§3. Measurements of Flow Velocity Fluctuation in an ECR Plasma

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Plasma turbulence has been intensively studied to understand the structure formation and to control the particle/heat transport. Turbulent electromotive force, turbulence helicity, and the other nonlinear quantities are the key parameters to clarify the structure formation, but the measurement of these quantities has not been performed, so far. We have measured the ion flow velocity fluctuation in an electron cyclotron resonance (ECR) plasma and estimated the nonlinear particle flux as the preliminary experiment of turbulent helicity measurement.

The experiments were performed in the HYPER-I device at NIFS.[1] The HYPER-I device consists of a cylindrical vacuum chamber (2.0 m in axial length and 0.3 m in inner diameter) and 10 magnetic coils. An argon ECR plasma was produced with a microwave (2.45 GHz). To measure the electron density n and the ion flow velocity U, a Mach probe shown in Fig. 1(a) was used. The radial profiles of mean electron density n_0 and mean flow velocity U_0 are shown in Fig. 1(b) and 1(c), respectively. In the plasma center region ($r < 60$ mm), the density is uniform, and the plasma rotates in the azimuthal direction as a rigid-body. The plasma flows in the axial direction, and the axial flow velocity is comparable to the azimuthal rotation velocity in the outer region ($r > 60$ mm).

The frequency power spectra of (a) electron density, (b) axial flow velocity, and (c) azimuthal flow velocity are shown in Fig. 2. In the spectra of density, it is found that a low frequency mode with a frequency of $f \sim 5$ kHz is excited. This mode can also be found in the velocity power spectra, but the radial distributions of power density are different compared with that of density: the amplitude vanishes at $r = 70$ mm in Fig. 2(b) and $r = 90$ mm in Fig. 2(c).

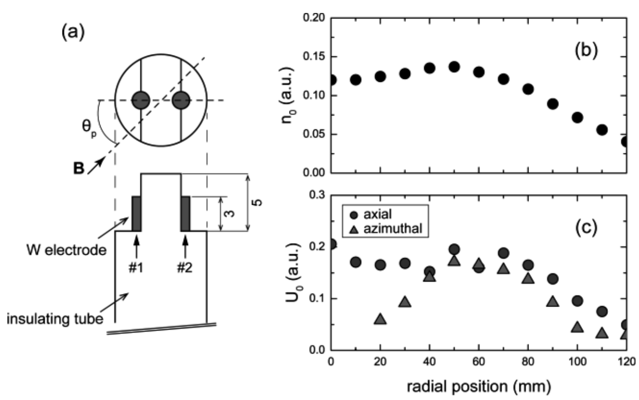

Fig. 1. (a) Schematic diagram of Mach probe. Radial profiles of (b) mean electron density and (c) mean flow velocities.

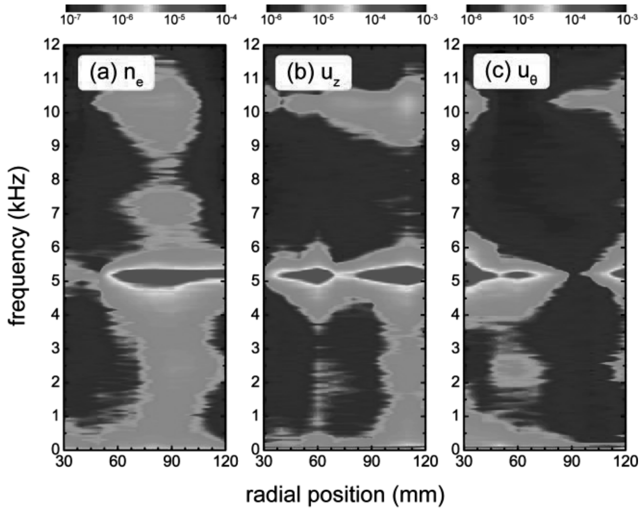

Fig. 2 Radial profiles of frequency power spectra: (a) electron density, (b) axial flow velocity, and (c) azimuthal flow velocity.

To study the nonlinear effect, we have calculated the nonlinear axial flux $\gamma_z = \langle \tilde{n}\, \tilde{U}_z \rangle$ in a frequency range of $f = 3 - 6$ kHz, where $\tilde{n}$, $\tilde{U}_z$, and $\langle\ \rangle$ indicate the density fluctuation, axial velocity fluctuation, and an appropriate ensemble average, respectively. Figure 3(a) shows the radial profile of γ_z. The nonlinear axial flux is large in the plasma edge region. The magnitude of relative nonlinear flux as a function of radial position $|\gamma_z/\Gamma_z| = |\langle \tilde{n}\, \tilde{U}_z \rangle/(n_0 U_{z0})|$ is shown in Fig. 3(b). The nonlinear axial flux is about 7% of the total flux in the plasma edge region. This result indicates that the nonlinear effect associate with the velocity fluctuation affects the flow structure formation.

We have measured the electron density and the ion flow velocity fluctuations with a Mach probe in an ECR plasma. A low frequency fluctuation is observed in both the density and velocity frequency spectra. By estimating the nonlinear axial flux, the considerable contribution of nonlinear effect is found in the plasma edge region. In future work, we will measure the nonlinear kinetic helicity and study the effect of nonlinear helicity on the flow structure formation in turbulent plasma.

1) S. Yoshimura et al.: J. Plasma Phys. **81** (2015) 3481024.

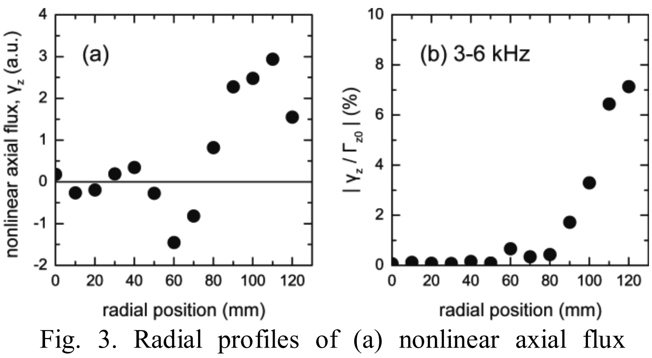

Fig. 3. Radial profiles of (a) nonlinear axial flux ($f = 3 - 6$ kHz) and (b) magnitude of relative nonlinear axial flux, $|\gamma_z/\Gamma_z| = |\langle \tilde{n}\, \tilde{U}_z \rangle/(n_0 U_{z0})|$.