§ 2. Achievement of a High-Ion Temperature in Argon-Seeded Discharges by High-Energy NBI Heating

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The Large Helical Device (LHD) is equipped with a negative-ion-based neutral beam injection (NBI) system, which consists of three tangential injectors. Since the injection energy of hydrogen is as high as 150 – 180 keV, most of the ionized beam power goes to electrons, and, moreover, a large part of the injected beam passes through the plasma without ionization in low-density hydrogen plasmas. As a result, the achieved ion temperature has been less than 2.5 keV in such a hydrogen discharge. High-Z discharges are effective to increase the direct ion heating power, because the ionization rate of the injected neutral beam is higher especially in low densities and the ion number density is reduced compared with the electron number density. We already confirmed the increase in the ion temperature in high-Z plasmas with neon-seeded discharges in the 5th experimental campaign [1,2].

The high-Z plasma is diluted with the wall-absorbed hydrogen during the discharge, and a degree of the dilution is large in the low-density plasmas. To realize the low-density and high-Z plasmas, a glow discharge cleaning was intensively performed with neon gas for reduction of the wall-absorbed hydrogen. Successive three nights of Ne-glow discharge cleaning led to a gradual reduction of the residual hydrogen.

To realize the higher-Z discharges with lower-densities, argon gas was puffed to low-density plasmas. Figure 1 shows the time evolution of the various plasma parameters in an Ar-puffed plasma. The central ion temperature is much increased after the Ar gas puff and reaches 7 keV with an injection power of 9.8 MW at an electron density of $0.3\text{x}10^{19}$ m^{-3}. The toroidal rotation is correlated with the increase in the ion temperature, and the toroidal rotation velocity reaches 40 km/s, which is about 30 % of the Ar-thermal velocity.

Figure 2 shows the central ion temperature as a function of the density-normalized NBI absorption power. Although the horizontal axis in the figure is the NBI power divided by the electron density, it roughly corresponds to the ion heating power divided by the ion density. In the Ne-puffed plasma, the ion temperature is achieved to about 5 keV at an electron density of around $1\text{x}10^{19}$ m^{-3}, and is decreased below this density, probably because the ion number is not so relatively reduced due to the background hydrogen ions. In the Ar-puffed plasma, on the other hand, high-Z discharges are kept in lower densities less than $1\text{x}10^{19}$ m^{-3} due to its higher charge number. As a result, the density-normalized power is extended to higher values and the ion temperature is proportionally raised to 7 keV.

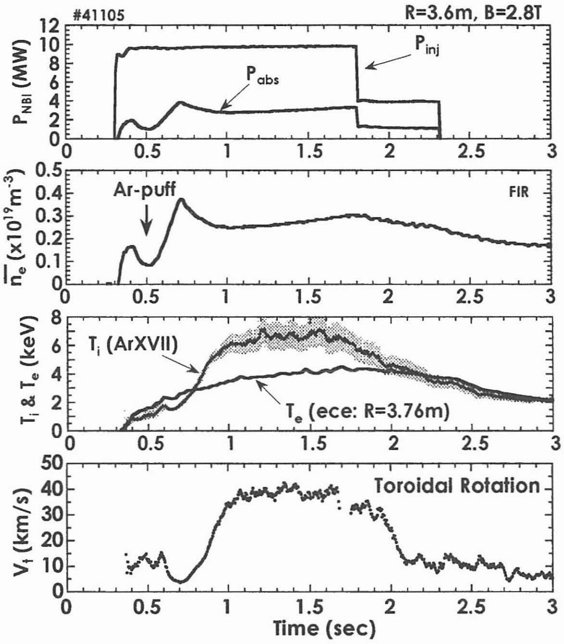

Fig. 1 Time evolution of the various plasma parameters in an Ar-puffed plasma. The central ion temperature is measured with the Doppler broadening of Ar XVII.

The above results suggest that a high ion temperature should be achieved as well in hydrogen discharges if the direct ion heating power is increased to the same power as that in the Ar-seeded discharges.

[1] Y. Takeiri, *et al.*, Phys. Plasmas **10**, 1788 (2003).
[2] S. Morita, *et al.*, 19th IAEA Fusion Energy Conference, Lyon, 2002, EX/P2-18.

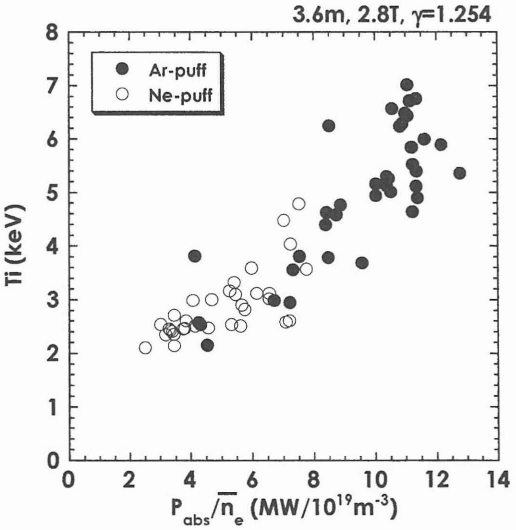

Fig. 2 Central ion temperature as a function of the density-normalized NBI absorption power.