Laser oriented electrostatic shocks in low density plasmas to produce energetic collimated ion beams and study low velocity astrophysical shocks

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Résumé

Laser driven sources of high energy ions have applications in plasma and fusion science as an electromagnetic field probe and may find other applications in medical science and laboratory astrophysics. These sources commonly use thin solid foils, and ions are accelerated at their rear side in the electrostatic field created by hot electrons. Gaseous targets can also produce ion beams with characteristics comparable to those obtained with solid targets. In the low target density laser ion acceleration, volume effects dominate, while for solid foils, ion acceleration is directly related to the electron surface density and the number of accelerated ions is limited. Using Particle-In-Cell simulations, we have studied in detail ion acceleration with high intensity laser pulses interacting with low density plasmas. The efficiency of this regime strongly depends on the plasma length, the laser pulse duration and intensity. It is shown that by adjusting the laser and plasma parameters, a two-step acceleration process can be triggered: first, ions are accelerated in volume by electric fields generated by hot electrons, second, the ion energy is boosted in a strong electrostatic shock propagating along the descending density profile. In the one-dimensional (1D) model, both processes are electrostatic by nature, whereas in 2D and 3D, the first step involves both the electric field and the magnetic field, while the second step being essentially electrostatic. We discuss the limits of this regime in terms of ion beam characteristics (maximum proton energy, divergence, intensity) and the possibility to accelerate heavier ions. A new model describing this acceleration process has been developed and verified using Particle-In-Cell simulations and a Vlasov-Poisson code. The first step of the acceleration process requires a hot electron population and a descending density profile, and the second step develops if the ion bunch resulting from the first step enters in a low density plasma. This model has been used to prepare new experiments of laser ion acceleration with low density targets. The strong electrostatic shock launched during this process is therefore easy to control and can be applied to study low velocity astrophysical shocks relevant to supernovae explosions and gamma ray bursts.

Mots-Clés: Plasma Laser Particle, In, Cell Ion Acceleration Shock

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