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Reduction of the electron beam divergence of laser wakefield-accelerators by integrated plasma lenses

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We report on electron-beam collimation using a passive plasma lens[1], integrated directly into a laser wakefield-accelerator stage operating in the high-charge regime. The lens is created by the reshaping of the gas-density profile of a supersonic jet at the beam's exit side. It reduces the beam's divergence by a factor of 2 to below 1 mrad (rms), while preserving the total charge of 170 pC and maintaining the energy spread. Ultrafast probing of plasma dynamics and Particle-in-Cell (PIC) simulations reveal that the effect is induced by the focusing field of the generated beam-driven wakefield as the remnant laser intensity drops significantly. The resulting spectral-charge density, defined here as the charge per energy bandwidth and emission angle, of up to 7pC/MeV mrad played a key role in the recent experimental demonstration of free-electron lasing[2]. The simple and robust gas-shaping technique presented holds the potential to generate specific density profiles, which are essential for the application of adiabatic focusing or staging of accelerators.

[1] Y.-Y. Chang, et al. "Reduction of the electron beam divergence of laser wakefield-accelerators by integrated plasma lenses", Physical Review Applied 20, L061001(2023)

[2] M. Labat, J.P. Couperus Cabadağ, A. Ghaith, A. Irman, et al. "Seeded free-electron laser drive by a compact laser plasma accelerator" Nature Photonics 17, 150(2023)

Working group

WG1 : Laser-driven plasma wakefield acceleration

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