Self-Injection And Stability In Laser-Plasma Accelerators

A. Lifschitz[1], C. Thaury[1], K. Ta Phuoc[1], S. Corde[2],
E. Guillaume[1], A. Döpp[1], X. Davoine[3], R. Lehe[1], and V. Malka[1]

[1]Laboratoire d'Optique Apliqueé, ENSTA-CNRS-Polytechnique, UMR 7639 , Palaiseau, France
[2]LCLS, SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA
[3]CEA-DAM, DIF F-91297 Arpajon, France

Laser-plasma accelerators can produce high quality electron beams, up to giga-electronvolts energy, from a centimeter scale device. The properties of the electron beams and the accelerator stability are largely determined by the way electrons are injected into the accelerator. The accelerating structure, i.e. the wakefield created at the trail of the laser pulse, moves at a velocity close to the velocity of light. To gain energy, electrons must be injected with relativistic velocities in the correct region of the wakefield. The simplest mechanism of injection is the self-injection, in which the wakefield is strong enough to trap cold plasma electrons into the laser wake. The main drawback of this method is its lack of shot-to-shot stability. We present here experimental and numerical results on the different regimes and the different mechanisms of self-injection. We will firstly show the existence of two different self-injection mechanisms co-existing at low plasma densities, namely transverse and longitudinal self-injection [1]. The first one is shown to lead to low stability and poor quality electrons, because of a strong dependence on the intensity profile of the laser pulse. In contrast, longitudinal self-injection, which is unambiguously observed for the first time, is shown to lead to much more stable acceleration and higher quality electron beams. We also explore the high plasma density regime of self-injection, and discuss the applications of the electron beams that can be obtained in this regime.

[1] S. Corde, C. Thaury, A. Lifschitz et al, Nature Comm. **4**, 1501 (2013)