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Controlled Injection in a Laser Plasma Accelerator via an Optically Generated Waveguide Constriction

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Following recent advances that have pushed LPA energy gains to the 10 GeV level, attention is beginning to shift toward enhancing beam quality, tunability, and reliability in this regime. In this context, we propose a novel scheme for controlling the injection of a high-quality electron bunch into a channel-guided laser-plasma accelerator. This all-optical technique, *constricted waveguide injection*, creates a highly tunable, controlled injection structure natively within a plasma waveguide, a key requirement for the efficient acceleration of high-quality multi-GeV electron beams. We describe a simple optical setup to tailor the plasma and present start-to-end simulations showing the injection structure formation and the generation of a 1.1 GeV electron beam with 10 pC of charge and 0.35% energy spread using 1 J of drive laser energy. We additionally discuss the scalability of the scheme to higher energies. Highly tunable tailored plasma sources, like those proposed here, enable fine control over the injection and acceleration processes and thus will be crucial for the development of application-focused laser-plasma accelerators.

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