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Asymmetric effects in shock-injection of laser-plasma acceleration of electrons

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An easy to install method for controlling electron injection in relativistic plasma waves relies on a sharp density downramp that is achieved by introducing a hydrodynamic shock into the gas flow before it gets ionized. Although the leading-order, desired effect of the shock is the generation of a 1D longitudinal drop in the density profile responsible for well localized electrons injection, there can be higher-dimensional side effects, caused by the asymmetric shape of the shock. Such asymmetries can distort and cause asymmetries in the accelerating bubble's shape; these, in turn, can negatively impact the accelerated beam's quality. In a recent experiment at the HIGGINS high-power-laser laboratory at the Weizmann Institute of Science [1], we have observed the splitting of an accelerated electron beam, where the major part of the beam is oriented in the axial direction as expected, but a fraction of the beam splits off and is lost to an off-axis direction. This result was observed both experimentally (using a relativistic electron probe [2]) and in full 3D particle-in-cell (PIConGPU [3]) simulations. By understanding the causes of these quality degradations, we believe that they can be compensated by correctly designing the gas target and the laser pulse, in a way that will maximize the efficiency of the energy transfer to the accelerated particles.

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Footnotes

[1] Kroupp, E. et al. Commissioning and first results from the new 2x100 TW laser at the WIS. doi:10.1063/5.0090514
[2] Wan, Y. et al. Direct observation of relativistic broken plasma waves. doi:10.1038/s41567-022-01717-6
[3] Bussmann, M. et al. Radiative signatures of the relativistic Kelvin-Helmholtz instability. doi:10.1145/2503210.2504564

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