§28. Low-Frequency Instabilities Due to Flow Velocity Shear in Magnetized Plasmas

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

Field-aligned (parallel) plasma flow velocity shears play an important role in the generation of low frequency plasma instabilities. Recent theoretical works using kinetic treatment have predicted that the parallel flow velocity shear causes electrostatic ion-cyclotron and ion acoustic instabilities.[1] According to the experimental results, on the other hand, it is demonstrated that the ion-acoustic, ion-cyclotron, and drift-wave instabilities are excited and suppressed by the parallel velocity shear, where the destabilizing and stabilizing mechanisms are well explained by the kinetic theory.[2] In the experimental investigation, however, it is difficult to change the shape and the location of the velocity shear, and the plasma parameters such as the ratio of the ion to electron temperature, which are very effective in the growth rate of the shear driven instabilities.

In this sense, a particle simulation is very useful method to clarify the effects of the velocity shear, because the simulation can easily set these parameters. From the viewpoint of investigating the general properties of the velocity shear driven 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,[3] where an external uniform magnetic field directs to the positive z direction. Electrons and 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 electrons and ions per unit cell is 64. The ion to electron mass ratio m_i/m_e is fixed at 400. The ratio of the electron cyclotron to electron plasma frequency is $\omega_{ce}/\omega_{pe} = 5$ and the ion to electron temperature ratio is T_i/T_e=0.5. The time step width Δt is $0.1\omega_{pe}^{-1}$. The parallel ion flow velocity shear is introduced by means of 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.

Figure 2 shows time evolutions of the real (solid line) and the imaginary (dashed line) parts of the spatial Fourier mode of the ion density fluctuation $\tilde{n}_i/\bar{n}_i$ corresponding to the ion-cyclotron wave. This mode is measured in the uniform ion flow velocity region (60 < x/λ_{De} < 64) and in the velocity shear region (32 < x/λ_{De} < 36), which are indicated in Fig. 1 as "A" and "B", respectively.

The ion-cyclotron wave is destabilized in the Region A, when the ion drift speed exceeds a certain threshold. The spiky fluctuations in the time domain are locally observed in the Region B, i.e., in the velocity shear region, which are caused by the simultaneous existence of several coherent ion-cyclotron harmonics. Based on these results, the flow velocity shear is found to enhance not only the fundamental mode but also the high harmonic modes locally in the large velocity shear region.

In conclusion, it is clarified that the parallel ion flow velocity shear can excite the ion-cyclotron wave locally in the velocity shear region. These results are consistent with the analysis based on the local theory.

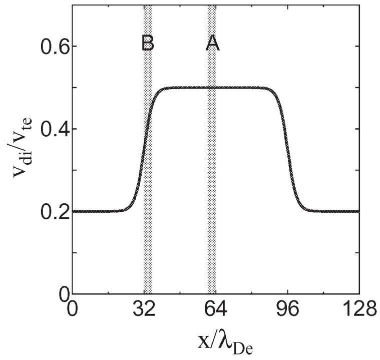

Fig. 1. Profile of ion flow velocity v_{di} in the x direction.

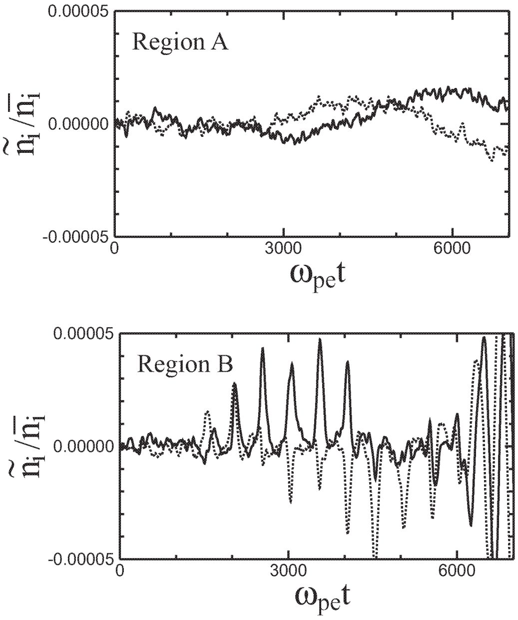

Fig. 2. Time evolutions of the real (solid line) and the imaginary (dashed line) parts of the spatial Fourier mode of the ion density fluctuation $\tilde{n}_i/\bar{n}_i$.

Reference

1) Ganguli, G. *et al.* : Phys. Plasmas **9** (2002) 2321.
2) Kaneko, T. *et al.* : Phys. Rev. Lett. **90** (2003) 125001.
3) Matsumoto, N. *et al.* : J. Plasma Fusion Res. SERIES, **6** (2004) 707.