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Parametric instabilities, electron injection and acceleration from relativistic laser interaction with solid targets

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Efficient direct electron acceleration in the plasma channel with injection through the breaking of plasma waves generated by parametric instabilities was demonstrated experimentally and reproduced in the 2D3V PIC simulations. The electron bunch was produced using the specific plasma profile containing arbitrary sharp, ~0.5λ, gradient at the vicinity of 0.1–0.5 critical density and a long tail of a tenuous preplasma. Such a preplasma profile was formed by an additional nanosecond laser pulse with intensity of 5×10^12 W cm−2. In the case of optimal preplasma parameters femtosecond laser pulse with an intensity of 5×10^18 W cm−2 and an energy of 50 mJ generates a collimated electron bunch having divergence of 50 mrad, exponential spectrum with the slope of ~2 MeV and charge of tens of pC. The charge was confirmed measuring neutron yield from Be(g, n) photonuclear reaction with threshold of 1.7 MeV. By the contrast, a ring-like electron beam with divergency of 300 mrad and significantly lower charge is generated if the prepulse intensity drops to 5×1011 W cm−2. The 2D PIC simulations confirmed beamed electron's acceleration in the plasma channel (so-called direct laser acceleration). This channel is formed in a long tail of teneous preplasma by the laser pulse specularly reflected from the arbitrary sharp gradient. The ring-like electron beam was attributed to the longer gradient case enlarging divergence of the reflected laser beam, preventing channel's formation and electron acceleration by the so-called vacuum laser acceleration, or VLA. We also showed that injected electrons appeared from the wave breaking of plasma waves of hybrid SRS-TPD instability for the both gradients. Electrons received an initial momentum from this breaking to be effectively injected into the plasma channel.

Primary author: Prof. SAVEL'EV, Andrei (Lomonosov Moscow State University)

Co-authors: Mr ZAVOROTNY, Akim (Lomonosoc Moscow State University); Mrs GORLOVA, Diana (Lomonosov Moscow State University); Dr TSYMBALOV, Ivan (Lomonosov Moscow State University); Dr IVANOV, Konstantin (Lomonosov Moscow State University); Mr SHYLUAPOV, Sergei (Lomonosov Moscow State University)

Presenter: Prof. SAVEL'EV, Andrei (Lomonosov Moscow State University)

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