Virtual collective Thomson scattering measurement of foreshock instabilities in collisionless shock experiment at ILE

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In space collisionless shocks are ubiquitously observed. Dissipation mechanism at a collisionless shock is highly complex and has not been well understood. Recently, collisionless shocks have been successfully reproduced in a laboratory by using high power laser facilities. We have performed the laboratory experiment on collisionless shocks by using Gekko XII high power laser in collaboration with the Institute of Laser Engineering (ILE) at Osaka University. To measure the local plasma quantities in the shock transition region, collective Thomson scattering (CTS) measurement is utilized. The CTS is the scattering of low frequency incident electromagnetic waves by collective oscillations of plasma electrons. The spectrum of the scattered waves enables us to infer the local plasma quantities like electron density, electron and ion temperature, valence of ions, etc, as a function of local position along the path of the incident probe laser light. If a plasma is nearly in equilibrium, scattered wave spectrum typically has two types of peaks called electron and ion features. The electron (ion) feature is produced when the incident waves are scattered by Langmuir (ion acoustic) waves.

On the other hand, the CTS theory in a non-equilibrium plasma has not been established. In the foreshock region a back streaming plasma is often observed as a beam by which beam instability is easily generated. Although the electron feature is usually too weak to be detected in an equilibrium plasma, it is possibly enhanced by the beam instability in the foreshock. Therefore, electron feature measurement is planned in the ILE experiment.

Numerical simulation greatly helps to interpret the experimental results. PIC (Particle-In-Cell) simulation is regarded as a first principle simulation of a collisionless plasma. It can reproduce a variety of non-equilibrium plasma phenomena in a self-consistent manner. However, the time resolution usually assumed in a PIC simulation is not enough to reproduce the CTS with realistic parameters. In this study we construct a simulation system of virtual CTS for realistic parameters in the ILE experiment. A foreshock beam instability is reproduced by using a PIC simulation. Then, the time-series data of electron density obtained from the PIC simulation is used to solve a wave equation of the scattered waves separately with much higher temporal resolutions. We performed this virtual CTS simulation for a parameter set typical in the ILE experiment and confirmed that electron feature is strongly enhanced through an electron-beam instability in a foreshock. In the meeting we will discuss characteristics of virtual CTS spectra for a variety of beam-plasma systems.

Keywords: Collisionless shock, Non-equilibrium plasma, Collective Thomson scattering