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Plasma shaping in laser-plasma accelerators: injection, energy boost and beam collimation

CEDRIC THAURY, LOA, CNRS-ENSTA-Ecole Polytechnique

The longitudinal density profile is a key parameter to optimize the properties of electron beams in laser-plasma accelerators. Tailored density profile can notably be used to control injection or increase the electron energy via density tapering. Here we present three different experiments illustrating the use of density tailoring for injecting, increasing the energy or focusing relativistic electron beams. First, we discuss results on shock-front injection in a gas mixture. We show that shocks allow to confine injection and hence to reduce significantly the beam energy spread, compared to pure ionization injection. Then we demonstrate that, with a different setup, shock fronts can also be used to rephase the electron beam with the wakefield. Using this setup we obtained an increase of the electron energy by almost 50 percent. Finally, we present the principle of the laser-plasma lens and show that this device can be used to reduce the electron beam divergence by a factor of almost 3. This last result is of particular importance for applications requiring beam transport; the divergence reduction should actually be sufficient to avoid transverse emittance growth in quadrupole triplets, provided that the energy spread is lower than 3 percent (chromatic emittance growth is due to the combination of large divergence and energy spread).