

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

Thursday, 30 January 2020 10:30 (25 minutes)

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, $\sim 0.5\lambda$, 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 $5 \times 10^{12} \text{ W cm}^{-2}$. In the case of optimal preplasma parameters femtosecond laser pulse with an intensity of $5 \times 10^{18} \text{ W cm}^{-2}$ and an energy of 50 mJ generates a collimated electron bunch having divergence of 50 mrad, exponential spectrum with the slope of $\sim 2 \text{ MeV}$ and charge of tens of pC. The charge was confirmed measuring neutron yield from $\text{Be}(g, n)$ photoneuclear 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 $5 \times 10^{11} \text{ W cm}^{-2}$. 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 tenuous 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.

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Session Classification: Applications of Plasmas