§9. Density Modulation Experiments in Detached Plasma of LHD

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Detached plasma is one of the important plasma operation to reduce heat load on divertor plate. In LHD, a sustainment of stable detached plasma is realized at outwardly shifted configuration, where the magnetic axis position (R_{ax}) is 3.9m with resonant magnetic perturbations (RMP)[1]. RMP at R_{ax} =3.9m forms m/n=1/1 island in the edge ergodic layer. Although applying RMP enhances particle transport [2], an improvement of global confinement time was found after detach phase with RMP[1]. In order to understand the particle transport of detach plasma, density modulation experiments are done and the effect of ion scale micro turbulence, where $k\rho_i$=0.1-1, are studied by using a two dimensional phase contrast imaging (2D-PCI) [3].

Figure 1 shows time trace of line averaged density and line integrated fluctuation in attached and detached plasma. Both are modulated at 2.5Hz by external fueling modulation. In attached plasma, density is clearly modulated and fluctuation follows density modulation suggesting that density gradient play a role on saturation mechanism of turbulence. While in attached plasma, fluctuation amplitude does not flow change of the density clearly suggesting that saturation mechanism of turbulence is different. Figure 2 shows comparisons of profiles. In Fig.2 (a-2) and (b-2), modulation amplitude profiles are shown from the difference of the density profiles at 6.1 and 6.3sec. As shown in Fig.2 (a-1) and (a-2), in attached phase, modulation amplitude profiles are similar to the background profiles. While in detached phase, modulation amplitude is hollowed compared with background profiles as shown in Fig.2 (b-1) and (b-2). Higher diffusion induces larger penetration and small phase shift in density modulation experiment, when convection is small. Thus, it is likely that Fig. 2. (a-2) shows small phase shift and deeper penetration suggesting higher diffusion in attached plasma and Fig.2 (b-2) shows shallow penetration and larger phase shift suggesting lower diffusion in detached plasma. However, estimation of difference of particle source is necessary to understand the particle transport quantitatively. Also, it is preferable to compare attach and detach plasma in similar collisionality since particle transport has strong dependence on collisionality [2].

Fluctuation has two peaks in space on both detached and attached plasma. One is at |reff/a99|=0.8, the other is at |reff/a99|=1.15. The shape of the spatial profile is clearly different in attached and detached phase. In attached phase, the fluctuation amplitude is almost symmetric in upper (positive reff/a99) and lower (negative reff/a99) side of equatorial plane as shown in Fig.2 (a-4), but in detached phase, fluctuation at |reff/a99|=1.15 becomes highly asymmetric as shown in Fig.2 (b-4). The increase of the fluctuation at transition from attached to detached phase at t=4.3sec of Fig.2 (b) is likely due to the increase of the turbulence at reff/a99=-1.15. This edge turbulence does not repond to the change of the edge density gradient. As shown in Fig. 2 (a-5), (a-6), (b-5) and (b-6), the k spectrum does not change clearly, while phase velocity becomes clearly small in detached phase. These difference of fluctuation profiles may play an important role in change of particle transport in attached and detached plasma.

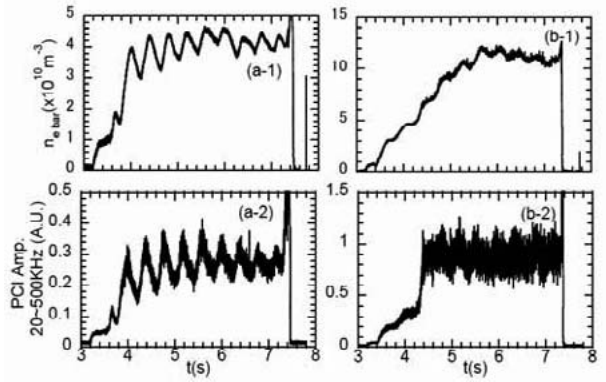

Fig.1 Time trace of line averaged density and line integrated fluctuation amplitude (a-1), (a-2) attached plasma, (b-1),(b-2) detached plasma

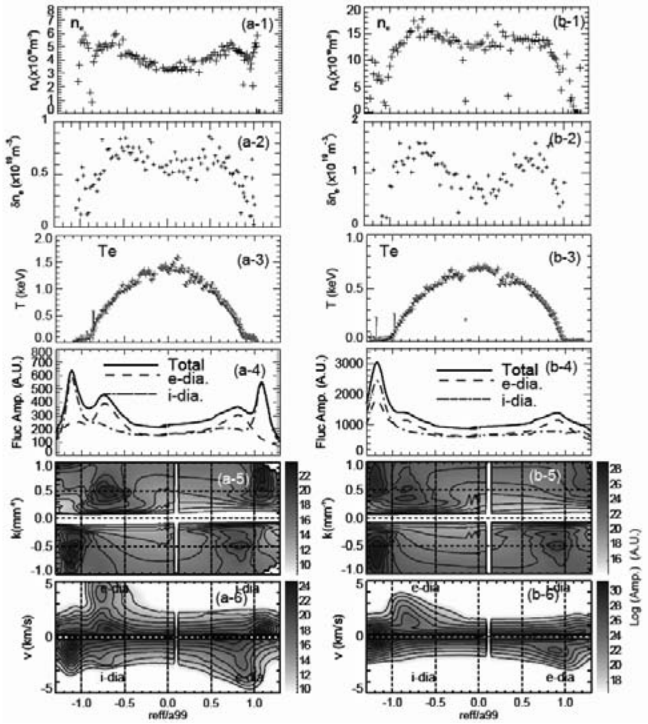

Fig.2 Comparison of profile in attached (a) and detached profile. Ne and Te profile are at t=6.1s. (a-2),(b-2) change of density at t=6.1-6.3s. Fluctuation profiles are obtained from signals at t=6.1-6.3s

1) Kobayashi, M. et al., Nucl. Fusion **53** (2013) 093032
2) Tanaka. K., Plasma Fusion Res. **8** (2013) 2402141
3) Tanaka. K., et al., Rev. Sci. Instrum. 79, 10E702 (2008)