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Weibel instability mediated collisionless shock generation using large-scale laser systems

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Collisionless shocks are considered to be sources of high-energy particles or cosmic rays, and occur when a coulomb mean-free-path is longer than the shock-front thickness. In such plasmas wave-particle interactions and collective effects play an essential role in the shock formation. In addition to local observations of spaces plasmas by spacecraft and global emission measurements of astrophysical plasmas, a laboratory experiment can be an alternative approach to study the formation of collisionless shocks.

In this paper, we investigate the formation of Weibel-instability mediated collisionless shocks in counter-streaming plasmas produced by large-scale laser systems. Kato and Takabe investigated the collisionless Weibel shock in two-dimensional PIC simulation using the injection method [1]. A scaling-law derived in simulation revealed that high-density (electron density $\sim 10^{20}$ cm^{-3}), high-flow velocity ($\sim$1000 km/s) plasmas are required to produce the collisionless Weibel shock. In order to achieve these plasma parameters, a MJ-class high-power laser system or the word largest laser, the NIF laser (LLNL, USA), is required. Before starting the NIF experiment, we conducted OMEGA laser (LLE, USA) experiment and measured plasma parameters such as electron and ion temperatures, electron density, and flow velocity of counter-streaming plasmas using collective Thomson scattering, and current filaments produced by the Weibel instability using proton-radiography.

[1] T. N. Kato and H. Takabe, The Astophys. J. Lett. 681, L93 (2008).

Keywords: collisionless shock, weibel instability, large-scale laser experiment