

FOREWORD

A new issue of The EuPRAXIA Files is presented here, bringing together a selection of recent publications relevant for the implementation of EuPRAXIA technologies.

The EuPRAXIA Consortium for the Preparatory Phase is reaching the end of its journey. On October 31, the EU Grant is coming to an end.

This date is not the completion of EuPRAXIA journey, as there is a long trip toward the implementation of the EuPRAXIA Research Infrastructure, with two sites (at INFN-Frascati and at ELI-ERIC beamlines).

To this purpose, a new Grant will start soon (EuPRAXIA Early Implementation Phase).

As usual, this issue of EuPRAXIA Files highlights recent work from plasma-accelerator physics and beam transport to compact FELs, plasma sources, diagnostics, optimisation, and emerging applications.

We all thank Antônio and Debdeep for preparing this issue, and I wish you an interesting reading.

Pierluigi Campana

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FUNDAMENTALS

Experimental demonstration of dephasing reduction in an optically guided laser-plasma accelerator

R. Lahaye, I. A. Andriyash, J. Gautier, O. Kononenko, A. Leblanc, J.-P. Goddet, A. Tafzi, and C. Thaury

PHYSICAL REVIEW RESEARCH 8, 023274 (JUNE 10 2026)

<https://doi.org/10.1103/pc2y-hxj9>

Dephasing between accelerated electrons and the plasma wave is one of the fundamental limitations on the energy gain achievable in laser-plasma accelerators. Here, the authors experimentally investigate a combination of plasma density tapering and optical guiding to extend the effective acceleration length. Using

a joule-class femtosecond laser coupled into an optically guided plasma wave with a controlled density gradient, electron beam energies exceeding 1.6 GeV are achieved, representing a 40% increase compared with the constant-density configuration. Particle-in-cell simulations reproduce the main experimental observations and identify the roles of delayed injection, nonlinear laser evolution, and self-focusing in the enhanced energy gain.

Dephasingless laser wakefield acceleration of electrons using a flying focus

C. D. Arrowsmith et al.

NATURE PHYSICS (JULY 10 2026)

<https://doi.org/10.1038/s41567-026-03352-x>

The energy gain in laser wakefield acceleration is fundamentally constrained by dephasing, as accelerated electrons eventually outrun the plasma wave driven by the laser pulse. This work demonstrates experimentally that a flying-focus laser pulse can mitigate this limitation by controlling the position of the laser focus and driving a wakefield that propagates at the speed of light. The experiment accelerates electrons to energies beyond the conventional dephasing limit, providing a demonstration of spatiotemporal control of the wakefield and a possible route towards higher-energy laser-driven electron beams.

Unveiling the beam-wake interactions in plasma wakefield acceleration

Y. Wan et al.

NATURE COMMUNICATIONS (SEPTEMBER 16 2026)

<https://doi.org/10.1038/s41467-026-77754-z>

Understanding the interaction between a driving particle bunch and the plasma wake is essential for controlling beam-driven plasma accelerators. In this work, femtosecond ultrarelativistic electron microscopy is used to characterize both the wakefield and the driving electron bunch in situ from single-shot measurements. By varying the driver charge, the authors observe the transition from linear to nonlinear wakefield regimes and investigate how the structure of the wake evolves with the properties of the driving bunch. The results provide detailed experimental insight into beam-wake interactions and the mechanisms governing plasma wakefield acceleration.

Resonant Excitation of Surface Plasmon for Wakefield Acceleration by Beating GW Lasers on Smooth Cylindrical Surface

B. Lei, H. Zhang, A. Bonatto, B. Liu, J. Resta-López, M. Zepf, G. Xia, and C. Welsch

PHYSICAL REVIEW LETTERS 137, 105002 (SEPTEMBER 4 2026)

<https://doi.org/10.1103/2dkn-db5z>

This work proposes a wakefield acceleration scheme based on the resonant excitation of surface plasmons at a smooth cylindrical plasma-vacuum interface. Two co-propagating laser pulses are used to excite surface modes whose dispersion is modified by the curvature of the plasma boundary. Three-dimensional particle-in-cell simulations demonstrate that the resulting fields can reach tens to hundreds of GV/m and can support electron trapping and acceleration. The proposed approach provides a grating-free mechanism for phase matching and explores a new class of structured plasma surfaces for compact particle acceleration.

CONTROL & OPTIMIZATION

Longitudinally resolved measurement of energy-transfer efficiency in a plasma-wakefield accelerator

L. Boulton et al.

PHYSICAL REVIEW RESEARCH 8, 023231 (JUNE 1 2026)

<https://doi.org/10.1103/b8hj-shvc>

Efficient energy transfer from a plasma wake to an accelerated electron bunch is essential for the development of high-efficiency plasma accelerators. Conventional measurements based on downstream electron spectroscopy provide an efficiency averaged over the accelerator length and require an invasive diagnostic. This work demonstrates a noninvasive method based on the excess plasma light generated following the beam-plasma interaction. The technique provides longitudinally resolved measurements of the local energy-transfer efficiency and could enable real-time monitoring and optimization of multistage plasma wakefield accelerators.

Plasma dechirper and lens for electron beams from laser wakefield acceleration in a tailored density profile

T. L. Steyn et al.

PHYSICAL REVIEW ACCELERATORS AND BEAMS 29, L080501 (AUGUST 31 2026)

<https://doi.org/10.1103/fdkn-8hpg>

Electron beams produced by laser wakefield acceleration can exhibit significant energy chirp and divergence, limiting their suitability for applications such as free-electron lasers. This work experimentally demonstrates the simultaneous use of plasma dechirping and plasma lensing in a tailored plasma density profile. A density down-ramp followed by a low-density plasma region modifies the longitudinal and transverse properties of the accelerated electron beam, reducing its energy spread while providing strong focusing. The results demonstrate how tailored plasma profiles can combine multiple beam-manipulation functions within a compact plasma-based stage.

Slice emittance preservation and focus control in a passive plasma lens

J. Björklund Svensson et al.

PHYSICAL REVIEW RESEARCH 8, 033242 (AUGUST 27 2026)

<https://doi.org/10.1103/jjxz-3fr4>

Plasma lenses provide extremely strong focusing fields and are therefore promising for the compact transport and matching of high-energy electron beams. This work experimentally investigates the preservation of the transverse slice emittance of an electron beam focused by a passive plasma lens. The results demonstrate that the lens can preserve the beam quality required for free-electron-laser applications while providing focusing strengths approximately two orders of magnitude larger than those achievable with conventional quadrupoles. The focal properties of the plasma lens can also be controlled through the plasma and beam parameters, highlighting its potential for advanced accelerator beamlines.

TECHNOLOGY

Ultra-compact plasma photocathode in a hybrid wakefield accelerator

P. Ufer et al.

COMMUNICATIONS PHYSICS 9, 273 (AUGUST 17 2026)

<https://doi.org/10.1038/s42005-026-02814-1>

Plasma photocathodes offer a route to generating high-quality electron beams directly within a plasma accelerator. This work demonstrates a plasma photocathode in a millimetre-scale hybrid wakefield accelerator driven by a 150 TW laser system. The high plasma density enables micrometre-scale source dimensions and rapid acceleration over very short distances, providing favourable conditions for producing high-brightness electron beams. The demonstration opens a path towards compact plasma-based electron sources capable of meeting the beam-quality requirements of advanced applications such as free-electron lasers.

Laser wakefield acceleration in a capillary gas cell to produce high-quality GeV-scale electron beams

S. Maity, F. Massimo, A. Whitehead, P. Sasorov, and A. Molodozhentsev

PHYSICAL REVIEW ACCELERATORS AND BEAMS 29, 093601 (SEPTEMBER 9 2026)

<https://doi.org/10.1103/l8b2-j67x>

This work presents a computational study of laser wakefield acceleration in a capillary gas-cell configuration designed to produce high-quality GeV-scale electron beams. Hydrodynamic simulations are used to model the gas target and provide plasma density profiles for subsequent particle-in-cell simulations. The proposed configuration combines a short helium-nitrogen injection region with a longer pure-helium acceleration section, enabling control of injection and beam evolution. The simulations predict electron beams with mean energies above 1 GeV and properties relevant to upcoming laser wakefield acceleration experiments at ELI Beamlines within the EuPRAXIA framework.

BEAMLINES & APPLICATIONS

Ultrafast electron diffraction with MeV electron source from a laser wakefield accelerator

Y. Fang et al.

NATURE PHOTONICS 20, 1056–1061 (AUGUST 19 2026)

<https://doi.org/10.1038/s41566-026-01980-6>

Laser wakefield accelerators can provide ultrashort electron bunches for time-resolved electron diffraction, potentially enabling compact ultrafast probes of matter. This work demonstrates an MeV ultrafast electron diffraction system driven by a laser wakefield accelerator and coupled to a miniaturized permanent-magnet beamline. An isochronous double-bend achromat and energy-selection system are used to control the electron beam properties, producing electron bunches with femtosecond-scale duration and timing stability.

The system is demonstrated through diffraction measurements of single-crystal gold, establishing a compact platform for ultrafast electron-scattering experiments.

High-Flux X-Ray Emission due to Injection into a Laser-Wakefield Accelerator beyond Its Depletion Length

J. C. Wood et al.

PHYSICAL REVIEW LETTERS 137, 105001 (SEPTEMBER 3 2026)

<https://doi.org/10.1103/krsl-322s>

Betatron radiation from laser wakefield accelerators provides a compact source of high-energy X-rays, with the emitted flux strongly dependent on the electron trajectories inside the plasma wake. This work investigates X-ray emission from a laser wakefield accelerator operated beyond the depletion length of the driving laser pulse. Using a variable-length gas target, the authors observe the generation of a second, high-charge electron bunch after the nominal depletion point. This bunch dominates the resulting X-ray emission, producing more than 5×10^{10} photons per shot with critical photon energies in the 12–17 keV range. The results demonstrate how controlled injection beyond the depletion length can substantially enhance compact X-ray sources.

THEORY & SIMULATION

Combined tools for particle-in-cell simulations performed with transversely asymmetric chirped lasers

I. Moulanier, F. Massimo, T. L. Steyn, and B. Cros

PHYSICS OF PLASMAS 33, 073105 (JULY 20 2026)

<https://doi.org/10.1063/5.0333754>

Accurate modelling of realistic laser fields is important for particle-in-cell simulations of laser wakefield acceleration, particularly when experimental laser profiles include transverse asymmetries and temporal spectral chirp. This work introduces the Asymmetric Chirped Electric field reconstruction (ACE) toolbox, a suite of algorithms for reconstructing realistic laser transverse distributions together with their chirped temporal profiles and implementing them in cylindrical and Cartesian particle-in-cell simulations. The approach is demonstrated for a laser wakefield acceleration experiment in which spectral chirping is used to optimize the properties of the accelerated electron bunch. The toolbox provides a practical framework for incorporating experimentally measured laser characteristics into high-fidelity plasma accelerator simulations.

Laser wakefield acceleration in nanostructured plasmas

A. Bonatto et al.

EUROPEAN PHYSICAL JOURNAL PLUS 141, 1043 (SEPTEMBER 11 2026)

<https://doi.org/10.1140/epjp/s13360-026-08213-3>

Nanostructured solids provide an alternative regime for plasma-based acceleration in which extremely high plasma densities and microscopic acceleration lengths can be exploited. This work investigates laser wakefield acceleration in plasmas formed from carbon-nanotube arrays using three-dimensional particle-in-cell simulations. The simulations predict wakefields reaching the teravolt-per-metre scale, together with

electron self-injection and the generation of ultrashort electron bunches over micron-scale distances. The results explore the potential of nanostructured solid-state plasmas as a route towards highly compact plasma accelerators operating at energy scales relevant to advanced photon and particle sources.

Self-adaptive catch-up injection of positrons in plasma wakefield acceleration

L. Q. Han et al.

PHYSICAL REVIEW ACCELERATORS AND BEAMS 29, L070501 (JULY 17 2026)

<https://doi.org/10.1103/n95z-ty9l>

Efficient positron acceleration remains a major challenge for plasma-based accelerator concepts, particularly because the transverse focusing properties of plasma wakes differ significantly for positrons and electrons. This work proposes a self-adaptive catch-up injection scheme in which a positron source is positioned ahead of a hollow, positively charged driver. As the wake generated by the driver propagates, it catches up with the positron source and captures positrons into accelerating phases of the wake. Three-dimensional quasi-static particle-in-cell simulations demonstrate the acceleration of approximately 12 pC of positrons to energies above 14 GeV using a 10 GeV hollow positron driver, with accelerating fields reaching approximately 16 GV/m. The scheme provides a possible approach to controlled positron injection in beam-driven plasma accelerators.

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