Controlled Generation of Collimated Quasi-Monoenergetic Electron Beams

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The development of compact, high-quality electron sources based on laser wakefield acceleration necessitates advanced techniques for precise control over beam parameters. This study presents two approaches for such control implemented on a terawatt laser system. The first approach involves spatio-temporal engineering of the plasma target. Utilising shock waves generated by auxiliary nanosecond pulses in a gas jet, we demonstrate dynamic manipulation of the plasma density profile. This technique enables the production of tunable, quasi-monoenergetic electron beams in the 6–12 MeV range with a narrow energy spread of approximately 2.5 MeV and a divergence below 1.5°.

The second methodology is based on direct wavefront control of the driving laser pulse. We experimentally establish that introducing controlled aberrations, such as astigmatism via a tilted parabolic mirror, significantly alters the laser-plasma interaction dynamics. This manipulation facilitates a transition into the pump depletion regime, resulting in the generation of quasi-monoenergetic beams with higher maximum energies, reaching up to 20 MeV. This dual strategy, encompassing both target structuring and laser pulse shaping, provides a technique for controlling electron acceleration to meet specific application requirements.