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

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

Magnetic field-aligned (parallel) plasma flow velocity shear has been regarded as playing an important role in the generation of low-frequency plasma instabilities. In order to experimentally clarify the effects of the velocity shear on the instabilities, we have carried out laboratory experiments and demonstrate that the drift-wave is excited and suppressed by the parallel velocity shear, where the destabilizing and stabilizing mechanisms are well explained by the kinetic theory [1,2]. In the experimental investigation, however, it is difficult to control the shape and the location of the velocity shear, which is 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. Therefore, in order to understand the experimental results and clarify the essential mechanism of the shear driven instabilities, we have attempted to investigate the time evolutions of various spatial Fourier modes of the ion density by using the electrostatic particle simulation.

In our work, a three dimensional electrostatic particle simulation with a periodic boundary model is performed, 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, the shape of which is given by

$$v_{di}(x) = 0.3v_{te} + 0.2v_{te}\exp\left(\frac{x-64\lambda_{De}}{24\lambda_{De}}\right), \quad (1)$$

where v_{te} is electron thermal speed. Figure 1 shows profiles of the ion flow velocity $v_{di}(x)$ in the cases of uniform flow (solid line) and non-uniform flow (dashed line) described by Eq. (1).

Figure 2 (a) shows time evolutions of spatial Fourier mode of the ion density fluctuation $\tilde{n}_i/\bar{n}_i$ with $k_x\rho_i$= 0, $k_y\rho_i$ = 0.137 and $k_z\rho_i$ = 0.069, for the case that the ion flow is spatially uniform (v_{di} = $0.5v_{te}$), i.e., the shear strength $|dv_{di}/dx|/\omega_{ci}$ = 0. The ion density fluctuation is observed not to grow temporally. This is because the ion flow velocity is too small to excite the instabilities. When the ion flow velocity is not uniform, i.e., the velocity shear exists ($|dv_{di}/dx|/\omega_{ci}$ = 0.5), on the other hand, the fluctuation amplitude $\tilde{n}_i/\bar{n}_i$ gradually increases with time, as given in Fig.2 (b). According to the fluctuation frequency in the ion frame $\omega_r \sim 0.002\omega_{pe}$ which is nearly equal to k_zC_s (C_s: ion acoustic velocity), the observed instability turns out to be an obliquely propagating ion-acoustic instability. Since the spatially averaged ion flow velocity in the presence of the velocity shear is $0.37v_{te}$ and is smaller than that (v_{di}=$0.5v_{te}$) in the absence of the velocity shear, the instability is found to be enhanced by not the ion flow but the ion flow velocity shear. This indicates that the parallel flow velocity shear plays an important role in destabilizing the ion-acoustic wave.

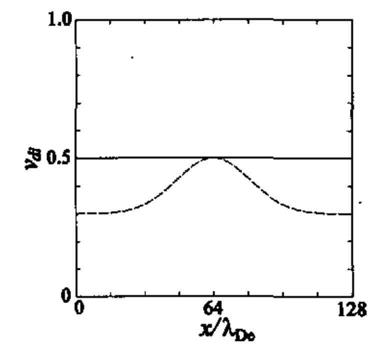

Fig. 1. Profiles of ion flow velocity v_{di} in the cases of uniform flow (solid line) and non-uniform flow (dashed line) in the x direction.

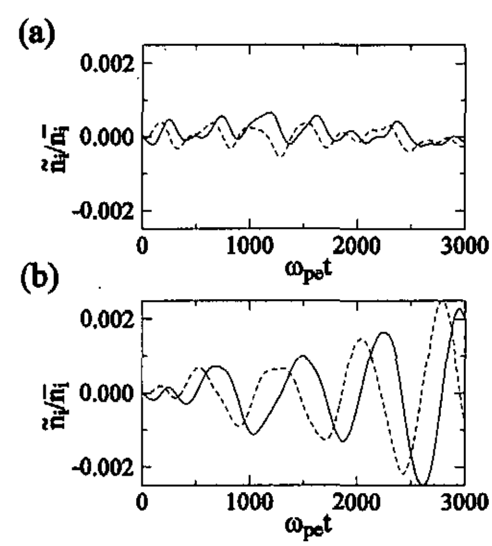

Fig. 2. Time evolutions of the real (solid line) and the imaginary (dashed line) parts of the spatial Fourier mode of the ion density fluctuation $\tilde{n}_i/\bar{n}_i$ (a) in the absence of velocity shear, and (b) in the presence of velocity shear for $|dv_{di}/dx|/\omega_{ci}$ = 0.5.

Reference
1) Kaneko, T., *et al.* : Phys. Rev. Lett. **90** (2003) 125001.
2) Kaneko, T., *et al.* : Phys. Rev. Lett. **92** (2004) 069502.