Studying near-relativistic collisionless shocks with high-intensity laser-plasma interactions

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Collisionless shocks are pervasive in space and astrophysical plasmas and are known to be efficient particle accelerators; however, the microphysics underlying shock formation and particle acceleration is not yet fully understood. The fast progress in laser technology is bringing the study of near-relativistic collisionless shocks into the realm of laboratory plasmas.

We use multi-dimensional particle-in-cell simulations to explore the laboratory conditions associated with intense laser-plasma interactions that allow for the study of the physics of collisionless shocks and particle acceleration.

It is shown that in the piston regime, where an ultraintense laser interacts with an overcritical plasma, relativistic flows can be generated and drive a cold return current. The counterstreaming flows are Weibel unstable, leading to the generation of a Weibel-instability-mediated shock [1]. The possibility of observing Fermi acceleration in these laboratory shocks will be discussed.

As the laser intensity is decreased and near-critical density plasmas are used, electron heating dominates over radiation pressure. These conditions are shown to lead to the formation of electrostatic shocks, which can reflect ions from the background plasma, accelerating them to high energies [2]. By controlling the plasma density profile, we show the possibility of controlling the spectrum of the shock-accelerated ions and generate high-quality 200 MeV ion beams for medical applications, such as radiotherapy [3].