Extremely intense laser-based electron acceleration in a plasma channel

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Plasma channels represent a well-suited environment for particle acceleration using lasers. The reasons for this are twofold. On one hand, the laser can be self-guided within the channel, which allows for long propagation distances. In fact, the highest electron energy to-date from laser wakefield acceleration ($\sim$4 GeV) was obtained in a capillary discharge waveguide [1]. On the other hand, the channel can affect the particles directly. For example, self-generated electromagnetic fields can assist direct laser acceleration within the channel and allow energy gain beyond the vacuum acceleration limit [2]. As fluctuations of the longitudinal electric field affect the dephasing between the electrons and the laser, it becomes possible to generate "superponderomotive" electrons [3] within the channel.

Laser pulses of extreme intensities ($I > 10^{22}$ W/cm^2) are about to become available in the laboratory. The prepulse of such a laser can induce a plasma expansion that generates a low-density channel in near-critical gas jets. Here we present a study of channel formation and subsequent direct laser acceleration of electrons within the pre-formed plasma channel [4]. We show that the radiation reaction is important for the global plasma dynamics and affects the electron acceleration in two ways. It first interferes with the motion of the return current on the channel walls, which changes the dynamics of the channel-splitting. In addition, it reduces the radial expelling efficiency of the transverse ponderomotive force, leading to radiative trapping of particles near the channel axis. Both effects are favourable for placing particles in the region of space where they interact with the peak laser intensity and can attain multi-GeV energies.

References

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