§3. Extension of High-temperature Regime in the Large Helical Device in the Period 2010-2015

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Higher ion temperature (T_i) and higher electron temperature (T_e) have been achieved in the Large Helical Device (LHD) with the upgrade of the heating system and the improvement of the plasma operation. The report shows the summary of the extension of the high temperature regime in the Large Helical Device (LHD) in the period 2010-2015.

Figure 1 shows the dependence of the central ion temperature (T_{i0}) on the ion heating power normalized by the electron density (n_e). New perpendicular NBI (6 MW), which can heat ion effectively due to its low beam energy of 40 keV, was installed in 2010. Then the total NBI power increased up to 28 MW and T_{i0} reached 6 keV. New operation scenario was developed in 2011 with intensive wall conditioning using high power ICRF and/or ECRH. The neutral hydrogen recycling significantly decreased due to the wall conditioning operation and the deposition power in the plasma core region increased, leading to the extension of T_{i0} up to 8.1 keV even though the NBI-port-through power has not been increased since 2010.

Enhancement of the output power per gyrotron has been planned in the LHD and the replacement of the existing gyrotrons with higher-power tubes is in progress. At present, three 77-GHz gyrotrons and two 154-GHz gyrotrons with an output power of more than 1 MW each are operational. The LHD now has 5.4 MW of a simultaneous-injection-ECRH power available for plasma experiments. Figure 1 (b) shows the map of simultaneously attained T_{e0} and the line-averaged electron density (n_{e_fir}) for ECRH discharges. The plasma parameter regime with regard to the electron temperature was successfully extended in high density conditions. The achievements of the central electron temperature (T_{e0}) were 20 keV with the lower n_{e_fir} of 0.2×10^{19} m^{-3} and 10 keV with higher n_{e_fir} of 2×10^{19} m^{-3}.

In future reactors, the fusion reaction is expected to be sustained under the electron heating dominant condition, where both T_i and T_e are high. Thus the characterization of the thermal transport for the plasmas, of which T_i and T_e are simultaneously high, is necessary. In recent years, an integration of high T_i and high T_e with the simultaneous formation of an i-ITB and an e-ITB has been successfully achieved in the LHD by the combination of NBI and ECRH. Figure 1 (c) shows the latest high-temperature operational regime in the LHD. We finely adjusted the ECRH injection angle and the EC wave polarization taking account of the actual plasma profiles in real time. The circles and the squares in Fig. 1 (c) represent the data with and without the adjustment, respectively. The operational regime was successfully extended mainly due to the upgraded ECRH system and the optimization of the ECRH injection. In the present status of the LHD, the envelope of the high-temperature operational regime illustrated in Fig. 1 (c) is determined by the heating power, in other words, by the thermal transport characteristics.

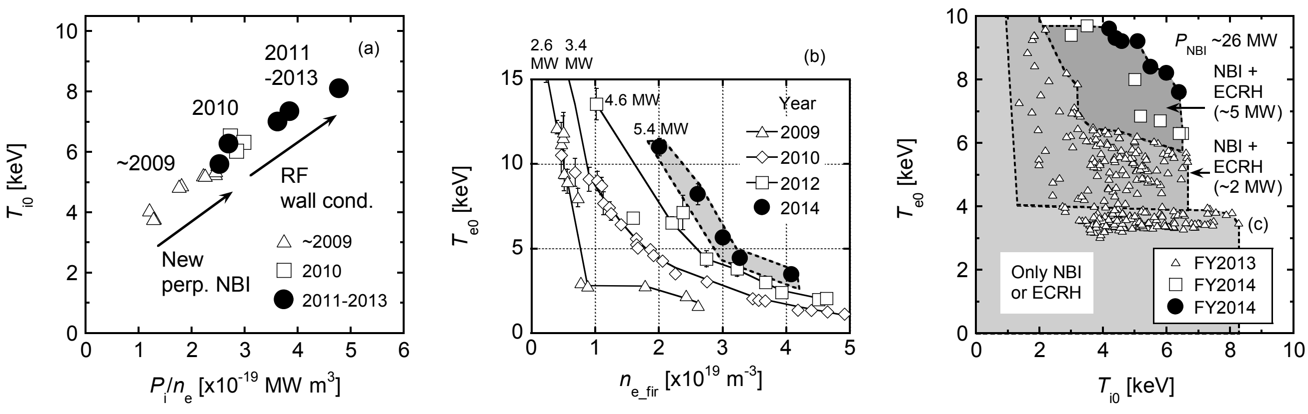

Figure 1. (a) The dependence of the central ion temperature (T_{i0}) on the ion heating power normalized by the electron density (n_e), (b) the map of simultaneously attained T_{e0} and the line-averaged electron density (n_{e_fir}) for ECRH discharges, (c) the latest high-temperature operational regime in the LHD.