§40. Density Clamping Phenomena by ECRH

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Density clamping or pump out phenomena are observed both in tokamaks and helical systems during high power heating, in particular electron cyclotron resonance heating. These phenomena are discussed in terms of the enhanced electron diffusion induced by the perpendicular acceleration in velocity space and the resultant electric field [1]. It is also pointed out that the change in the electron temperature profile can enhance radial flux due to a non zero off-diagonal term in the transport matrix which can be appreciable by the excitation of turbulent instabilities like trapped electron modes[2]. Such degradation of particle confinement is also observed in a tangential negative ion neutral beam (N-NB) heated plasma in LHD for low density discharges, where electron heating is dominant but heating in parallel to the magnetic field. Such observation also supports the enhancement of the off-diagonal transport term. In order to distinguish both effects, series of experiments are performd. High power second harmonic local ECRH is applied on the ripple top or bottom resonance position where the width of the loss cone is wider for bottom than that for top, but expected power deposition profile is identical to each other in LHD.

In order to enhance the difference in the electron flux by ECRH, the heating positions and magnetic field strength are selected so that the toroidal ripple top and bottom are heated but keeping the identical normalized radial position on the same vertically elongated cross section. The magnetic field strength is adjusted to meet the second harmonic resonance condition (1.5 T for 84 GHz) at desired position. These configurations are chosen so that the power deposition profile estimated from the multi-raytracing code is identical for both cases. In both cases, density decrease is observed by applying ECRH, but the time behavior of the decrease in the density clearly changes as the heating position. The line averaged density decreases faster in ripple bottom heating case than in top one. The decrease rate saturates in the time constant of 200 ms for the bottom heating case, while that for the top heating case keeps constant during the ECRH injection of 500 ms. Electron temperature increases within 100 ms and keeps almost constant during the injection for both cases. The profile changes of density reconstructed from a multi-chord FIR interferometer are shown in Fig.1. It should be noted that the density drops at $\rho > 0.4$ but central part does not affected by the ECRH injection for top heating case, while that drops almost whole region for bottom heating case.

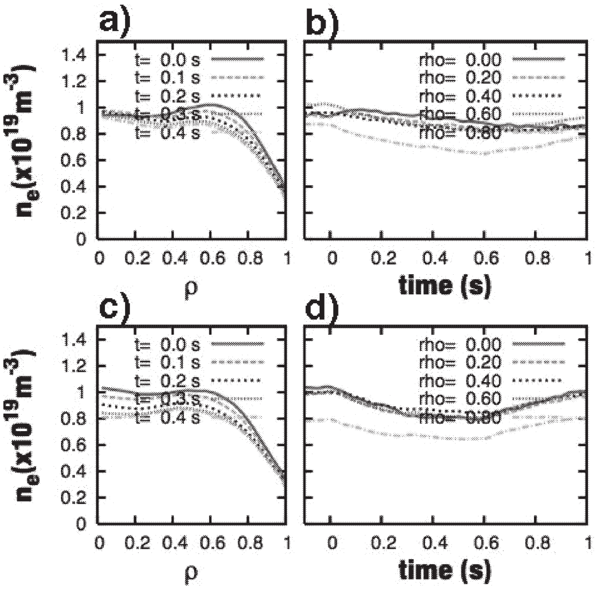

Fig. 1. *Density profile at several time slices after ECH injection [a) and c)]. Time evolutions of the density at several spatial points b), and d) for ripple top [a) and b)] and bottom [c)and d)] heating cases.*

Neglecting the source and sink term other than that due to ECRH, diffusion equation can be written by electron density $n_e(r,t)$and temperature profiles $T_e(r,t)$ as

$$\Gamma_e(r,t) = D_{e,n}(r,t)\frac{\partial n_e(r,t)}{\partial r} + D_{e,T}(r,t)\frac{\partial T_e(r,t)}{\partial r} + \Gamma_{ECH}(r,t). \quad (1)$$

Here, $D_{e,n}(r,t)$ and $D_{e,T}(r,t)$ denote the diagonal and off diagonal electron diffusion coefficient. Then the radial flux can be estimated by integrating the diffusion equation as

$$\Gamma_e(r,t) = -\frac{1}{r}\int_0^r r'\frac{\partial n_e(r',t)}{\partial t}\mathrm{d}r'. \quad (2)$$

by the experimentally observed quantity $n_e(r',t)$. The analysis is underway by comparing this radial particle flux for both cases. As is described above, the temperature profile change occurs only at the beginning 100 ms after ECRH injection for both cases. So the correlation between the deduced flux and the temperature gradient should also be weak. These results indicate that the change in the deduced particle flux for the ripple top and bottom cases are directly driven by ECRH, although the dynamical dependence of the diffusion coefficient on the temperature and its gradient, off-diagonal term and the effect of the radial electric field should be considered more carefully.

references

[1]H. Idei *et al.*, Fusion Engineering and Design **26**, 167 (1995).
[2]C. Angioni *et al.*, Nuclear Fusion **44**, 167 (2004).