§4. Simulations of Large-Amplitude Plasma Waves and Particle Acceleration by Use of SNET

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By using SNET and super computers at NIFS, we have studied the behavior of large-amplitude plasma waves and strong particle acceleration processes caused by these waves. The subjects we have studied are 1) ultrarelativistic electron acceleration in large-amplitude Alfven wave packets [1], 2) parallel electric field in nonlinear magnetosonic waves in a three-component plasma consisting of electrons, positrons, and ions [2], 3) shock formation processes in a collision of two plasmas in an external magnetic field [3], 4) evolution of cylindrical shock wave and the trapping and acceleration of electrons in it [4], and 5) effect of ion composition on the ion acceleration in a shock wave in a two-ion-species plasma [5]. For the investigations of No. 1 – No. 3, we have used a one-dimensional, fully kinetic, relativistic, electromagnetic particle simulation code. For No. 4 and No. 5, respectively, we have used two-dimensional and three-dimensional codes.

Figure 1 is a result of the study No. 2; parallel electric field in nonlinear magnetosonic waves in a three component plasma. This figure shows the integral of the parallel electric field along the magnetic field, F, in a magnetosonic shock wave as a function of the positron-to-electron density ratio n_{p0}/n_{e0}. As n_{p0}/n_{e0} decreases, the magnitude of F decreases, and F becomes zero in a pure electron-positron plasma (n_{p0}/n_{e0}=1). This explains the simulation result [6] that the positron acceleration is stronger in a plasma with a lower positron density.

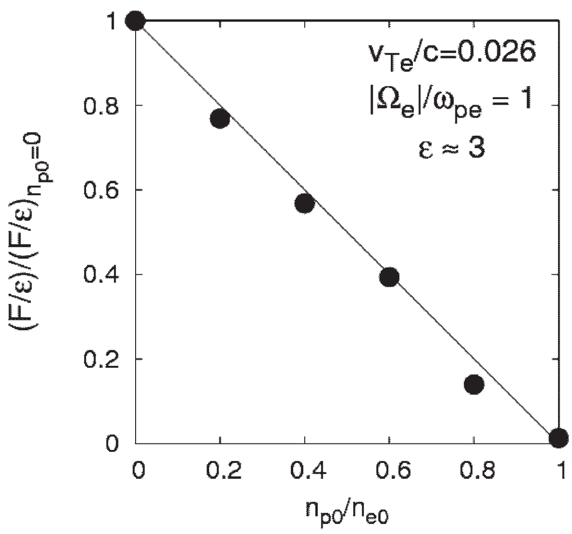

Fig. 1. Magnitude of F as a function of the positron-to-electron density ratio n_{p0}/n_{e0}. The dots and solid line represent the simulation result and theoretical prediction, respectively, and ε is the wave amplitude.

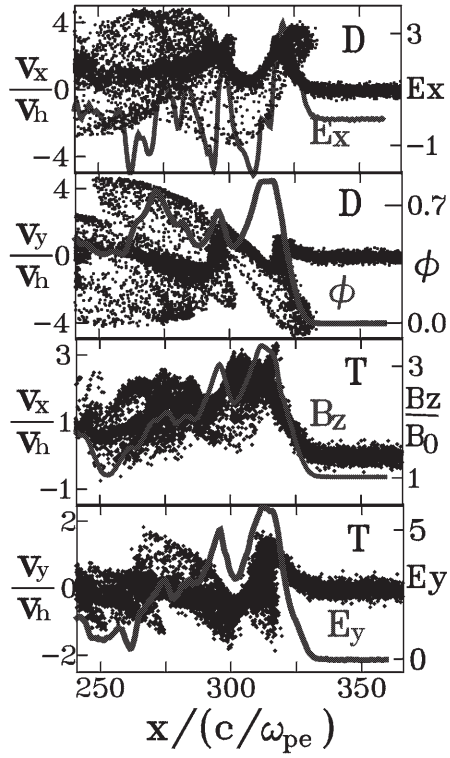

Fig. 2. Ion phase spaces (x, v_x) and (x, v_y) for a shock wave in a D-T plasma. Field profiles are also shown.

Figure 2 is a result of three-dimensional simulations with the number of simulation particles $N_i=N_e=10^9$ for the study No. 5; effect of ion composition on the ion acceleration in a shock wave in a two-ion-species plasma. This figure shows ion phase spaces for a shock wave in a deuterium-tritium (D-T) plasma. From the simulations for H-T plasmas and for D-T plasmas, we have found that the frequency difference Δ_ω between the cutoff frequency of the high-frequency mode of the magnetosonic wave and the resonance frequency of the low-frequency mode plays an important role in the wave evolution and thus in the acceleration of particles. For a D-T plasma with $n_D=n_T$, in which Δ_ω is smaller than in H-T plasmas, we have a high-frequency-mode shock wave. All the T ions are accelerated by the transverse electric field, and a great number of D ions gain energy from the longitudinal electric field.

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