§42. Effects of Multiple-Species Ions on Plasma-Flow Velocity-Shear-Driven Instabilities

Kaneko, T., Hatakeyama, R.
(Dept. Electronic Eng., Tohoku Univ.),
Ishiguro, S.

Sheared plasma flows parallel to magnetic field lines are recognized to play an important role in generation and suppression of low frequency plasma instabilities. According to the experimental results, it is demonstrated that the ion-acoustic, ion-cyclotron, and drift-wave instabilities are excited and suppressed by the parallel flow velocity shear, where the plasma consists of one positive ion and electron species.[1,2] However, the shear-modified instability should be extended to a more general case, namely, effects of several kinds of positive and negative ions (multiple-species ions) on the instability should be taken into account because the actual plasmas such as space and fusion plasmas often contain the multiple-species ions. In this sense, a particle simulation is very useful method to clarify the effects of the multiple ions on the shear-modified instability, because the simulation can easily set these several kinds of ions in the system. Therefore, a three dimensional electrostatic particle simulation with a periodic boundary model is performed,[3] where an external uniform magnetic field points to the positive z direction.

In the first stage of this research, the negative ions have been introduced in the system as the multiple-species ions. Therefore, in the second stage, two kinds of positive ions with different masses are introduced, where the mass ratio between an electron, a light positive ion, and a heavy positive ion is fixed at 1 : 400: 1600. The density ratio between the light n_L and heavy n_H ions is defined as $S = n_L/(n_L+n_H)$. The parallel ion flow velocity shears are introduced by changing the ion flow velocities v_{di} spatially in the x direction corresponding to the light (solid line) and heavy (dotted line) ions as shown in Fig. 1, where v_{te} is the electron thermal speed.[4]

Figure 2 shows time evolutions of the real (solid line) and the imaginary (dashed line) parts of the spatial Fourier mode of the positive ion density fluctuation $\tilde{n}_i/\bar{n}_i$ for (a) S=1, (b) S=0.75, and (c) S=0.5 in the velocity shear region ($32 < x/\lambda_{De} < 36$). According to the frequency spectra of the mode in Fig. 2(a), the observed wave is identified as an obliquely propagating ion-acoustic wave. The fluctuation amplitude is found to be suppressed when the heavy ions are introduced in the system as shown in Fig. 2(b). When the densities of the heavy and light ions are almost equal, the fluctuation amplitude is down to the noise level.

It has already been clarified that the ion-acoustic wave is excited by the parallel flow velocity shear, because the phase velocity of the wave in the ion flame increases with an increase in the shear strength, resulting in the reduction of Landau damping caused by the light ions. When the heavy ions are introduced, however, the Landau damping of the wave is newly caused by the heavy ions, the velocity distribution function of which is different from that of the light ions. Based on these results, the introduction of the two kinds of positive ions is found to regulate the growth of the fluctuations.

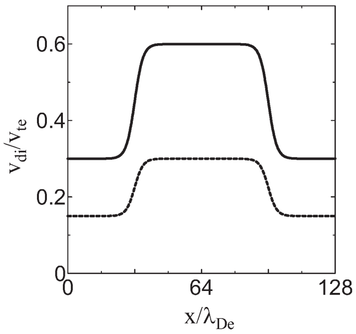

Fig. 1. Profiles of ion flow velocities v_{di} in the x direction.

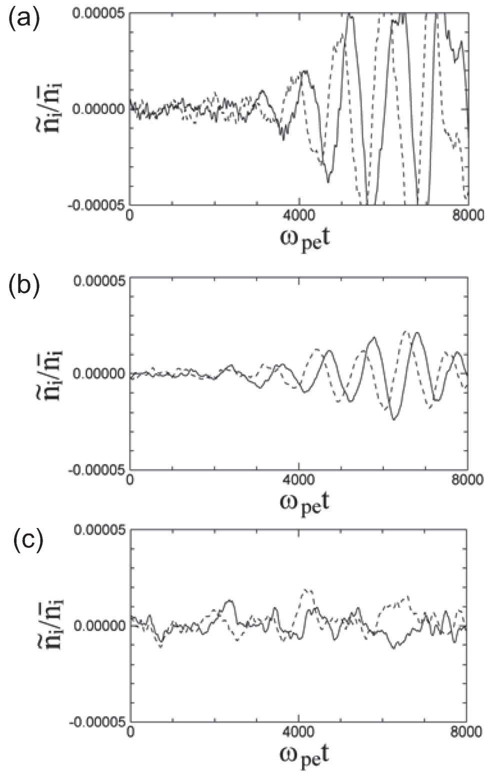

Fig. 2. Time evolution of the real (solid line) and the imaginary (dashed line) parts of the spatial Fourier mode of the positive ion density fluctuation $\tilde{n}_i/\bar{n}_i$ for (a) S=1, (b) S=0.75, and (c) S=0.5.

1) Kaneko, T. *et al.* : Phys. Rev. Lett. **90** (2003) 125001.
2) Kaneko, T. *et al.* : Plasma Fusion Res. (2008) in press.
3) Matsumoto, N. *et al.* : J. Plasma Fusion Res. SERIES, **6** (2004) 707.
4) Kaneko, T. *et al.* : J. Plasma Phys, **72** (2006) 989.