]

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The energy required to drive a large-amplitude plasma wave can be delivered over many plasma periods, rather than in a single period, if the driving pulse is modulated. This approach opens up plasma accelerators to novel laser technologies which can provide the required energy at high pulse repetition rates, and with high wall-plug efficiency. The required modulation can be achieved in a two-step process: (i) spectral modulation of the long drive pulse by co-propagation with a low-amplitude plasma wave driven by a short, low-energy seed pulse; (ii) conversion of the spectral modulation to temporal modulation via a dispersive optic to generate a train of short pulses suitable for resonantly driving a plasma accelerator. Existing, efficient thin-disk lasers can be used to accelerate electrons to GeV level energies at kHz-repetition-rate.

Poster Session / 108

Beam dynamics studies with comb electron beams for Particle driven WakeField Acceleration.

Author: Gilles Jacopo Silvi[1]

Co-authors: Alberto Luigi Bacci [1]; Andrea Mostacci [2]; Anna Giribono [1]; Cristina Vaccarezza [1]; Daniele Francescone [1]; Enrica Chiadroni [2]; Fabio Bosco [1]; Lucia Giuliano [1]; Luigi Palumbo [2]; Marcello Rossetti Conti [1]; Martina Carillo [1]; Massimo Ferrario [1]; Mauro Migliorati [2]; Riccardo Pompili [1]; Vladimir Shpakov [1]

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Comb electron beams are fs and high brightness electron bunches used to drive plasma accelerating modules. An ultra-relativistic beam of charged particles (the driver) through a plasma generates a wake of charge density useful for accelerate a witness beam (Particle driven WakeField Acceleration - PWFA). The witness dynamics control is fundamental to achieve the optimum transverse and longitudinal matching at the plasma entrance. Beam dynamics simulations were performed under velocity bunching conditions to observe how the witness (about 30pC) bunch dynamics changes due to the driver (about 200pC). A pulse shaping parametric scan has been performed starting from a well-defined initial condition, i.e. EUPRAXIA @SPARC_LAB working point. This working point is a 30-pC witness, 290 fs long gaussian beam with 0.175 mm transverse dimension and a 200-pC driver, 230 fs long gaussian beam with 0.35 mm transverse dimension. The 100 MeV Linac has been optimized to achieve optimal emittance, spot size, energy, energy spread and longitudinal distance between bunches. SPARC_LAB machine layout has been used for this analysis with ASTRA simulation tool.

Poster Session / 109

Laser-driven Ion Acceleration from pre-expanded thin foils.

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Laser-Ion acceleration typically uses thin foils as targets, where the density is typically a few hundred times the critical density (n_c). Targets with just a few times n_c constitute an interesting target system for laser plasma acceleration. Unfortunately, these densities are hard to achieve in experiment. In this poster we present an exploding foil experiment, were we pre-expand a thin foil via a dedicated pre-pulse (⊠10⊠^15 W/cm^2) prior to the interaction with the main pulse (⊠10⊠^20 W/cm^2). A Nano-second probing beam in combination with a streak camera is used to diagnose the state of the Plasma during expansion. This experiment is still ongoing and our aim is to diagnose the optimum plasma density for ion acceleration for preliminary results to be presented.

Poster Session / 110

Probing Ion-motion Recovery in a Beam-driven Plasma-wakefield Accelerator

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Beam-driven plasma-wakefield acceleration is a promising avenue for the future design of compact linear accelerators with applications in high-energy physics and photon science. Meeting the luminosity and brilliance demands of current users requires the delivery of thousands of bunches per

second – many orders of magnitude beyond the current state-of-the-art of plasma-wakefield accelerators, which typically operate at the Hz-level. As recently explored at FLASHForward, a fundamental limitation for the highest repetition rate is the long-term motion of ions that follows the dissipation of the driven wakefield (R. D'Arcy, et al. Nature 603, 58–62 (2022)). Studying the dynamics of plasma recovery in greater detail is an essential first step in advancing beam-driven plasma-wakefield acceleration towards meaningful application in future high-energy-physics and photon-science facilities. Here we present the measurement methodology, the data processing, and discuss latest experimental results.

Poster Session / 111

Hosing of a long proton bunch induced by an electron bunch

Author: Tatiana Nechaeva[1]

Co-authors: Jan Pucek [2]; livio verra [3]; Michele Bergamaschi [4]; Giovanni Zevi Della Porta ; Patric Muggli [5]; AWAKE collaboration

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We study experimentally hosing [1] of a long proton bunch in plasma in AWAKE. We induce this process with misalignment between the trajectories of a preceding short electron bunch and that of the proton bunch. We observe hosing as transverse oscillation of the proton bunch centroid position in the plane of misalignment at the period of the wakefields. Self-modulation (SM) occurs in the perpendicular plane. The two processes (hosing and SM) are reproducible from event to event. Misalignment to the opposite sides with respect to the given bunch axis leads to the oscillations being in counter phase. The amplitude of oscillation increases with the proton bunch charge [2] and is also affected by the extent of misalignment.
We will present the latest experimental results.

[1] D. Whittum et al., Phys. Rev. Lett. **67**, 991 (1991)
[2] C. Schroeder et al., Phys. Plasmas **20**, 056704 (2013)

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Poster Session / 112

A novel analytical model of space charge forces in RF-guns

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A novel model of space charge forces is proposed for a low-energy (γ~1) bunch with arbitrary charge distribution in RF-guns. By exploiting Green function method, it is possible to develop an analytical approach and derive expressions of self-induced forces for any transverse and longitudinal bunch distribution. The model is accurate also in the approximation of low energy beams, when the 3D distribution can be decoupled in the two longitudinal and transverse planes. After having reproduced the results known in literature for Gaussian and Uniform charge distribution, we derive space charge forces in parabolic charge distributions. The proposed model highlights the dependence of rms beam emittance on the non-linearities, observed in the transverse phase space due to the space charge forces. Moreover, the model shows that the strongest non-linearities of the transverse phase space are already generated at the cathode when the beam is emitted. Finally, the method allows to include a quadrupolar perturbations on the transverse charge density.

Special Topic / 113

Hosing of a long proton bunch induced by an electron bunch

Author: Tatiana Nechaeva[1]

Co-authors: Jan Pucek [2]; livio verra [3]; Michele Bergamaschi [4]; Giovanni Zevi Della Porta ; Patric Muggli [5]; AWAKE collaboration

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We study experimentally hosing [1] of a long proton bunch in plasma in AWAKE. We induce this process with misalignment between the trajectories of a preceding short electron bunch and that of the proton bunch. We observe hosing as transverse oscillation of the proton bunch centroid position in the plane of misalignment at the period of the wakefields. Self-modulation (SM) occurs in the perpendicular plane. The two processes (hosing and SM) are reproducible from event to event. Misalignment to the opposite sides with respect to the given bunch axis leads to the oscillations being in counter phase. The amplitude of oscillation increases with the proton bunch charge [2] and is also affected by the extent of misalignment.
We will present the latest experimental results.

[1] D. Whittum et al., Phys. Rev. Lett. **67**, 991 (1991)
[2] C. Schroeder et al., Phys. Plasmas **20**, 056704 (2013)

Poster Session / 114

Experimental and theoretical characterization of very long plasma source for plasma-based particle accelerators

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Co-authors: Maria Pia Anania [1]; Sahar Arjmand [1]; Mostafa Behtouei [1]; Marco Bellaveglia [1]; Angelo Biagioni [1]; Enrica Chiadroni [1]; Alessandro Cianchi [2]; Gemma Costa [1]; Martina Del Giorno [1]; Giampiero Di Pirro [1]; Zeinab

Ebrahimpour [1]; Mario Galletti [1]; Luca Giannessi Giannessi [1]; Anna Giribono [1]; Pasqualina Iovine [1]; Valerio Lollo [3]; Andrea Mostacci [1]; Tommaso Napolitano [3]; Donato Pellegrini [1]; Riccardo Pompili [1]; Stefano Romeo [1]; Vladimir Shpakov [1]; Angelo Stella [1]; Cristina Vaccarezza [1]; Fabio Villa [1]; Arie Zigler ; Massimo Ferrario [1]

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Innovative particle accelerators based on plasma technology allow a drastic reduction in size, thanks to the high acceleration field established inside plasmas, created and confined by particular devices. Plasma wake-field acceleration experiments are performed at the SPARC LAB test facility by using devices consisting in gas-filled capillaries, in which the plasma formation is achieved by ionizing the hydrogen gas through high voltage pulses. In this work, the experimental and theoretical characterization of a 400 mm long plasma source is presented, which represents the testing of the first plasma source for the EuPRAXIA@SPARC_LAB project. Its exceptional length of 400 mm makes it one of the world's largest plasma sources for particle accelerators based on the high voltage ionization technique. The 3D-printed capillary is characterized by means of the spectroscopic technique based on the Stark broadening method, which allows to measure the evolution of the plasma density profile along the main plasma channel. In addition to the experimental analysis, the CFD software OpenFoam is used to simulate the dynamics of the neutral gas from its entrance inside the capillary to the ionization instant.

Special Topic / 115

Recent advances in quasi-static Particle-in-Cell simulations for modeling plasma accelerators

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Modeling plasma-based accelerators is a computationally challenging task.
To resolve the full kinetic behavior of the beams and the plasma, particle-in-cell (PIC) codes are the method of choice. In the quasi-static approximation it is assumed that the beams evolve on a different time scale than the plasma,allowing for a separate treatment of the beams. Consequently, quasi-static PIC enables large time steps in comparison to conventional electromagnetic PIC codes. In the last years, the quasi-static PIC method has been significantly improved. Here, the latest advances are presented, including novel algorithmic and numeric implementations, as well as porting the quasi-static PIC algorithm to the latest high-performance computing architectures. The impact of these developments on established experiments like AWAKE is evaluated. Finally, future needs and development plans are discussed.

Poster Session / 116

HiPACE++: GPU-accelerated modeling of plasma wakefield accelerators

Authors: Severin Diederichs[1]; Carlo Benedetti[2]; Axel Huebl[2]; Remi Lehe[3]; Andrew Myers[2]; Alexander Sinn[4]; Jean-Luc Vay[5]; Weiqun Zhang[2]; Maxence Thévenet[None]

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Modeling plasma wakefield accelerators is computationally challenging. Using cost-reducing algorithms like the quasi-static approximation allows for efficient modeling of demanding plasma wakefield accelerator scenarios. In this work, the latest highlights of the performance-portable, 3D quasi-static particle-in-cell (PIC) code HiPACE++ [1] are presented. The code applies modern HPC practices like a performance-portability layer, standard I/O formats, continuous integration, and is open-source (https://github.com/Hi-PACE/hipace).
HiPACE++ demonstrates orders of magnitude speed-up on modern GPU-equipped supercomputers in comparison to its CPU-only predecessor HiPACE. Therefore, HiPACE++ enables fast and accurate modeling of challenging simulation settings, including the proton-beam-driven accelerator AWAKE [2] or certain positron acceleration schemes.

[1] S. Diederichs, et al. "HiPACE++: A portable, 3D quasi-static particle-in-cell code", Computer Physics Communications 278 (2022): 108421.
[2] E. Gschwendtner (AWAKE Collaboration), "AWAKE, The advanced proton driven plasma wakefield acceleration experiment at CERN", Nucl. Instrum. Methods Phys. Res., Sect. A 829 (2016), 76.

Special Topic / 117

Development and characterization of Plasma Targets for LWFA experiments at SPARC_LAB

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One of the most important features of laser-plasma based accelerators is their compactness while still providing very high accelerating fields up to hundreds of GV/m. The main challenge lies in characterizing and controlling the plasma itself, which determines its proper synchronization with the particle beam to be accelerated, an issue that strongly influences the quality of the accelerated bunches.
The characterization and optimization of plasma targets used at the SPARC_LAB laboratories for LWFA will be presented. In particular, the study and the realization of the plasma guiding process of a laser pulse inside a plasma-filled capillary discharge will be shown. This laser pulse confinement technique becomes particularly relevant for extending the acceleration channel, for example, in a plasma elongated to several centimeters or more. It will be discussed how this optical process was achieved for an ultra-short $10\ mJ$ laser pulse in a $500\ \mu m$ diameter capillary discharge, using time-resolved online spectroscopic measurements of the transverse and longitudinal density distribution of the generated plasma.

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Numerical simulation study of the propagation of a short electron bunch and a long proton bunch in a plasma ramp

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A particle bunch propagating through plasma will induce a non-linear response when $n_b \gg n_{e0}$ [1]. A negatively charged bunch will drive a blow-out, in which all plasma electrons are expelled from the propagation axis. A positively charged bunch will attract plasma electrons, which will flow-in to the propagation axis, creating a filament [2]. This will sustain focusing fields for the positively charged bunch and defocusing for negatively charged particles.

In the Advanced Wakefield Experiment (AWAKE) [3], in which a long proton bunch drives high-amplitude wakefields for electron acceleration through self-modulation [4], there is a plasma density ramp at the entrance and exit of the plasma [5]. The density in the plasma ramp can be up to five orders of magnitude lower than that of the long plasma. We present a numerical study performed with the particle-in-cell code LCODE [6] using parameters similar to those of the experiments. We show that the plasma ramp would have a detrimental effect on the propagation of both a seed electron bunch placed inside of the proton bunch and for an electron bunch injected in a second plasma for acceleration [7], if that plasma had a density ramp at the entrance.

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EARLI: designing a LWFA for AWAKE Run2

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Following a successful Run 1 experiment, AWAKE has developed a baseline plan for Run 2 that requires the implementation of a compact electron source for external injection of a witness bunch in the plasma wave. The feasibility of using a laser wakefield accelerator (LWFA) to produce the electron bunch is investigated. The EARLI project (Electron Accelerator driven by a Reliable Laser for Industrial uses) aims to design injectors ready for applications, the first being a stand-alone injector that meets AWAKE requirements. EARLI includes a laser system, a plasma cell and a transfer line, able to produce a high-quality electron beam and reliable and stable over long periods. For the EARLI design, methods from conventional accelerators are applied to the LFWA physics.

Poster Session / 120

Measuring spatial-temporal couplings using modal multi-spectral wavefront reconstruction

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With the possibility of using high-power laser systems as drivers for particle acceleration, laser diagnostics becomes even more important in that field.
Knowledge of spatial-temporal couplings such as pulse-front tilt or curvature is important to determine the focused intensity of high-power lasers. Common techniques to determine these couplings are either qualitative or complex to set up. Here we present a simple method to measure low-order spatio-temporal couplings of a laser by measuring the spectrally resolved wavefront. To do so, we introduce different bandpass filters into an image of the laser's nearfield and subsequently measure the wavefront of the specific colour using a Shack-Hartmann sensor. Our technique is easy and cheap to implement in existing facilities and, based on our analysis, presents are reasonable trade-off between acquisition time and spatio-temporal resolution.

Special Topic / 121

e4AWAKE: Next generation electron source for the Advanced Wakefield Experiment (AWAKE) at CERN

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Proton-driven plasma wakefield acceleration of electrons was first demonstrated in 2018 by the Advanced Wakefield Experiment (AWAKE) at CERN [1]. Following this achievement, AWAKE has developed the Run 2 research program, aimed at producing high-quality electron bunches reaching tens of GeV [2].
In the baseline Run 2 program, a one-meter gap is required between two plasmas to inject electron bunches generated by an RF-based source. The gap in plasma reduces wakefields by a factor of two, limiting acceleration, and the RF-based source does not allow for injection of electron bunches spaced by the plasma wavelength, limiting luminosity. It is therefore interesting to explore alternative injection schemes.
The e4AWAKE project aims to avoid both limitations by producing electron bunches inside the plasma, using a high-power laser impinging on a movable solid target, as proposed in Ref. [3]. The project can be developed and tested in parallel with the baseline Run 2 program. Parameters, simulations and design considerations for the e4AWAKE project will be discussed.
[1] E. Adli et al. (AWAKE Collaboration), Nature 561, 363–367 (2018)
[2] E. Gschwendtner et al. (AWAKE Collaboration), Symmetry 14(8), 1680 (2022)
[3] V. Khudiakov and A. Pukhov, Phys. Rev. E 105, 035201 (2022)

Special Topic / 122

KALDERA

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Laser-plasma accelerators (LPA) will be at the core of next-generation accelerators. Advancing LPA core technolgies, including the development of high average power drive lasers, is an integral part of DESY's accelerator R&D.

We will update on the recent developments of KALDERA, DESY's flagship LPA drive laser currently under development. KALDERA will deliver 100TW LPA drive laser pulses at up to 1kHz repetition

rate. These high repetition rates will be crucial to achieve reproducible and application-ready high-quality electron beams through fully exploiting active stabilization techniques and machine learning concepts.

Poster Session / 123

A semi-analytical method to calculate wakefield from electron beams passing through dielectric-coated circular waveguides

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The dielectric accelerator is one of the most advanced accelerator concept, in which the ultra high accelerating field can be excited by either optical to infrared laser or ultrashort relativistic electron bunches. The beam driven dielectric wakefield accelerators (DWFA) make use of the electromagnetic Cherenkov radiation (wakefield) from the electron bunches that pass through the dielectric-lined waveguides. These high gradient fields may create strong instabilities on the beam itself causing issues in plasma acceleration experiments (PWFA), plasma lensing experiments and in recent beam diagnostic applications. We propose a semi-analytical method to calculate these high gradient fields without resorting to time consuming simulations. Ultra-relativistic bunches traveling in these dielectric capillaries can interact only with TM0n modes that travel at the speed of light. Any perturbation can be written as sum of potentially excitable harmonics, with amplitudes dictated by the shape of the power spectrum of the beam. By executing 2D simulations on a generic section of the structure it is possible to calculate the dispersion diagram of the modes and estimate the frequencies at which these modes can be excited. Finally, with these frequencies it is possible to calculate the coefficients with which to multiply the amplitudes of the corresponding harmonics

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Carrier-envelope phase control of a kilohertz laser-wakefield accelerator

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The interaction of an ultra-intense single-cycle laser pulse with an underdense plasma in a laser-wakefield accelerator can lead to an asymmetry in the plasma response that depends on the carrier-envelope phase (CEP) of the laser driver[1]. In our experiment, we use near-single cycle pulses with controlled CEP to accelerate electrons in a laser wakefield accelerator. We observe the oscillation of the accelerated electron beam pointing in the laser polarization direction in phase with the CEP. This

effect is significant, with an oscillation amplitude as high as 15 mrad. A dependence of the injected charge to the laser CEP is also observed. Particle-in-Cell simulations explain these observations through highly localized, off-axis injection of sub-fs, ultralow emittance electron bunches triggered by the CEP-dependent asymmetry in the plasma wake [2,3,4,5]. These observations imply that we achieve sub-cycle control on the injection and subsequent dynamics of the electron beam through the waveform of the laser.

[1] E.N.Nerush and I.Yu.Kostyukov, Phys. Rev. Lett. 103,035001 (2009)
[2] J. Kim et al, Phys. Rev. Lett. 127, 164801 (2021)
[3] J. Huijts et al, Physics of Plasmas 28, 043101 (2021)
[4] J. Huijts et al, Phys. Rev. X 12,011036 (2022)
[5] L. Rovige et al, arXiv:2205.08374 (2022)

Special Topic / **125**

Conclusions from the 2021 Snowmass Process

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The U.S. Particle Physics Community Planning Exercise, 'Snowmass 2021' was completed in July 2022 and provides input for the Particle Physics Project Prioritization Panel (P5), which will develop a ~10 year scientific vision for the future of the U.S. high energy physics program. In this contribution we provide a general overview of the Snowmass 2021 conclusions and discuss the outcomes relevant for the Advanced Accelerator Community and the advanced collider concepts, which aim to reduce the dimensions, C02 footprint and costs of future high energy physics machines.

Poster Session / **126**

Steady-state microbunching in storage rings with distributed laser-electron interaction

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Among the new accelerator concepts presently under discussion are electron storage rings with steady-state microbunching to provide coherent emission of synchrotron radiation with high intensity and ultrashort pulses like free-electron lasers with the additional benefits of the excellent stability and high repetition rate inherent in circular machines. Driving storage rings with laser pulses interacting with the electrons in an undulator would provide stable phase-space buckets similar to a radiofrequency system but on a much smaller wavelength scale – micrometers instead of centimeters. The fundamental issue of the required isochronicity of the electrons over one turn can be mitigated by distributing several undulators along the ring circumference. The next logical step would be to omit undulators altogether and perform the laser-electron interaction in all dipole magnets of the ring where each dipole acts like an undulator half-period. While the interaction in a single dipole is weak, the large number of them still provides enough energy modulation to drive the electron beam. Numerical estimates and technical issues of this novel scheme are discussed.

Poster Session / **127**

Effects of plasma ramp measured in AWAKE

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We study the propagation of an electron bunch travelling within a proton bunch through a plasma density ramp. Because the proton bunch density in the ramp is higher than the plasma density, the bunch generates a high density, on-axis plasma electron filament. This filament is defocusing for the electron witness bunch that can therefore be lost along the ramp. At AWAKE we have measured this effect by changing the relative timing of the electron bunch with respect to the proton bunch. When the electron bunch propagates in front of the proton bunch (i.e. seeding the self-modulation), the electrons travel until the electron spectrometer, downstream of the plasma column. A position of the electrons within the proton bunch, where seeding stops, exists. Beyond this position electrons are lost and do not reach the spectrometer. We will present latest experimental data obtained during Run 2.

Special Topic / 128

Khz rep-rate, kW average power class laser development with Tm-based ceramics

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Increasing the luminosity of laser-driven electron accelerators to the level required for future FEL or TeV-class collider applications ideally requires a 100-1000 fold stepping up in the average power of driver lasers, translating into ultrashort/ultraintense systems close to or exceeding the kHz repetition rate and the 1-10kW average power. Scaling current technology based on Nd-pumped TiSa amplifiers to these levels is hindered by thermal management issues and complexity. A novel approach has recently been investigated, consisting in replacing TiSa with longer upperstate lifetime materials and extracting the stored energy over multiple pulses (Multi-Pulse Extraction, MPE); advantages include the possibility of (quasi)CW, direct pumping with commercial diodes, thus dramatically increasing the wall-plug efficiency, less stringent requirements on the extraction fluence, and so on.
Here we report on the design and development of a kW-class average power system based on MPE. The system, based on a commercial OPA, mJ energy front-end, will feature Tm-based multipass amplifiers with active-mirror configuration, and aims at delivering <100fs duration, >500mJ energy, 2μm-wavelength pulses at >1KHz rep rate. Issues including the (direct) pumping geometry optimization, the thermal management on each amplifier and the MPE temporal dynamics will be discussed.

Poster Session / 129

Electron Phase Space Shaping in an RF-cavity-based UTEM

Authors: Simona Borrelli[1]; Stefan T. Kempers[2]; Walter Schaap[2]; Peter H.A. Mutsaers [2]; Erik Kieft[3]; Bart Buijsse[3]; Ton K.A.H. van Leeuwen [2]; Jom O.J. Luiten[2]

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Developing new methods for tailoring the phase-space distribution of electron beams is a challenging and essential task in next-generation particle accelerators, compact x-rays sources, and ultrafast electron microscopy. RF-cavities are routinely employed in accelerator science to manipulate the electrons' phase-space. This contribution shows the use of a miniaturized RF-cavity to chop the continuous beam of a conventional transmission electron microscope into ultrashort pulses. We developed an RF-cavity-based ultrafast transmission electron microscope (UTEM) generating few-100-fs pulses with GHz-MHz repetition rate, which preserves the low emittance and energy spread of the TEM Schottky field emission gun.

Beyond time-resolved investigation of specimens, UTEMs entitle novel free-electron quantum optics. We devise techniques to control and shape the electron wavefunction amplitude and phase for coherent detection methods and distinct phase-contrast imaging. A laser oscillator is integrated into the RF-cavity-based UTEM setup, thus allowing the observation of the synchronized interaction between free-electrons and fs-laser pulses.

We propose to exploit this interaction to coherently shape the electron wavefunction in photon-induced near-field electron microscopy and light-based Zernike phase plate imaging. We present experimental results and a theoretical model of the ponderomotive interaction between free-electrons and laser pulses, which opens the path to the phase-manipulation of high-relativistic electron beams.

Poster Session / 130

GENERATION OF MULTI-PULSE LASER-WAKEFIELD DRIVERS VIA DELAY MASKS

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Laser-plasma accelerators are rapidly developing to produce high-quality sub-GeV electron beams capable of Free Electron Laser (FEL) operation. Their reduced size and cost with respect to conventional accelerators can widely spread the use of particle beams in medical physics and industry. Although multi GeV electron energies were demonstrated, more work is needed to establish high quality acceleration in this energy range. The Resonant Multi-Pulse Ionization (ReMPI) injection scheme has been proposed to produce FEL quality electron bunches with existing ultrashort and ultraintense laser systems, combining the advantages of the multi-pulse acceleration and the two-color injection.

Here we report on how to produce a multi-pulse driver for the ReMPI scheme focusing the laser beams generated via wavefront division of a single ultrashort pulse by a glass delay mask, which demonstrated to have the right features to be used for ReMPI. A spatio-temporal characterization of the pulse train obtained with this method is presented. An experimental scheme to detect the effectiveness of the delay mask in triggering a resonant wake excitation, based on a density scan of the gas-jet target, was modelled and it will be discussed in detail.

Poster Session / 131

Traveling-wave electron accelerators – leveraging exascale computing towards scalable laser-plasma accelerators

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Traveling-wave electron acceleration (TWEAC) is an advanced laser-plasma accelerator scheme, which is neither limited by dephasing, nor by pump depletion or diffraction. Such accelerators are scalable to energies beyond 10 GeV without the need for staging and are candidates for future compact electron-positron colliders based on existing CPA lasers.
Requiring to model a large plasma volume in 3D at high-resolution over an extended acceleration distance for high-fidelity results, TWEAC simulations need exascale compute resources – even "small" test simulations need hundreds of GPUs.
We present recent progress in TWEAC simulations and various technical advances in the 3D3V particle-in-cell code PIConGPU that enable running on the upcoming Frontier cluster (#1 in TOP500), most notably support of the HIP computational backend allowing to run on AMD GPUs, as well as openPMD, PICMI and algorithmic developments. These advances are mainly driven by our participation in OLCF's Frontier Center for Accelerated Application Readiness providing access to the hardware platform of the Frontier exascale supercomputer. We show performance data and present recent applications of PIConGPU profiting from these developments.

Poster Session / 132

3D-Printed THz Radiator for Pump-probe Experiments

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THz radiation with sufficient intensity finds various applications, including pump-probe experiments in free-electron lasers, wireless communication, material analysis, process control in biology, pharmacy, and medicine. The most common process for generating THz radiation is by optical rectification, in which laser pulses incident to a nonlinear crystal produce broadband THz pulses. A compact and cost-efficient alternative approach uses free electrons passed along a periodic structure, which emits synchronous radiation via the Smith-Purcell effect. In this work, we designed and 3D-print a periodic conical shape structure out of PMMA (n=1.628) to generate and guide the THz radiation. According to our simulation, the THz radiation improves by increasing the refractive index; therefore, we are exploring the use of mixture of quartz or Zirconia with PMMA resin to print the structure.

Poster Session / 133

Time-resolved studies of beam-loading variations at FLASHForward.

Authors: Carl A. Lindstrøm[1]; Felipe Peña[2]; Gregor Loisch[3]; Jens Osterhoff[3]; Jimmy M. Garland[3]; Jonas Björklund-Svensson[3]; Jonathan Wood[3]; Judita Beinortaite[4]; Lewis Boulton[5]; Pau Gonzalez Caminal[6]; Richard D'Arcy[3]; Sarah Schröder[3]; Stephan Wesch[3]

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The FLASHForward experimental facility is a test-bed for beam-driven plasma-wakefield (PWFA) research and development, with a view towards both photon-science (e.g. FELs) and high-energy-physics applications (e.g. linear colliders). The facility benefits from the FEL-quality electron bunches provided by the FLASH linac to drive a wakefield in a plasma produced inside a windowless gas cell with lengths of order cm. One of the most recent achievements of the FLASHForward facility has been to demonstrate energy-spread preservation and high energy-transfer efficiency by strongly beam loading the wakefield with tailored-current-profile bunched beams. On the grounds of this success and with the powerful diagnostic capabilities of a novel transverse deflection structure, the dependence of the beam-loading quality on critical machine parameters is further investigated. The results show that the plasma-acceleration process is extremely sensitive to the stability of the bunch compression scheme at the linac, which directly affects the amount of beam-loading through the modification of the current profile of the generated driver-trailing bunch pairs.

Special Topic / 134

Self-matching in a quasilinear wakefield

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Particle acceleration in a quasilinear plasma wake provides access to high acceleration gradients while avoiding self-trapping of the background electrons. However, this regime is highly nonlinear, with the focussing field acting on an externally injected witness bunch strongly dependent on the plasma response to the witness itself. Here we discuss matching of the witness bunch to the plasma, and show how the unique physics of the quasilinear wake gives rise to broad tolerances for the witness bunch radius at the injection point.

Special Topic / 135

Enhancing the proton cutoff energy in Target Normal Sheath Acceleration via an improved laser-to-electron coupling in long-scale plasma gradients

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Proton bunches produced via Target Normal Sheath Acceleration have unique features (ultra-short duration, high-flux and low emittance at the source), which could enable a plethora of new applications. However, the beam maximum energy and quality are still open challenges.
Recent experimental results obtained at the Intense Laser Irradiation Laboratory (INO-CNR, Italy) demonstrated a reliable path toward increasing the proton cutoff energy via pre-expanding in a controllable way the front surface of not-so-thin foils (Gizzi et al. 2021 Sci. Rep. 11, 13728). In this talk, I will present results from two and three-dimensional Particle-In-Cell simulations performed under the same experimental conditions and discuss the physics underpinning this energy enhancement. Simulations indicate that in the presence of a long-scale pre-plasma, a standing wave is generated in the under-dense pre-plasma. Electron motion in the standing wave becomes stochastic, enabling a more efficient laser energy absorption. As a result, electrons get heated to higher temperatures, and protons from the back surface of the target are accelerated to energies up to three times higher than the cases with no pre-plasma. The long-scale pre-plasma seems to further positively affect the quality of the proton bunch by also reducing the overall divergence of the beam.

Special Topic / 136

Laser-plasma acceleration for tomography and radiotherapy

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Laser technology is evolving fast and high-power lasers needed for plasma acceleration are already available as commercial products, offered by several companies, and in compact setups suitable for space-limited environments in industrial or hospital settings. It is time to identify key areas where compact laser-plasma accelerators can have a scientific and/or societal impact. Here, two application-oriented activities pursued at Lund University will be presented.
Dose deposition and beam manipulation towards fractionated stereotactic high-energy radiotherapy is explored using magnetically focused, laser-accelerated electrons with energies up to 160 MeV. Such high-energy electrons can potentially produce a more favourable radiotherapy dose distribution compared to a state-of-the-art photon based radiotherapy technique.
X-rays from a laser-plasma accelerator is used to reveal the 3D structure of a highly atomising fuel injection spray. The technique allows for simultaneous optical fluorescence measurements, providing

complementary information on the spray break-up. The results are very promising for the analysis of a variety of challenging transient spray systems, e.g., the injection of liquid synthetic and biofuels used for future clean-combustion applications.

Special Topic / 137

OPCPA as an amplifier technology for high repetition rate 100 TW-class lasers

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In this talk we present on the role of optical parametric chirped pulse amplification (OPCPA) in high energy laser systems at ELI-Beamlines. OPCPA is an integral part of 3 of the 4 lasers at the ELI-Beamlines laser facility and will be used as the chief amplification technology in the L2-DUHA laser which is currently under development and intended to serve as a driver for laser wakefield acceleration. We discuss the performance and parameters of the L1-Allegra picosecond OPCPA laser (operating at 1 kHz), the Joule-level, 5 Hz front end OPCPA-based front end for the L4-Aton laser, and how these amplification schemes are combined in the L2-DUHA, 50 Hz, 100 TWA OPCPA system.

Special Topic / 138

PALLAS, a laser-plasma injector test facility, development status

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The prototyping accelerator based on laser-plasma technology (PALLAS) project is aiming to build a laser-plasma injector accelerator (LPI) test facility with the aim to deliver within a few years electron beams of 150-250 MeV, < 5% energy dispersion, >30 pC, <1 mm.mrad emittance beam at 10 Hz with control and stability comparable with RF accelerator. The project approach is based on three axis: advanced laser control, plasma target development and compact electron beam transport and

characterization. After a quick overview of the installation progress, updates in laser control will be given. Recent results on plasma gas cell type targets development and testing for localized ionization injection and laser-plasma injector modelling will be reported. The recent progress in the electron beam characterization line will be discussed.

Special Topic / 139

an update on advanced plasma accelerator activities in China

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In this talk, an update on advanced plasma accelerator technology development in China will be presented. First, recent relevant research activities in the major laser labs in china (THU, PKU, SJTU, SIOM, LFRC) will be reviewed. Then two major initiatives on plasma wakefield accelerator involving two major accelerator labs in China (IHEP and Shanghai Light source) will be introduced. In the end, recent results from a long term (more than 7 years) laser development program in China on industry level compact TW-PW lasers will be presented, and a funded new major laser plasma accelerator facility in Henan Province based on this laser development will also be introduced.

Special Topic / 140

Particle Physics Applications for Proton-Driven PWA

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Proton-driven PWA is particularly well-suited for producing bunches of high-energy electrons. A number of particle physics applications for these types of beams will be presented. These include beam-dump, fixed target, and collider applications covering a wide range of fundamental physics research.

Special Topic / 141

Effects of plasma ramp measured in AWAKE

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We study the propagation of an electron bunch travelling within a proton bunch through a plasma density ramp. Because the proton bunch density in the ramp is higher than the plasma density, the bunch generates a high density, on-axis plasma electron filament. This filament is defocusing for the electron witness bunch that can therefore be lost along the ramp. At AWAKE we have measured this effect by changing the relative timing of the electron bunch with respect to the proton bunch. When the electron bunch propagates in front of the proton bunch (i.e. seeding the self-modulation), the electrons travel until the electron spectrometer, downstream of the plasma column. A position of the electrons within the proton bunch, where seeding stops, exists. Beyond this position electrons are lost and do not reach the spectrometer. We will present latest experimental data obtained during Run 2.

Special Topic / **142**

An Introduction to the Center for Bright Beams and its Research

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The Center for Bright Beams (CBB) is a U. S. National Science Foundation Science and Technology Center with more than 10 participating institutions and includes participating universities and affiliated U.S. national laboratories. I'll give an introduction to the research scope of the center, which spans beam production via photocathodes, beam acceleration with superconducting radiofrequency cavities, and beam dynamics and control, where the latter spans multiple accelerator archetypes. I'll then have a brief discussion of how CBB's research fits into the global accelerator research community.

Special Topic / **143**

Status of the EuPRAXIA@SPARC_LAB project

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The EuPRAXIA@SSPARC_LAB facility is the beam driven pillar of the EuPRAXIA project which is expected to provide by the end of 2028 the first European Research Infrastructure dedicated to demonstrating usability of plasma accelerators delivering high brightness beams up to 1-5 GeV for users.
Among the possible EuPRAXIA@SPRC_LAB applications the realization of a short wavelength Free Electron Laser (FEL) able to provide radiation in the "water window" of the e.m. spectrum for biophysical investigations is one of its main goals. Another interesting X-ray radiation source based on betatron radiation will be implemented by the end of 2025. In addition the production of high-quality electron beam as the one required to drive an FEL is expected to be also a fundamental milestone towards the realization of a plasma driven future Linear Collider (LC).
In this talk we report about the recent progress in the context of the EuPRAXIA collaboration with reference to the recent breakthrough results obtained at the EuPRAXIA@SPARC_LAB test facility SPARC_LAB at INFN-LNF and the new perspectives offered by the Italian Next Generation Eu program (PNRR).

Special Topic / 144

Overview of betatron radiation sources and applications

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The x-rays produced by laser wakefield accelerators have a unique combination of properties: they have an ultrafast duration, smooth broadband spectrum and emanate from a micrometre sized source. They are also readily co-located and synchronised with laser driven experiments. These properties make them well suited to a range of applications including high energy density physics.

This talk will provide an overview of x-ray generation by laser wakefield accelerators, including how the x-ray energy and brightness vary with the drive laser properties. I will also discuss progress in experiments which use betatron radiation for applications including tomographic imaging, imaging dynamic objects and x-ray absorption spectroscopy.

Poster Session / 145

Ion acceleration by laser-matter interaction: status and perspective with the upcoming I-LUCE facility at INFN-LNS

Authors: Giuseppe Cirrone[1]; Giada Petringa[2]; Roberto Catalano[1]; Giacomo Cuttone[1]; Salvatore Tudisco[1]

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In the framework of both EuAPS and SAMOTRACE projects funded by the PNRR Italian program, a new high-power laser facility called "I-LUCE" (INFN Laser indUced radiation acCEleration) will be realized at LNS-INFN. Thanks to the use of the latest available technology, the system will be able to amplify light with a power of 500 TW, with a fs duration, and with a repetition rate of 1Hz. This will open the possibility to initiate and study new physics regimes for the production of high-intensity, high-energy radiation with exceptional spatio-temporal characteristics. With such a system INFN-LNS will bring together its scientific, engineering and medical missions for the benefit of industry and society alike. First of all, the system will open new possibilities in particle physics, nuclear physics, high energy beam science, nonlinear field theory, and ultrahigh-pressure physics.Besides its fundamental physics mission, a paramount objective of the new system will be to provide ultra-short energetic particles (10 to 100 GeV) and radiation (up to a few MeV) beams produced with compact laser plasma accelerators. In this work the status and perspectives of the I-LUCE facility will be presented.

Special Topic / 146

Latest developments of high repetition rate TiSa lasers for laser plasma accelerators

Authors: Christophe SIMON-BOISSON[1]; Sandrine RICAUD[2]; Alain PELLEGRINA[2]; Antoine JEANDET[2]; Hervé BESAUCELE[2]; Loïc LAVENU[2]; Olivier CHALUS[2]

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Laser plasma accelerators have been the subject of intensive research over the past decades since the availability of ultra high intensity lasers based on chirped pulse amplification technique. Record electron energy close to 10 GeV have been demonstrated and implementation of several controls on LPA systems combined with the use of the latest machine learning techniques have allowed very stable operation of LPA over long term runs. However the requirements for next generation high performance LPA such as EuPRAXIA as well as the need of high particle flux for medical applications such as VHEE (Very High Energy Electrons) for cancer therapy will lead to the use of higher repetition rates and higher average power lasers. In this paper we report the development of a new generation of lasers operating at a repetition rate of 100 Hz using Titanium Sapphire as active material for the main amplification stages. We report about an amplification stage delivering above 300 mJ per pulse at 100 Hz with room temperature operation thanks to optimized geometry and thermal management of the TiSa crystal. We present also the technology roadmap towards a future 1 Joule laser system working at 100 Hz and higher laser average power

Special Topic / 147

Dielectric laser accelerators for relativistic energies

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The energy gain that has been achieved experimentally in dielectric laser accelerators has been limited to below 1 MeV to date. Limitations arise from the available laser pulse energy and from keeping the particles aligned in the microscopic accelerating channels. A significant progress in the focusing of the particles, and thus in the containment in the accelerating channel, has recently been achieved by the alternating phase focusing (APF) scheme. Here, drift sections between structure cells lead to jumps in the synchronous phase, which can be designed to provide a net focusing of the beam. In the present work, we model the energy reach of dielectric laser accelerators to relativistic energies, investigating the effect of structure design on beam dynamics and particle loss during acceleration.

Special Topic / 148

US Advanced Accelerator Facilities

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Advanced Accelerator Facilities in the US cover a broad range of topics and applications. Prominent facilities include FACET-II at SLAC, BELLA at LBNL, AWA at Argonne, ATF at Brookhaven, and the Texas Petawatt Laser. Combined, these facilities generate enormous scientific output. We review major results from the past decade and expected outcomes in the near future. We also consider steps toward next-generation facilities that will support staging and high repetition rate operation.

Special Topic / 149

Operational Aspects of Beam-Driven Facilities

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Beam-driven plasma wakefield acceleration experiments require state-of-the-art facilities in order to operate. In this talk, we review challenges associated with operating these facilities, including: beam quality and stability, machine-experiment interface, controls challenges, diagnostic challenges, and communication and scheduling issues. We hope that by clarifying these issues, we can develop better tools, methods, and processes that enable efficient experimental operation.

Special Topic / 150

EuPRAXIA

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EuPRAXIA (European Plasma Research Accelerator with eXcellence In Applications) is an ESFRI project for a compact European infrastructure with 5 GeV electron beams based on plasma accelerators. It will soon enter its Preparatory Phase, recently approved and funded by the European Union. The EuPRAXIA project is supported by a large consortium and foresees two main construction sites. One site is focused on beam-driven plasma acceleration (PWFA) at the Laboratori Nazionali di Frascati (INFN-LNF) in Italy. This site had already received construction funding from the Italian government. The second site will be based on laser-driven plasma acceleration (LWFA) with candidate sites in Czech Republic, United Kingdom and Italy. Centres of excellence planned for Portugal, France, the United Kingdom, Germany, Hungary and the Czech Republic, will support both construction sites. Major technical building blocks of EuPRAXIA include advanced photo injectors, X band RF technology, high power lasers, plasma accelerators, high resolution instrumentation and application beamlines. The EuPRAXIA concept will be presented and target parameters introduced. The foreseen EuPRAXIA user applications and their specific advantages will be shortly discussed. Finally, the next steps and the path to full implementation will be described.

Special Topic / 151

Coherent combination of fiber lasers towards drivers for future wakefield accelerators

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The talk will summarize the current status of high peak power ytterbium- and thulium based fiber lasers (i.e. at 1µm and 2µm wavelength) based on coherent combination. In addition the nonlinear pulse compression to few-cycle pulses at mJ pulse energy level and high repetition rate (100kHz) as well as paths for temporal contrast enhancement will be presented. The discussion of the scaling potential towards Joule pulse energies will conclude the presentation.

Special Topic / 152

Introduction

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Free-electrons manipulation with light in an RF-cavity-based Ultrafast Transmission Electron Microscope

Authors: Simona Borrelli[1]; S. T. Kempers[1]; E. Kieft[2]; P.H.A. Mutsaers[1]; K.A.H. van Leeuwen[1]; O.J. Luiten[1]

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Developing new methods for tailoring the phase-space distribution of electron beams is a challenging and essential task in next-generation particle accelerators, compact x-rays sources, and ultrafast electron microscopy. RF-cavities are routinely employed in accelerator science to manipulate the electrons' phase-space. This contribution shows the use of a miniaturized RF-cavity to chop the continuous beam of a conventional transmission electron microscope into ultrashort pulses. We developed an RF-cavity-based ultrafast transmission electron microscope (UTEM) generating few-100-fs pulses with GHz-MHz repetition rate, which preserves the low emittance and energy spread of the TEM Schottky field emission gun.
Beyond time-resolved investigation of specimens, UTEMs entitle novel free-electron quantum optics. We devise techniques to control and shape the electron wavefunction amplitude and phase for coherent detection methods and distinct phase-contrast imaging. A laser oscillator is integrated into the RF-cavity-based UTEM setup, thus allowing the observation of the synchronized interaction between free-electrons and fs-laser pulses.
We propose to exploit this interaction to coherently shape the electron wavefunction in photon-induced near-field electron microscopy and light-based Zernike phase plate imaging. We present experimental results and a theoretical model of the ponderomotive interaction between free-electrons and laser pulses, which opens the path to the phase-manipulation of high-relativistic electron beams.

Poster Session / 161

Phase shaping of the free-electrons wavefunction with fs-laser pulses in an RF-cavity-based UTEM

Authors: Simona Borrelli[1]; S.T. Kempers[1]; W. Schaap[1]; P.H.A. Mutsaers[1]; E. Kieft[2]; B. Buijsse[2]; O.J. Luiten[1]; K.A.H. van Leeuwen[1]

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Interest is growing around developing techniques to shape the wavefunction of electrons.
We propose to use the time-dependent electromagnetic fields of ultrashort laser pulses to control the quantum-mechanical phase of electron pulses. We present a theoretical model showing that the ponderomotive interaction between electrons and a high-intensity strongly-focused laser beam can be used to develop a non-material phase-shaper. This contribution also a model of the interaction, in which we derive a quantal phase from the classical action integral along the relativistic classical path. Results extend to realistic configurations of the electromagnetic fields. Our model proves that

a phase-shift of π/2 can be achieved by focusing the laser pulses produced by a fs-oscillator to a waist size of 2⊠. Any phase shift can be induced by suitably varying the laser power and spot size.
An application of the method is the development of light-based phase-plates for phase contrast imaging of weakly scattering specimens. A light-based phase-plate ensures a stable, tunable phase shift, helping overcome material device limitations.
We provide details on the experimental realization of the device in an RF-cavity-based ultrafast transmission electron microscope that has a 75 MHz fs-oscillator integrated into its setup.

Special Topic / 162

Plasma-wakefield acceleration at high repetition rates

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The GV/m accelerating gradients inherent to plasma accelerators may hold the key to unlocking cost-effective accelerators, facilitating the acceleration of particle bunches to higher energies over shorter distances. However, in order to reach the luminosity and brilliance demands of high-energy physicists and photon scientists, plasma accelerators of the future must be capable of accelerating thousands of high-intensity bunches per second—many orders of magnitude more than the current state of the art. The first step towards answering whether or not plasma accelerators can meet this lofty goal was recently made by ascertaining that the minimum possible separation between two consecutive acceleration events is defined by the fundamental physics of long-term plasma evolution. The many-nanosecond-level recovery time measured at FLASHForward establishes the in-principle attainability of megahertz rates of acceleration in plasma. In order to reach this upper limit with a practical accelerator, however, further scientific results as well as robust developments in plasma-source technology will be required. This presentation will report on the most recent results in the field with an outlook towards reaching a practical solution in the future.

Special Topic / 163

Accelerator on a chip program overview

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Acceleration of particles in photonic nanostructures fabricated using semiconductor manufacturing techniques and driven by ultrafast solid state lasers is a new and promising approach to developing future generations of compact particle accelerators. Substantial progress has been made in this area in recent years, fueled by a growing international collaboration of universities, national laboratories, and companies. We'll review the major results as well as the outlook for the near term and long term future of this high gradient acceleration scheme.

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Phase space control and net energy gain in photonic chip based accelerators

Author: Stefanie Kraus[1]

Co-authors: Roy Shiloh [2]; Tomas Chlouba [3]; Johannes Illmer [4]; Leon Brueckner [3]; Julian Litzel [3]; Peter Hommelhoff [5]

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Particle accelerators have a wide variety of applications in science, industry and medicine. Shrinking these devices to chip-based solutions would, as well as reducing costs, allow new tools such as a miniature endoscopic electron irradiation device. The individual components needed to create particle accelerators on a chip had all been established, but a beam confinement system that could handle nano- and micrometer-sized objects was still necessary. Due to transverse forces acting on the electrons traversing the structure, significant particle losses and dephasing limits the current throughput. We used the alternating phase focusing (APF) [1,2] adopted from accelerator physics to directly control the transverse phase space of the electron beam and confine the beam in a submicrometer wide channel. In this talk we will show the results of a low-loss electron transport over a 77.7 micrometer long nanostructure and the current state of the experiment to build a particle accelerator with significant energy gain on a mm sized chip.

[1] Niedermayer, U., Egenolf, T., Boine-Frankenheim, O., Hommelhoff, P., Phys. Rev. Lett. 121, 214801 (2018).

[2] Shiloh, R., Illmer, J., Chlouba, T., Yousefi, P., Schönenberger, N., Niedermayer, U., Mittelbach, A., Hommelhoff, P., Nature 597, 498–502 (2021).