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Polarization-Dependent Self-Injection and Electron Beam Dynamics in a Laser Wakefield Accelerator[1]

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Laser wakefield acceleration is a very promising alternative novel accelerator technology for scientific applications such as compact TeV electron-positron colliders, X-ray free electron lasers, experimental high-field quantum electrodynamics studies and many more. All these applications place highly restrictive requirements on the beam quality, which critically depends on control of the injection process and subsequent beam dynamics. In the so-called "self-injection" process of LWFA, the wakefield is driven by the ponderomotive force, which is determined by the intensity gradient and thus has no dependence on laser polarization. However, the laser pulse front ionize the gas medium to generate the plasma. As we know, ionization depends on laser polarization due to the well-known above threshold ionization process. Therefore, we presents an experimental investigation on the role of laser polarization on electron beam self-injection in laser-wakefield acceleration. The experimental results revealed that the self-injection threshold can be decreased by using laser pulses with circular polarization in laser-wakefield acceleration experiments, compared to the usually-employed linear polarization. A significantly higher electron beam charge was also observed for circular polarization compared to linear polarization over a wide range of parameters. Theoretical analysis and quasi-3D particle-in-cell simulations revealed a different injection mechanism for circularly polarized laser pulses, originating from the larger momentum gain during above-threshold-ionization, in which electrons gain residual momenta due to the conservation of transverse canonical momentum. This enables electrons to fulfill the trapping condition more easily. The expected resulting higher plasma temperature was confirmed via spectroscopy of the XUV plasma emission.

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