Laser acceleration of charged particles from low-density targets

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Laser-driven particle acceleration by femtosecond high-power pulses is a topic of extraordinary interest for fundamental research and possible applications. These issues motivated a worldwide search for different mechanisms of electron and ion acceleration with the aim to maximize both the yield and the energy of the generated particles. In this context, an important role is played by low-density targets with an electron density close to the relativistic critical density that is discussed here, mainly on the basis of the 3D particle-in-cell (PIC) simulations.

We have extended recently published results of so-called SASL (synchronized acceleration by slow light) simulations [1] to other schemes of laser-plasma interaction for proton acceleration involving manipulation of laser polarization and low-density targets which are available in practice. In all cases, the main idea is to capture the protons from a target front side in laser pulse ponderomotive electric field sheath and keep them synchronized with the latter due to specific nonlinear propagation and laser-target design. This is illustrated in Figure 1.

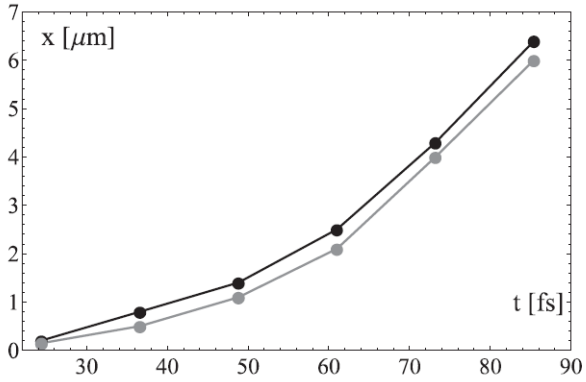

Figure 1. Synchronized motion of a laser pulse and a proton bunch: positions, x(t), of the laser pulse front (gray) and the front of the accelerated proton bunch (black) inside a target

The 3D PIC simulations have also demonstrated effective acceleration of electrons from low-density targets in terms of the increased electron yield. The electron charge per shot with energies in excess of 30 MeV reaches multi/multi-tens nC level for current femtosecond lasers that is hard-to-reach with gaseous or solid-density targets and constitutes an important step to a deep gamma-radiography based on laser-driven high-energy electrons.

This work was supported by the Russian Science Foundation (Grant No. 17-12-01283).

References

[1] A. V. Brantov, E. A. Govras, V. F. Kovalev, and V. Yu. Bychenkov, Phys. Rev. Lett. 116, 085004 (2016).