# §65. Recent Progress on High Ion Temperature Experiment in the LHD

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We had achieved the ion temperature of Ti=13.5keV on the argon discharge with the high-energy neutral beam heating (NNBI) of 10.5 MW in the 8th experimental campaign. Argon discharge is effective to improve the ion heating power even with the high-energy neutral beam. These experiments contributed to the research of the high temperature plasma above the 10keV

On the other hand, it is more important task to improve an ion temperature on a hydrogen discharge or a helium discharge that will be used for a fusion device. High-energy neutral beam is mainly deposit on electrons in the hydrogen plasma. Hydrogen beam sopping cross-section used the beam energy of 40keV is three times larger than the cross-section used the beam energy of 180keV. So we have adopted the low-energy NBI (PNBI) system to improve the hydrogen ion heating. Hydrogen neutral beams are injected perpendicularly with the beam power of 3MW at the beam energy of 40keV. Shine through ratio is designed to 50% at the electron density of $n_e=1\times10^{19}m^{-3}$. The tasks of the high temperature group are the improvement of the hydrogen ion temperature and the measurement of a fine ion temperature profile used the charge-exchange recombination spectroscopy (CXRS) in the 9th experimental campaign.

We have achieved the ion temperature of Ti=2.6 keV measured by the ArXVII X-ray spectroscopy on the hydrogen discharge with the heating of 11.5MW NNBI and 2.2MW PNBI at the shot number of 60502. The electron temperature and the averaged electron density is $T_e$=3.3keV from the Thomson scattering and the $\langle n_e \rangle=1.5\times10^{19}m^{-3}$ from the far-infrared interferometer, respectively.

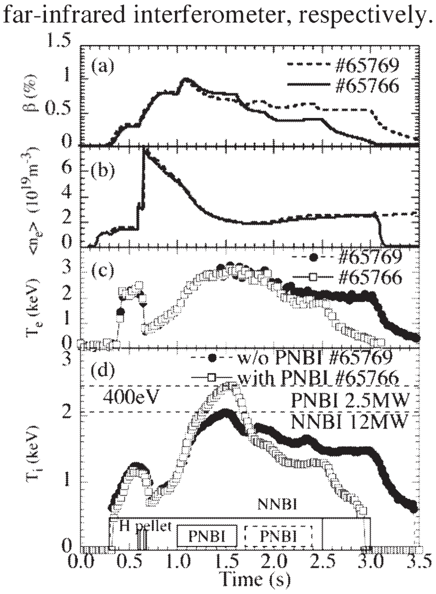


Fig. 1. Heating effect of hydrogen plasmas by PNBI

Figure 1 shows the effect of the PNBI with the power of 2.5MW at the energy of 40keV. Initial plasma is build up by ECRH and then it is sustained by NNBI heating. Electron density increases with the hydrogen ice pellet. The ion temperature increases to 2keV when the heating power of 12MW used three NNBIs. The ion temperature is improved to 2.4keV when we use the additional PNBI heating at the peak ion temperature. Ion heating power evaluated by the absorption efficiency and the ion heating efficiency is 1MW。 So the Ti increasing rate of $T_i/(P_i/n_i)$ is estimated to be $0.8keV/(MW10^{19}m^{-3})$ that is consistent of previous high-Z experiments.

We have installed two CXRS systems to measure the ion temperature profile. One views the plasma perpendicularly from the LHD 5-O port along the PNB used the convex mirror inside of the vacuum chamber, the other views the plasma tangentially from the LHD 7-T port along the NNB. Visible carbon charge exchange spectrum is used for the measurement. We have clearly observed the ion temperature profile in two sight lines with the time resolution of 50ms. Figure 2(a) shows the fine profile of the ion temperature measured by the poloidal CXRS. The peak ion temperate is 2.2keV at t=2.1s with a PNB injection and a pellet fueling. In the gas-puff case, the electron density becomes hollow profile then we have not observed the increasing of the ion temperature around the plasmas center. The ice pellet is effective to increase the center ion temperature because the electron density peaks around the plasma center in the decay phase of the density at t=1.8s. We have also observed the increasing of the ion temperature around the center by the CXRS used NNBI as shown in Fig. 2(b). These results will expect the increasing of the ion temperature and formation of the ion internal transport barrier if we will improve the ion heating power at the plasma center using PNBI heating.

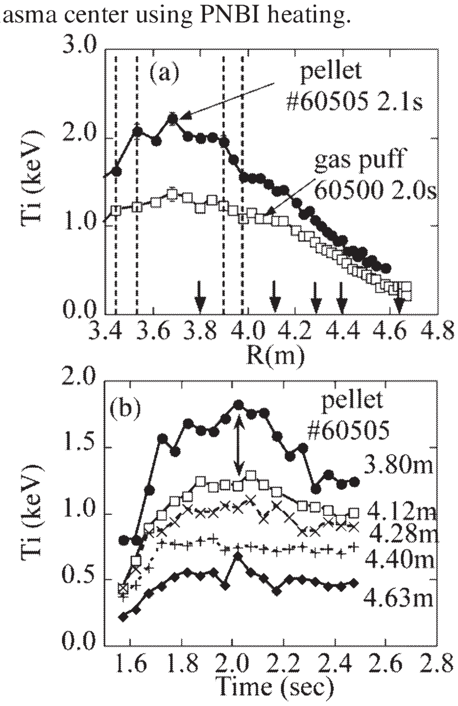


Fig. 2. Profile of the ion temperature from CXRS used PNBI (a). Time evolution of the ion temperature measured by the CXRS used NNBI (b)