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Interaction of ultra-high intensity laser pulse with a mass limited targets

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Ultra-high intensity laser pulses may be produced now via CPA scheme by using very short laser pulses of a relatively low energy. Interaction of such pulses with massive target is not very efficient as the energy delivered to charged particles spreads out quickly over large distances and it is redistributed between many secondary particles. One possibility to limit this undesirable energy spread is to use mass limited targets (MLT), for example droplets, big clusters or small foil sections. This is an intermediate regime in target dimensions between bulk solid and nanometer-size atomic cluster targets. A few experimental and theoretical studies have been carried out on laser absorption, fast particle generation and induced nuclear fusion reactions in the interaction of ultrashort laser pulses with MLT plasma.

We investigate here laser interactions with MLT via 2D3V relativistic electromagnetic PIC simulations. We assume spherical droplet as a typical MLT. However, the sphere is represented in 2D simulations by an infinite cylinder irradiated uniformly along its length. We assume that MLT is fully ionized before main pulse interaction either due to insufficient laser contrast or due to a prepulse. For simplicity, we assume homogeneous plasma of high initial temperature. We analyze the interaction of relativistic laser pulses of various polarizations with targets of different shapes, such as a foil, quadrant and sphere. The mechanisms of laser absorption, electron and ion acceleration are clarified for different laser and target parameters. When laser interacts with the target front side, kinetic energy of electrons rises rapidly with fast oscillations in the kinetic and field energy, caused by electron oscillations in the laser field. Small energy oscillations, observed later, are caused by the electron motion back and forth through the droplet. Approximately 40% of laser energy is transferred to the kinetic energy of electrons and ions.

When MLT is irradiated by ultra-high power laser pulse, the resulting plasma is strongly accelerated forward by the laser-induced ponderomotive force and its front side significantly compressed into a high density shock layer. The electrons in the shock layer are heated, and the plasma bunch then expands as a rocket. Thus, the forward acceleration of the high density region continues even after the laser pulse. The ion kinetic energy in this region can exceed tens of MeV at approximately solid density. For laser intensities above Coulomb threshold the efficiency of laser energy conversion into ion energy increases and the regime of direct plasma acceleration by light pressure may be reached. Since the plasma bunch is moving forward during the reflection, red-shift of the reflected light is observed. Twice higher maximum fast ion energy was found for droplet target compared to the standard thin foil target. In simulations of MLT including two different ion sorts, the observed maximum in the light ion distribution is caused by their additional acceleration in the electrostatic field of heavy ions. Parameters of this pike are determined by laser intensity and by the ion concentration ratio.

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