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Femtosecond laser-induced plasma filaments for beam-driven plasma wakefield acceleration

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Plasma-based acceleration technology can revolutionize particle accelerators, enabling the realization of compact systems capable of driving different user-oriented applications.
We propose developing a laser-based, high repetition rate (HRR), highly stable and tunable plasma filament stage for beam-driven plasma wakefield acceleration (PWFA) systems. The plasma filament, generated by a low-energy self-guided femtosecond laser pulse, is studied experimentally and theoretically in a low-pressure N2 gas environment.
Precise control of the plasma filament is crucial for plasma-based accelerators, and different techniques have been implemented to measure its density, temperature and dimensions. The measurements show the stable generation of a ≈4cm long channel with a ≈300μm diameter. The plasma density and temperature are ne≈1016cm−3 and Te≈1.3eV with a decay time of ≈8ns.
Compared to other plasma stages in PWFA configurations, the proposed one allows for inherently synchronized stages at HRR. The hundreds-μm transverse structure size extends the stage lifetime, and the highly tunable parameters allow us to explore different scenarios. This technology can provide GeV-level electrons at HRR in a compact space, maintaining the high quality and brilliance of the LINAC-generated beams. This development aligns perfectly within the goals of the EuPRAXIA European project.

Footnotes

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Europe

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