§27. Formation of Steep Wave Front of Drift Waves in Linear Magnetized Plasmas

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Importance of turbulent structures driven by nonlinear processes of turbulence has been recognized in the study on transport in magnetically confined plasmas [1]. Basic experimental plasmas, such as in linear devices, play important roles for study on nonlinear processes of the turbulence, since detailed measurements of fluctuations are possible. The streamer and the zonal flows have been observed, and the detail nonlinear processes have been studied [2], [3]. The formation of the steep wave front is one of important aspects of the nonlinear waves [4], so that we focus on the formation mechanism of the steep wave front of the solitary drift wave in cylindrical plasmas.

A three-dimensional simulation of resistive drift waves in a cylindrical plasma is performed using the Numerical Linear Device (NLD) code [5]. We focus on high density $n_e \sim 1 \times 10^{19}[\mathrm{m}^{-3}]$ with low temperature $T_e \sim 5[\mathrm{eV}]$ plasmas in an argon discharge. The set of the model equations of the simulation is based on an extension of Hasegawa-Wakatani equations to include the effects of the neutral particle and the nonlinearity of the electron parallel velocity. The details of the simulation conditions are described in [6].

The solitary drift wave is obtained in the regime where the collisional transport is important as well as fluctuation induced transport. The density fluctuation propagates without changing its shape as a solitary wave in the positive azimuthal direction, which is the electron diamagnetic direction. Figure 1 shows a snapshot of the azimuthal structure of the density fluctuation at $t = 6500$ with the fundamental, second and third harmonics modes. The steep wave front can be seen in the azimuthal direction around $-0.5\pi < \theta < 0$, and it faces in the propagation direction. In the region of the steep wave front, all the modes of the fundamental and its harmonics have negative slope so that the steep wave front is formed and is sustained by locking the phase relations among these modes. The phase difference is sustained for a long time compared to the drift wave oscillation, and is almost constant around $\Delta\Psi \approx \pi/2$.

We showed that this phase difference is the stationary solution of the phase evolution equation, which can be derived by focusing on the convective derivative of the density. The solutions of the phase evolution equation are $\Delta\Psi \approx \pm\pi/2$. The solution, $\Delta\Psi = \pi/2$, is that the fundamental mode precedes the second harmonics and the steep wave front faces forward in the propagation direction, and the solution, $\Delta\Psi = -\pi/2$, is related to the steep wave front facing backward in the propagation direction. The stabilities of the stationary solutions are determined by the sign of $\Xi \equiv \partial_r \ln(|\tilde{\phi}|/|\tilde{N}|)$, where $\tilde{\phi}$ and $\tilde{N}$ are the potential and the density fluctuation of the fundamental mode, respectively. When $\Xi > 0$, the solution with $\Delta\Psi = \pi/2$ is stable so that the steep wave front faces forward in the wave propagation direction. When $\Xi < 0$, the solution with $\Delta\Psi = -\pi/2$, which corresponds to the steep wave front facing backward in the propagation direction, is realized. We evaluated Ξ by using the simulation result, and the positive Ξ is obtained. It was confirmed that the simulation result, the steep wave front facing forward in the propagation as in Fig. 1 is consistent with the theoretical prediction.

In summary, the formation mechanism of the solitary drift wave is investigated by using the three-dimensional simulation of the resistive drift waves in cylindrical plasmas. The solitary drift wave forms a steep wave front in the azimuthal direction. The phase differences between the fundamental and second harmonic modes are locked so that the steep wave front is sustained for a long time compared to the drift wave oscillation. The simulation results can be explained by the phase entrainment of the drift waves. The details of this study are described in [6].

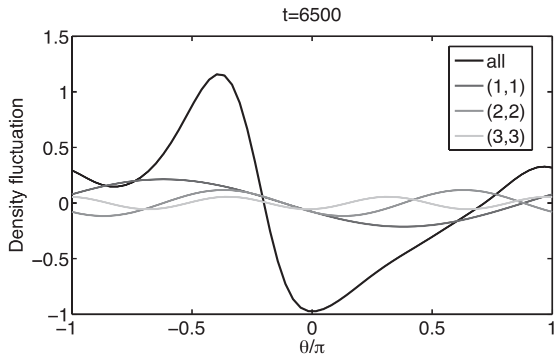

Fig. 1: Snapshot of the azimuthal structure of the density fluctuation at $t = 6500$.

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