§7. Turbulence Related to the Density Pumping Out by Electron Heating NBI in LHD

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Particle confinement under the electron heating is important, because α particles heat electron in the future reactor. In LHD, tangential injected negative ion source NBI (n-NBI) heat electron predominantly in low density regime. Therefore, low density n-NBI heated plasma is an appropriate example to study particle confinement under future reactor condition. Figure 1 shows an example of time traces of line density and central electron and ion temperatures in the density pumping out discharge. A 1 MW NBI (counter-injection) was injected till t =4.3sec, and 5.9MW NBI (2.5MW co- and 3.4MW counter-injection) was injected from t = 4.1sec. The central electron temperature started to increase after t = 4.1sec, while central ion temperature remained almost constant. This indicates electron heating was dominant. As shown in Fig.1 (a), the reduction of the line density is clearer in the central chords, indicating that density pumping out occurred in the central region. In tokamak, density pumping out was widely observed with ECRH heating [1]. Possible interpretation of density pumping out in tokamak is the outward directed thermo diffusion. The thermo diffusion can induce inward directed particle flux, when ion temperature gradient mode is dominant, but it can induce outward directed particle flux, when trapped electron mode is dominant with higher T_e/T_i. The observation in LHD is similar to the ones in tokamak although heating schema is different.

Figure 2 shows T_e, n_e, fluctuation power and fluctuation phase velocity profiles before and after density pumping out. The fluctuations were measured by the two dimensional phase contrast imaging (2D-PCI) [2]. As shown in Fig.2 (a) and (d), central density reduced around 40% and n_e profiles changed from peaked to flat one. Central electron temperature increased around 50%, although T_e scale length was almost constant. The stiffness of T_e shape is due to the broad deposition of NBI. As shown in Fig.2 (b) and (e), the fluctuations in core region (ρ<0.6) increased clearly with reduction of density in this region. This suggests increased fluctuation induced enhanced density pumping outs. Before density pumping out, most of fluctuation in core region propagated to the electron diamagnetic direction (e-dia.), and it reversed to the ion diamagnetic direction (i-dia.). Plasma rotation is not measured with spectroscopy in this discharge, although neoclassical ambipolar condition predicts around 0.5km/sec in e-dia. directed rotation both before and after density pumping out. It is not clear if the change of the fluctuation propagation direction is due to change of the plasma rotation or change of the fluctuation nature. In tokamak, linear theory predicts that the trapped electron mode induces outward thermo diffusion and e-dia. propagation in plasma frame. If neoclassical estimation of plasma rotation is correct, then fluctuation propagates to i-dia, direction after density pumping out. It is different results from expectation of tokamak linear theory. Further theoretical investigation and poloidal rotation measurements are required for detail understanding density pumping out in LHD.

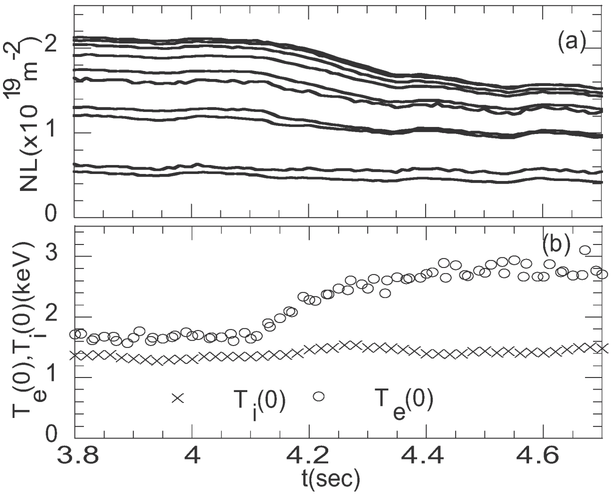

Fig. 1 Time history of (a) line density and (b) central electron and ion temperatures Upper and lower trace of Fig.1(a)indicate toward central and edge positions respectively.

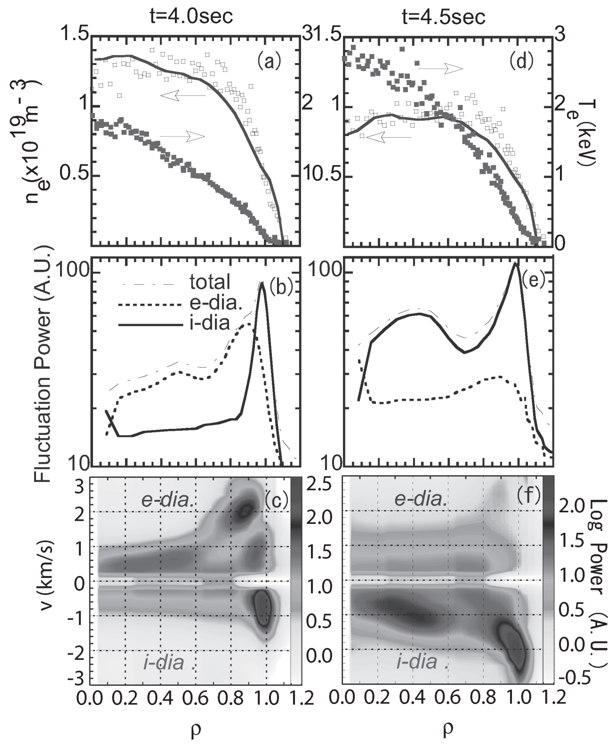

Fig.2 Comparison n_e and T_e profiles (a), (d), fluctuation power profiles and (c), (f) fluctuation phase velocity profile. (a)~(c) at t=4.0sec before and (d)~(f) at t=4.5sec after density pumping out respectively. Fluctuation wavenumber is ploidally dominated, phase velocity is in the laboratory frame.

1) Angioni, C., et al., Nucl. Fusion,44,827,(2004)
2) Michael, C., et al., Rev. Sci. Instrum. **77**, 10E923,(2006)