Collimated MeV electron beam generation in the interaction of intense ultrashort laser pulse with a dense plasma and its applications

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The interaction of intense laser radiation with matter is one of the key areas of research in modern laser physics. Currently the main efforts aimed at creating unique laser complexes with peak power in PW range. However, for many applications such as low-energy nuclear physics studies and x-ray imaging it is important to have a large electron beam charge (~nC) and a source size of several microns. This can be achieved using small femtosecond laser systems with a peak power of 1-20 TW, which are now commercially available. Such systems can provide an intensity on the target of 10^{18}-10^{19} W/cm^2, high beam charge can be obtained using laser-solid interaction. In this work we used a table-top Ti:Sa laser system to create an electron beam and used it for nuclear physics studies.

Experiments were carried out at the 1 TW Ti:Sa laser facility of the International Laser Center of Lomonosov MSU (800 nm, 50 mJ, 50 fs, 10 Hz). The peak vacuum intensity was 5×10^{18} W/cm^2. We used additional Nd:YAG laser (1064 nm, 10 Hz, 200 mJ, 10 ns) to create a preplasma. Prepulse intensity was varied from 5×10^{11} to 5×10^{12} W/cm^2.

We had shown experimentally that using an artificial prepulse with controlled parameters we can generate electron beam with a sufficiently small divergence (0.05rad for E>1 MeV), a charge of ~30 pC, and a temperature of ~2 MeV [1]. The charge was confirmed measuring neutron yield from Be(γ, n) photonuclear reaction with threshold of 1.7 MeV. We also found out that spatial alignment of two beams (main fs pulse and ns prepulse) is critical for obtaining such regime. This is due to the difference in preplasma profile, which is formed by ns prepulse. If these beams are aligned properly, electron beam exhibits great spatial and energy stability and is present for a wide range of other parameters (time delay between ns and fs pulses, angle of incidence onto the target, etc.) We also used this beam for nuclear physics studies (namely neutron and positron generation) [2].

[1] I. Tsymbalov et.al. Well collimated MeV electron beam generation in the plasma channel from relativistic laser-solid interaction. Plasma Physics and Controlled Fusion, 61(7):075016, 2019;

[2] D. A. Gorlova et.al. Investigation of the generation of positrons near the threshold. Physics of Particles and Nuclei, 50(5):597–604, 2019.