§4. Particle Transport Study in Super Dense Core Plasma in LHD

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A highly peaked density profile was obtained in pellet-injected discharges in LHD. The peaking factor, which is the ratio of the central to volume-averaged densities, increased from around 0.8 in the gas puff fuelled phase, up to more than 2.0 after multiple pellet injection. The core density reached to several times 10^{20}m^{-3}. This operation is called "Super Dense Core" (SDC) and is attractive high density operation regime in the future reactor [1]. Figure 1 shows examples electron density (n_e) and electron temperature (T_e) profiles after pellets injection in SDC shot at magnetic axis position (R_{ax}) is 3.75m, toroidal magnetic field (Bt) is 2.64T. The final pellet was injected at t=1.3sec. From t=1.3~1.5sec, density decreased keeping peaking factor constant (~1.8), the density profile started peaking again during t=1.5~1.8sec. This additional peaking was achieved by quicker decay of density in edge region than ones in core region. At t =1.8sec, the density peaking factor reached 2.8. After t=1.8sec, core density decayed quicker than edge density, then, density profile became broad and the density peaking factor decreased down to 1.7 at t= 2.17sec.

The particle confinement characteristics were studied from the relation between normalized particle flux and normalize density gradient [2]. The particle balance is given by the following equations.

$$\frac{\partial n_e}{\partial t} = -\nabla\cdot\Gamma + S = -\frac{1}{r}\frac{\partial}{\partial r}r\Gamma + S \qquad (1)$$

$$\frac{\Gamma}{n_e} = -D\frac{\nabla n_e}{n_e} + V \qquad (2)$$

Here, Γ is particle flux, D is diffusion coefficient, V is convection velocity and S is particle source rate. Since time derivative of density is much larger than S after pellet injection, thus, S can be neglected and particle flux can be estimated only from the temporal evolution of local density. Then, D and V can be estimated from the plot of eq.(2). The gradient of the plot gives D and offset of the linear fitted line gives V. Figure 2 shows plot of Γ/n_e vs $-\nabla n_e/n_e$ at ρ=0.5. During additional peaking and broadening phase, D and V can be estimated. Figure 3 show D and V profiles estimated in SDC shot and one from density modulation in low collisionality regime. In SDC discharge D and negative V (inward directed) increase toward the edge. This is strong contrast with the low collisionality modes where D is spatially almost constant and V is outward directed in low collisionality regime。 The additional density peaking was achieved by the enhanced D and inward V, density broadening was achieved by the reduced D and inward V. Figure 4 shows collisionality (νb*), which is normalized by the bounce frequency, dependence of D and V. Density modulation and SDC analysis provide the data of low and high νb* regimes. Figure 4 suggests the minimum D with zero convection is obtained at νb*=1~5. This regime might be favorable for the future reactor operation with good particle confinement but without impurity accumulation.

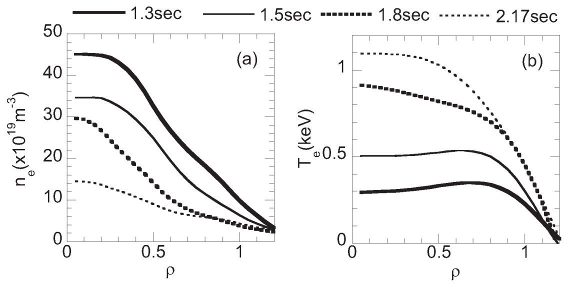

Fig.1 Time history of (a) n_e and (b) T_e profiles of SDC discharge

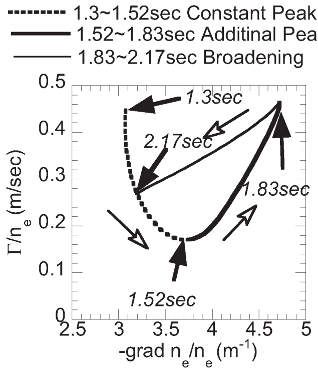

Fig.2 Time trace of Γ/n_e and –grad n_e/n_e at ρ=0.5

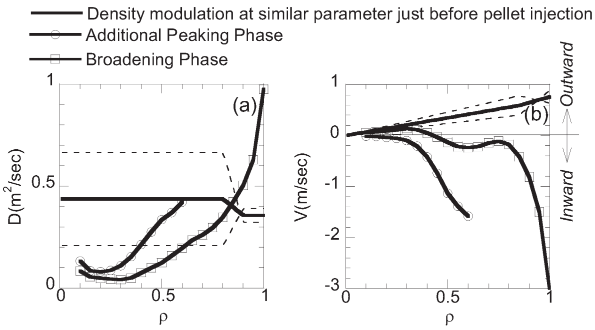

Fig 3. Profiles of (a) the diffusion coefficient (D) and (b) the convection velocity (V)

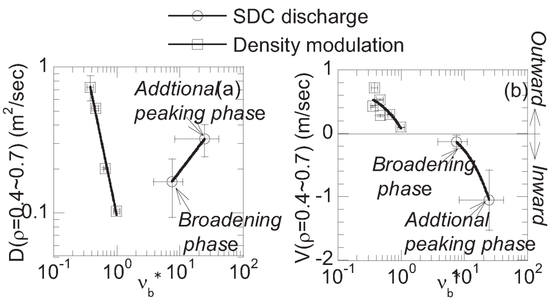

Fig.4 Collisionality dependence of (a) the diffusion coefficient (D) and (b) the convection velocity (V)

1) Oyabu N *et al.* 2006 *Phys. Rev. Lett.* **97** 055002-1
2) Tanaka K *et al.* 2008 to be published Journal of Physics Conference series