Numerical Investigation of Collisionless Shock Ion Acceleration in Different Materials Using EPOCH Particle-in-Cell Simulations

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Collisionless shocks are observed in a wide variety of astrophysical systems, such as active galactic nuclei, pulsar wind nebulae, and supernova remnants. Collisionless shocks are of great importance and interest as these shocks are excellent particle accelerators and sources of high-energy cosmic rays [1].

The development of high-intensity and high-power lasers is opening up a new era of study in the laboratory of the formation and evolution of collisionless shocks. Indeed, ion acceleration from laser-driven collisionless shock has already been demonstrated [2]. These ion beams have many potential applications, such as particle physics, cancer therapy, fast ignition, and proton radiography etc.

In this paper, we study through numerical simulations, using the EPOCH [3] particle-in-cell code, ion acceleration in electrostatic collisionless shocks and how the acceleration is influenced by in different materials . Our simulations use a density profile composed of exponentially increasing 5 um scale-length front, laser irradiated region, and 5 um wide uniform region and an exponentially decreasing 30 um scale-length rear region. The maximum electron density is fixed at the relativistic critical density N_c, i.e. a_0* N_c, where a_0 is the normalized laser vector potential. The laser is linearly polarized, normal incidence with Gaussian temporal profile of full-width-half-maximum of 1.5 ps, and maximum intensity of 1.4×10^{19} W/cm^2 (a_0 = 3.35). The density profile and laser parameter are same for all the materials. We show that for all materials when the Mach number of the electrostatic collisionless shock exceeds a critical value [4] of 1.6 ions are reflected from the shock front. The upstream temperature of electrons and the peak energy of the reflected ions from the shock front are similar for all the materials except hydrogen. As the ion charge to mass ratio decreases, the number of the accelerated ions from the shock front increases.

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