On the Control of e-Beam Parameters with Laser Plasma Accelerators

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Abstract: A previous experiment [1] has shown that the use of two colliding pulses in a collinear geometry [2] can produce a stable source of electrons that is also easily tunable in energy.

We report here results of recent experiments [3] with two laser beams colliding with an angle, thus having the advantage of protecting the laser system from any feedback. It not only confirms those earlier results but also proves that the charge and energy spread of the beam are also controllable independently of its energy.

Phase space volume of the injected particles can indeed be varied independently of the main accelerating structure, by changing the intensity or the polarization of the injection pulse. Charge can therefore be controlled together with the energy spread of the beam. Energy spread of the beam can also be reduced by changing the ratio between injection phase width and plasma wavelength. The good agreement between PIC simulations and experimental observations indicates that all the physical processes are well understood.

By adjusting the charge loaded in the wakefield, we have been able to observe experimentally, for the first time to our knowledge, the "beam loading" effect. Beam loading is of crucial importance because it is the phenomenon which limits the charge and the beam quality in plasma based accelerators [4]. In our experiment, beam loading manifests itself through the decrease of the electron beam energy, the reduction of dark current and the increase of the energy spread for large beam charge [5]. 3D PIC simulations are compared to the experimental results and confirm the effects of beam loading. It is found that, in our experimental conditions, the trapped electron beams generate decelerating fields on the order of 1 GV/m/pC and that beam loading effects are optimized for trapped charges of about 20 pC.

This first stable and fully tunable source is a major step towards a usable source of electrons generated by laser-plasma accelerators and for the design of future accelerators [6]. The first application of this source has been the fine characterization of the electron spectrum with a high resolution spectrometer which shows a relative energy spread in the 1% level [7]. The second being a detailed study of the beam loading which shows that optimum current of few tens of kA are suitable to achieve high quality electron beam.

References

[1] J. Faure, C. Rechatin, A. Norlin, A. Lifschitz, Y. Glinec, and V. Malka. « Controlled injection and acceleration of electrons in plasma wakefields by colliding laser pulses ». Nature, **444,**737–739, (2006)
[2] E. Esarey, E. Hubbard, W. P. Leemans, A. Ting and P. Sprangle, « Electron injection into plasma wake fields by colliding laser pulses », *Phys. Rev. Lett.* **79,** 2682 (1997)
[3] V. Malka, J. Faure, C. Rechatin, A. Ben-Ismail, J. K. Lim, X. Davoine, and E. Lefebvre. Laser- driven accelerators by colliding pulses injection: A review of simulation and experimental results. Phys. Plasmas, 16(5):056703, 2009.
[4] T. Katsouleas, S. Wilks, P. Chen, J. M. Dawson, J. J. Su, "beam loading in plasma accelerators", Particle accelerators **22**, 81 (1987)
[5] C. Rechatin, X. Davoine, A. Lifschitz, J. Faure, A. Ben Ismail, J. Lim, E. Lefebvre, and V. Malka, « Observation of beam loading in a laser-plasma accelerator », Phys. Rev. Lett. **102**, 164801 (2009)
[6] V. Malka, J. Faure, Y. A. Gauduel, E. Lefebvre, A. Rousse, and K. Ta Phuoc. Principles and applications of compact laser-plasma accelerators. Nature Physics, 44:447–453, 2008.
[7] C. Rechatin, J. Faure, A. Ben-Ismail, J. Lim, R. Fitour, A. Specka, H. Videau, A. Tafzi, F. Burgy, and V. Malka. Controlling the phase-space volume of injected electrons in a laser-plasma accelerator. Phys. Rev. Lett., 102(16):164801, 2009.