§2. Electron Heating with Perpendicular Neutral Beam Injection in Low and High Density Plasmas

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In JIPP T-IIU, the principal plasma heating method is neutral beam injection (NBI) heating, where a hydrogen beam with up to E=30keV energy is injected nearly perpendicular to the plasma. Depending on the electron temperature of a target plasma, NBI power is divided into electrons and ions of the target plasma. In ohmically heated plasmas of JIPP T-IIU, the electron temperature at the center T_{eo} is usually less than 1.8 keV. Therefore, more than 50 % of NBI power is deposited to electrons, and they are heated up in the beam slowing down time

$\tau = (\tau_\varepsilon^{ei}/1.5)[1 + (E/E_{cr})^{3/2}]$

where $E_{cr}=15T_e[A_b^{3/2}\Sigma(n_iZ_i^2/n_e/A_i]^{2/3} \sim 9.4\,T_e$ for the case the a hydrogen beam is injected into a deuterium plasma. We have studied electron heating by NBI in low and high density regimes.

In the low density discharge shown in Fig.1, electron temperature is fairly high ($T_{eo} \sim 1.5$ keV). In this discharge, the slowing down time τ is estimated to be about 40 ms, where averaged temperature and density are assumed to be 500 eV and 0.8 x 10^{19} m^{-3}. The electron density begins to increase continuously at the same time with NBI pulse. This is explained by particle fueling from NBI, of which fueling rate is estimated to be ~ 3 x 10^{19} m^{-3}/s, since particle recycling is not enhanced by a considerable amount of passed-through beam particles. As shown in Fig.2, bulk electrons are cooled due to the density rise in the beam slowing down time $\tau \sim 50$ ms. In the latter half of NBI, electrons are heated up and electron temperature is gradually increased, which is predicted from soft X-ray measurement. The sudden increase of ECE signals are related to the velocity space instability excited by a large amount of energetic electrons generated during NBI.

On the other hand, in high density (> 4 x 10^{19} m^{-3}) and relatively low electron temperature (T_{eo} ~600 eV) discharge obtained just after boronization, electrons are effectively heated up by NBI of about 500 kW absorbed power with short time delay (Fig.3), where the slowing down time is estimated to be about 1 ms.

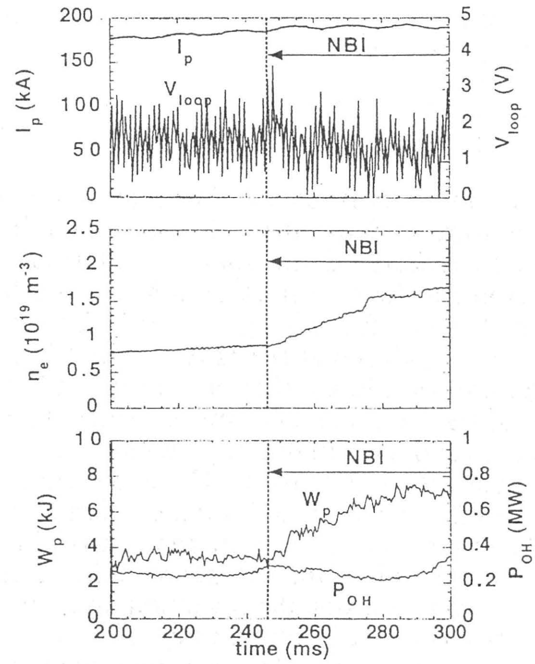

Fig.1 Time evolution of NBI heated low density plasma, where toroidal magnetic field Bt=2.9 T.

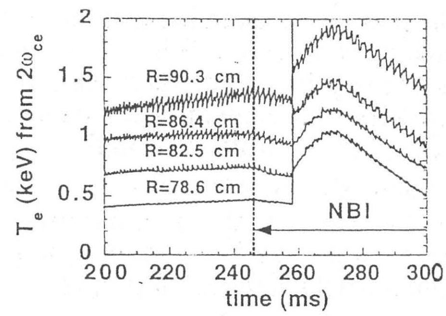

Fig.2 Time evolution of electron temperature measured by ECE polychromator in the discharge shown in Fig.1, where the plasma axis is R~ 92 cm. The sudden rise at 258 ms is due to a non-thermal electron effect.

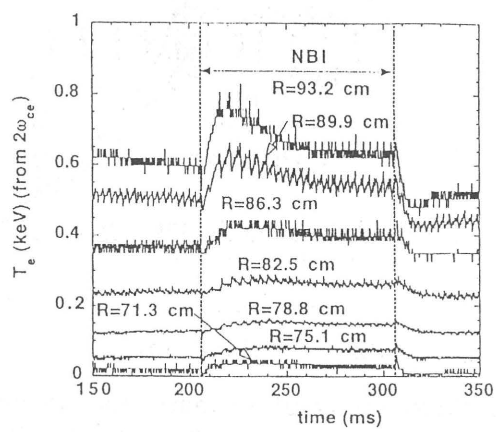

Fig.3 Time evolution of ECE temperature calibrated with YAG Thomson scattering in the high density NBI heated plasma.