Generation of fast ions by microclusters

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Laser interactions with a mixture of a gaseous plasma and microclusters exhibit a number of interesting phenomena, including fusion neutron production. Microclusters are generated in laboratory experiments by a supersonic gas jet expanding into a vacuum. Gas condensation produces small liquid density droplets and a high-intensity laser pulse converts them quickly into dense plasmas (microclusters). Neutron yield in laser-cluster experiments [1] results from collisions of fast deuterons (with energies above 10 keV) generated by expanding microclusters. At moderate laser intensities, the average energy absorbed per electron and the ponderomotive potential are well below 10 keV, which raises the question about the mechanism of ion acceleration to the energies required for fusion reactions. A plausible resolution of this difficulty is to consider that the laser field creates a two-component electron distribution in sufficiently large clusters, with a cold majority and a hot minority [2]. The hot minority undergoes additional stochastic heating, which allows it to reach energies exceeding the ponderomotive potential. The pressure of the hot component forces the cluster to expand, accelerating ions. Since only large clusters produce sufficiently fast ions via this mechanism, the knowledge of the tail of the cluster-size distribution is necessary to interpret the experiments and make quantitative predictions. We address the three key ingredients needed to find the population of fast ions generated by clusters: cluster-size distribution, electron heating, and ion acceleration. We present a first-principle model that self-consistently describes ion acceleration by an ambipolar electric field generated by the hot electron pressure and adiabatic cooling of the hot component. The stochastic electron heating is investigated numerically to find the rate and the saturation energy. We also present a new method for determining the cluster-size distribution from measurements of absorption and phase shift in a pump-probe experiment with a variable delay between the pulses [3]. We apply this method to analyze the data from recent pump-probe experiments at the University of Texas. This work was supported by the U.S. Department of Energy under Contracts No. DE-FC52-08NA-28512, DE-FG02-04ER-54742, and DE-FG03-96ER-40954.

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