Power laser experiment of magnetized shock: Reflected ions and nonstationarity

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The sustained attention paid to collisionless shocks stems from the complexity of their energy conversion (dissipation) mechanisms and the fundamental physics they involve. Specifically, the transition region serves as a rich repository of various nonlinear relaxation processes in nonequilibrium plasmas, multi-scale physics – spanning fluid ~ ion ~ electron scales – dominates the system, and collisionless shocks are believed to be deeply connected to one of the most fundamental questions in astrophysics: the origin of cosmic rays.

In this study we reproduce a collisionless shock using high-power laser experiment which is increasingly being recognized as a major empirical research tool in this field. Long pulse laser irradiates a plate target to create a high-speed plasma flow normal to the target plate. Surrounding gas is ionized with intense radiation generated from the interaction between the laser and the target material. Ambient magnetic field almost parallel to the plate surface is applied by using a Helmholtz-like coil so that the gas plasma was nearly homogeneously magnetized. The high-speed target plasma acts as a magnetic piston to form a shock in the ambient gas plasma.

The shock was identified from the spatial profile of the electron density obtained through electron feature of Thomson scattering measurement. By analyzing the spatiotemporal diagram from self-emission streak measurement, we extracted fluctuations of the shock front and demonstrated that their period is on the order of the inverse of the ion gyro frequency. The ion feature of Thomson scattering measurement in the transition region of the shock showed highly asymmetric spectrum, indicating that the local plasma is in a nonequilibrium state.

We developed 2D PIC simulation to reproduce collective Thomson scattering in a beam-plasma system in a self-consistent manner. Characteristics of 2D spectrum of the scattered waves for various beam parameters were examined. Assuming weak beam-plasma condition, the reproduced scattered wave spectrum showed asymmetric nature similar to what was observed in the experiment. Therefore, we conclude that the local plasma in the shock transition region observed in the experiment is composed of background ions, electrons, and beam (or reflected) ions. The presence of the weak reflected ion beam may cause the fluctuations of the shock front. The fluctuations may be attributed to breathing [1], a phenomenon observed in collisionless shocks with high ion temperatures.

Reference

[1] Comisel et al., *Ann. Geophys.*, **26**, 263 (2011).