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Effects of plasma density fluctuations on density transition-injected electrons in laser wakefield accelerators

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Laser wakefield accelerators are promising candidates for compact sources of relativistic electron beams and bright x-rays. Highly stable accelerator performance is required for applications of these electrons, but this is difficult to achieve due to the sensitivity of the injection and acceleration dynamics to initial conditions, resulting from the non-linear underlying physics. A key parameter in determining the quality of the accelerated electrons is the plasma density, often taken as a constant and controlled by the backing pressure of the gas target. By tailoring the density profile, such as introducing a sharp longitudinal density transition in the target, it may be possible to improve the shot-to-shot stability of the accelerator.

We present experimental results of the electron beams generated by a non-linear laser wakefield accelerator in a helium gas jet target with and without a density transition produced by a razor blade in the flow. The shot-to-shot variations of the plasma density profile for nominally equal conditions are diagnosed via interferometry and correlated to the characteristics of the accelerated electrons. The findings are supported by particle-in-cell simulations, which allow the variations of different density parameters to be decoupled. The results suggest that fluctuations of the density profile caused by motion of the blade in the gas are more significant than fluctuations caused by variations in gas pressure.

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