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Stability of ionization-injection-based laser-plasma accelerators

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Laser-plasma acceleration (LPA) is a compact technique to accelerate electron bunches to highly relativistic energies, making it a promising candidate to power radiation sources for industrial or medical applications. However, further improvements in terms of repetition rate and stability are required for LPAs to compete with already existing technologies. We report on the generation of electron beams from an 80 MeV-level LPA setup based on ionization injection (II) over a duration of 8 hours at a repetition rate of 2.5 Hz, resulting in 72,000 consecutive shots with charge injection and acceleration. During this time, the moving average of the total beam charge of 14.5 pC stayed constant. Using correlations of our final beam parameters to the experimental conditions, we identified the plasma density as our largest source of shot-to-shot jitter in the beam charge. This is supported by particle-in-cell simulations, which show that stronger laser self-focusing in higher density plasmas significantly increased the ionized charge along with the emittance of the beam. The nonlinearity of this process imposes tight constraints on the reproducibility of the laser-plasma conditions required for a low jitter II-LPA as desired for future applications.

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