§18. Reduction of Divertor Heat and Particle Loads with Neon Seeding

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Reduction of heat and particle loads to divertor is a crucial issue to realize fusion reactor. Divertor detachment is a favorable operation for the purpose. To achieve divertor detachment, reduction of electron temperature (T_e) in scrape-off-layer (SOL) is necessary. In present medium/large fusion devices, plasma facing material has been carbon, and carbon works as dominant radiator for reduction of T_e. However, carbon will not be utilized in fusion reactor to reduce tritium retention in vacuum vessel and to avoid large erosion of plasma facing components, and metallic material such as tungsten will be plasma facing material. Therefore, it is considered that impurity such as neon seeding is necessary to enhance radiation loss in SOL. In tokamaks, impurity seeding experiment has been conducted, and reduction of T_e in SOL has been observed.[1)] Against this background, neon seeding experiment was conducted in LHD which has unique magnetic field line structure such as existence of stochastic layer in SOL.

Figure 1 shows time evolutions of plasma parameters in a Ne seeding discharge with line average density ($n_{e,bar}$) of $5\times10^{19}m^{-3}$. Ne gas-puffing was conducted from t = 4 s for 120 ms. The Ne gas flux was ~ 1.6 Pa·m^3/s, and it is about 10 % of H_2 gas flux at t = 4 s. Total radiation power (P_{rad}) rose from 2 MW (~$0.15\times P_{NBI}$) to 4 MW (~$0.3\times P_{NBI}$) during Ne puffing. It is clearly shown that both divertor electron density ($n_{e,div}$) and T_e ($T_{e,div}$) decreased with Ne seeding. That means particle and heat loads to divertor were reduced. Ne seeding did not affect strongly global parameters such as plasma stored energy and $n_{e,bar}$. Figure 2 shows modification of the radial profiles of electron density (n_e) and T_e, respectively, due to the Ne seeding. In SOL and near LCFS in core plasma, n_e slightly increased, but center n_e did not change. Figure 2(c) shows T_e ratio between after and before Ne seeding. It is shown that T_e decreased in SOL, but there was almost no change in core plasma as n_e profile. They are good features of Ne seeding. Ne seeding in low density discharge ($n_{e,bar}$ ~ $2\times10^{19}m^{-3}$) was also conducted, and reduction of divertor loads was also observed. In this case, P_{rad}/P_{NBI} reached 0.5, though n_e and T_e in peripheral region in core plasma increased and decreased, respectively.

Ne seeding was also applied to Super Dense Core (SDC) discharges with pellet fueling,[2)] and reduction of the divertor loads was confirmed.

In LHD, other methods to reduce the divertor loads such as divertor detachment with magnetic island formation[3)] and SERPENS mode[4)] have been conducted. But they cannot be applied to inward shifted magnetic axis configurations up to now, and they need high density plasma. It should be noted that Ne seeding can be applied to inward shifted configurations and relatively low density plasma ($n_{e,bar}$ ~ $2\times10^{19}m^{-3}$).

1) Asakura, N. et al.: Nuclear Fusion **49** (2009) 115010.
2) Ohyabu, N. et al.: Physical Review Letters **97** (2006) 055002.
3) Kobayashi, M. et al.: Physics of Plasma **17** (2010) 056111.
4) Miyazawa, J. et al.: Nuclear Fusion **46** (2006) 532.

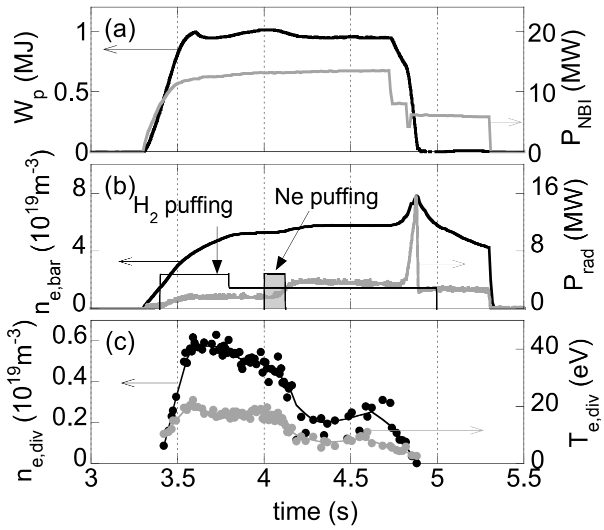

Fig. 1. Typical time evolutions of (a) plasma stored energy (W_p) and NBI power (P_{NBI}), (b) line averaged density ($n_{e,bar}$), radiation power (P_{rad}) and gas-puffing, (c) electron density ($n_{e,div}$) and temperature ($T_{e,div}$) in the divertor (torus inboard-side). (#103833, R_{ax}=3.60m, B_t=−2.8T, γ=1.2538, B_q=100%)

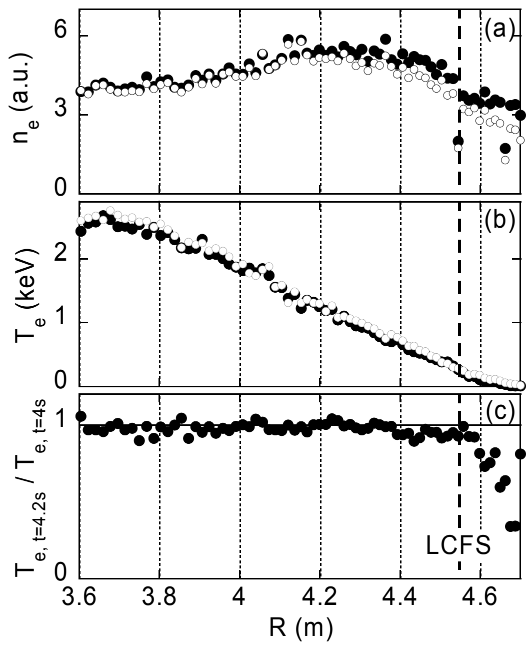

Fig. 2. Radial profiles of (a) electron density (n_e), (b) T_e before (t = 4 s, ●) and after (t = 4.2s, ○) Ne seeding, respectively, and (c) T_e ratio between after and before Ne seeding in the same discharge as Fig. 1.