APR05-2005-000622

Abstract for an Invited Paper
for the APR05 Meeting of
the American Physical Society

Formation of Strong Shocks by Laser Pulses

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Ultra intense lasers ($I > 10^{20} W/cm^2$) open a new path for the exploration of extreme scenarios. Laser matter interactions in this relativistic regime provide an excellent setting to test mechanisms present not only in the laboratory but also in astrophysical scenarios. Due to the nonlinear nature of the phenomena, massively parallel particle-in-cell simulations provide the ideal tool for exploration. I will examine the formation of strong shocks, and proton shock acceleration, in two scenarios: overdense targets, and clustered gases. The formation of high Mach number electrostatic shocks by laser pulses incident on overdense plasma slabs is observed, for a wide range of conditions. The shocks propagate undisturbed across the plasma, accelerating the protons to energies up to 300 MeV, with a clear signature in the ion spectrum. Shock structures can also be driven in the explosion of very large deuterium clusters. Small-scale shock shells in the expanding ion cloud are observed, and a technique to induce the formation of large shock shells inside a single cluster (increasing the probability of intra-cluster nuclear reactions) is proposed, and demonstrated. The possibility to control the shock dynamics is explored, allowing for the detailed study of the shock formation mechanisms, and ion shock acceleration.