§2. Integration of Ion ITB and Electron ITB in the Large Helical Device

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Extension of temperature regime of helical plasmas is a key issue for magnetically confined fusion reaserch and has been progressed in the Large Helical Device (LHD). In the 17th LHD experimental campaign, the integration of ion internal transport barrier (ion ITB) and electron ITB have been tried, and the central ion temperature of 6keV and the central electron temperature of 6keV have been achieved, which is a new regime of helical plasmas.

Figure 1 shows the typical wave form of the plasma with ion ITB and electron ITB formation. The concept of this plasma discharge is superposition of ECH on the ion ITB plasma formed after carbon pellet injection. The ion temperature increases after pellet injection. The perpendicular NBI with beam energy of 40 kV is, of course, effective to increase the central ion temperature, although the ion temperature decreases after the saturation of ion temperature in time. The electron temperature increases from 3.5 keV to 6keV during the application of strongly focused on axis ECH. If the power deposition profile is wide or off-axis ECH, the ion temperature decreases due to ECH. Figure 2 shows the profile of temperatures and density. The ion temperature is always wider than electron ITB. The normalized temperature gradient R/L_T of over 10 are obtained for ion and electron, indicating that both ion and electron heat transports are improved. The radial electric field is measured with heavy ion beam probe (HIBP), and a positive radial electric field is observed, where a negative radial electric field is observed in ion ITB plasmas without ECH[1-2]. It is noted that the ion heat transport is less sensitive to the radial electric field, that is, it can be improved with both negative and positive electric field.

Systematic analysis of similar discharge with ITBs has been performed. It is obtained that the ion heat transport depends on the temperature ratio (Te/Ti). In the high temperature ratio regime of Te/Ti >1, the normalized ion temperature gradient decreases. This dependence is not observed in electron heat transport. This characteristics of heat transport is a cause that the width of ion ITB is always wider than that of electron ITB.

The impurity hole is also formed in this plasma and is stronger that in ion ITB plasma without ECH application. The reversal of toroidal rotation is observed in the core plasma when on-axis ECH is applied and electron ITB is formed in the core region. The physics mechanisms of these interesting phenomena should be understood in near future.

1) K. Nagaoka, et al., Nuclear Fusion 51, 083022 (2011).
2) H. Takahshi, et al., Nuclear Fusion, 53, 073034 (2013)

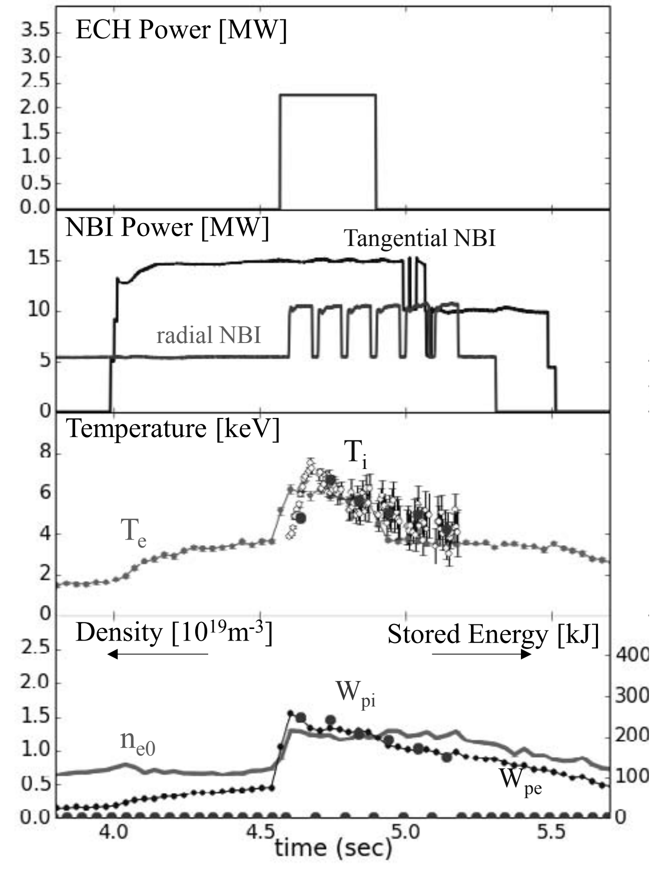

Fig. 1 Wave forms of typical plasma with ion and electron ITB formations.

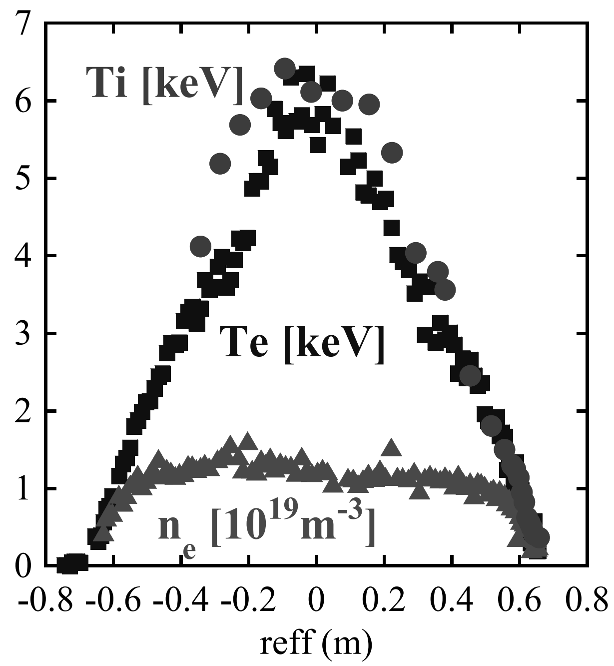

Fig. 2 Profiles of ion and electron temperatures and electron density.