§28. 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] 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 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. From the viewpoint of investigating the general properties of the shear-modified instabilities, the simulation should be performed in the three dimensional (3D) system because in most cases waves propagate obliquely or perpendicularly to the direction of the flow velocity gradient under the influence of the velocity shear.

In our work, a three dimensional electrostatic particle simulation with a periodic boundary model is performed,[2] where an external uniform magnetic field points to the positive z direction. Electrons and positive ions are uniformly loaded in the system at t=0. The system sizes L_x, L_y and L_z are $128\lambda_{De}$, $128\lambda_{De}$ and $512\lambda_{De}$, respectively. Here, λ_{De} is the Debye length. The number of the electrons and the ions per unit cell is 64. The positive ion to electron mass ratio m_i/m_e is fixed at 400. The ratio of the electron cyclotron to electron plasma frequency is $\omega_{ce}/\omega_{pe} = 5$. The parallel ion flow velocity shear is introduced by changing the ion flow velocity v_{di} spatially in the x direction as shown in Fig. 1, where v_{te} is the electron thermal speed.[3] In the first stage of this research, the negative ions are introduced in the system as the multiple ions, where the negative ion to electron mass ratio m_-/m_e is fixed at 1600. The negative ion exchange fraction is defined as $\varepsilon = n_-/n_i$, where n_- and n_i are the negative and positive ion densities, respectively.

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) ε=0 % and (b) ε=25 % in the velocity shear region ($32 < x/\lambda_{De} < 36$), which is indicated by "A" in Fig. 1. According to the frequency spectra of the mode in Fig. 2(a), the observed wave is identified as an obliquely propagating ion-cyclotron wave. The fluctuation amplitude is found to be suppressed when the negative ions are introduced in the system as shown in Fig. 2(b).

In the region of the absence of the velocity shear ($60 < x/\lambda_{De} < 64$) indicated by "B" in Fig. 1, on the other hand, the fluctuation is observed to be enhanced by introducing the negative ions in contrast with the case in the velocity shear region. Based on these results, the introduction of the negative ions affects the growth of the fluctuations depending on the presence or absence of the velocity shear.

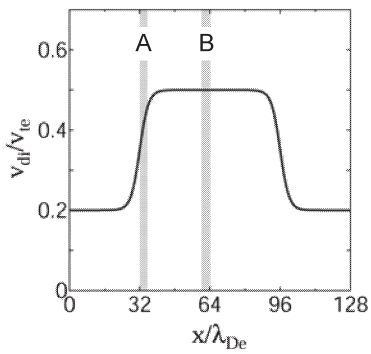

Fig. 1. Profile of ion flow velocity v_{di} in the x direction.

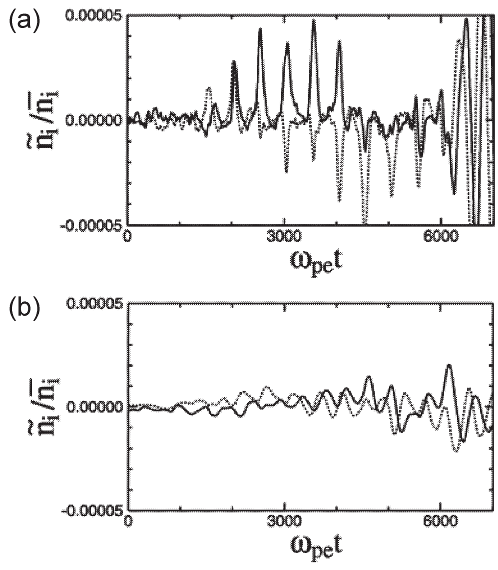

Fig. 2. Time evolution of the real (solid line) and the imaginary (dashed line) parts of the spatial Fourier mode of the positive ion density fluctuation $\tilde{n}_i/\bar{n}_i$ for (a) ε=0 % and (b) ε=25 %.

Reference

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