§3. Achievement of High Ion Temperature with Neon Injection

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The injection energy of the LHD-NBI system is so high, more than 150 keV (H), that the electron heating power would be dominant. Therefore, the effective ion heating power should be enhanced to raise the ion temperature. In the 5th experimental campaign the third injector was installed, and the injection power was much increased to 9 MW with a hydrogen beam energy of around 160 keV. In order to increase the plasma absorption power of the high-energy neutral beams in low-density plasmas, neon gas was injected, instead of hydrogen or helium gas. Figure 1 shows the comparison of the neon-injected plasma with the hydrogen one in R_{axis}=3.53m. Although the port-through NBI power is almost the same, around 8 MW, in both cases, the ionized beam power (plasma absorption power), estimated from the shine-through power measurement, is about 1.3 times larger in the neon plasma at t=1.0sec (n_e=1x$10^{19}$$m^{-3}$). The ion temperature in the neon plasma is higher by about 1 keV than that in the hydrogen plasma. Figure 2 shows the central ion temperature as a function of the plasma absorption power normalized by the line-averaged electron density for both neon and hydrogen plasmas in R_{axis}=3.6m. Since the Z_{eff} of the neon plasmas is higher, the beam ionization rate is 1.5 – 2 times larger than that in the hydrogen plasmas for low-density target plasmas below 1x10^{19} m^{-3} in R_{axis}=3.6 m. From the comparison of the beam ionization rates between the neon and the hydrogen plasmas, the Z_{eff} of the neon plasmas is roughly estimated to be 2 times larger than that of the hydrogen plasmas. Assuming that the Z_{eff} of the hydrogen plasmas is around 3, the ion density of the neon plasmas is nearly a half of that of the hydrogen plasmas. Since the electron temperature is not so different, the effective ion heating power rate is double for the neon plasmas. As shown in Fig. 2, the ion temperature in the neon plasmas is increased linearly to the normalized absorption power and reaches 5 keV, while it is lower and is saturated in higher powers in the hydrogen plasmas. The effect of the neon gas injection can be explained by the increase in the absorption power and the enhancement of the direct ion heating power with a reduced number of ions.

The transport analyses of the neon plasmas show that the electron transport is not largely changed compared with the hydrogen or helium plasmas. On the other hand, the ion transport cannot be locally analyzed as the ion temperature profile is not measured. The collisionality of neon ions is large and in the plateau regime because the ion collisionality depends on Z^3. The ion thermal diffusivity, roughly estimated by assuming that the ion temperature profile is parabolic, is 2 – 5 m^2/s in the neon plasmas, and is nearly the same as or a little bit larger than that in the hydrogen plasmas the collisionality of which is smaller by 1 – 2 orders of magnitude. The linear increase of the ion temperature in the neon plasma could be ascribed to the neon ions in the collisional plateau regime, while the hydrogen ions in the collisionless 1/ν regime could lead to the saturation of the ion temperature in the hydrogen plasma.

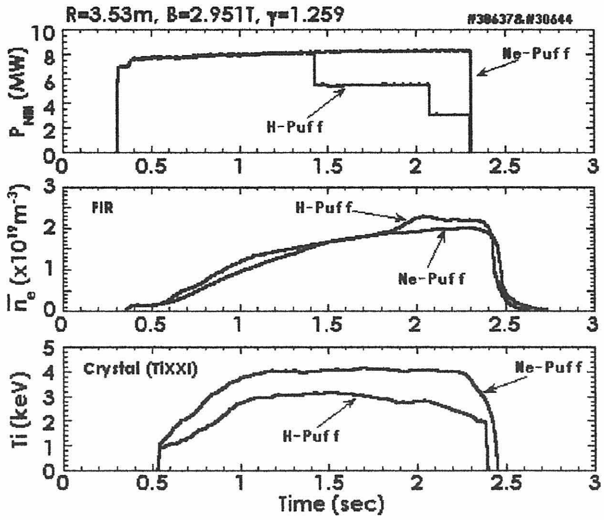

Fig. 1 Time evolution of the plasma parameters for the neon and the hydrogen discharges.

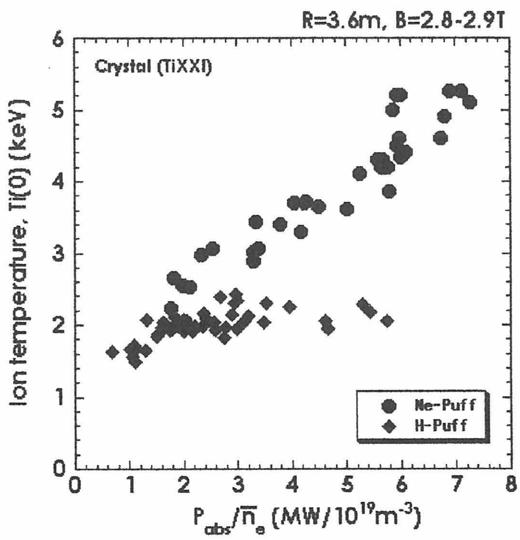

Fig. 2 Central ion temperature as a function of the plasma absorption power normalized by the electron density for the neon and the hydrogen plasmas.