§7. Development of Stable High-density Plasma Duration Using Radio-frequency Heating

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Achievement of stable higher-density plasma with electron density of 5 x 10^{19} m^{-3} and temperature over 1 keV is useful to investigate plasma physics for the native instability with low perturbation associated with energetic particles, particle fueling and density controls for plasma material interactions, and stable high-power plasma heating for ion cyclotron hearing (ICH) and electron cyclotron heating (ECH). In ICH, coupling power to plasma was up to 4.6 MW at short pulse discharge with duration time ~ 1 sec using three kinds of ICRF antennas, and relative high-density plasma discharge has been performed using ICH.

In FIY2013, FAIT (field-aligned impedance transform) antenna as a one of ICRF antenna was installed in LHD, and large imaginary antenna loading was demonstrated with relatively small excitation face area for ICH antenna. Since FIAT antenna has impedance transformer, which is up to imaginary antenna loading just in front of vacuum vessel, the impedance transformer successfully decreased maximum voltage in transmission line with actual antenna loading kept small. This idea is similar to pre-matching using pre-stub tuner installed at adequate position, and the additional impedance transformer just in front of vacuum vessel was installed in HAS (handshake shape) antenna. After the installation, imaginary antenna loading of HAS antenna was up to approximately two times higher than antenna loading before the installation, and effectively plasma heating was achieved in FIY 2014 [1].

Figure 1 shows the achievement of high density plasma sustainment by radio-frequency heating (ICH and ECH) in hydrogen minority heating regime with diagnostic neutral beam injection to measure ion temperature profile, and typical plasma performance at the stable region as follows: electron density ~ 6x10^{19} m^{-3}, electron and ion temperature ~ 1.3 keV, plasma stored energy from diamagnetic coils ~ 570 kJ, hydrogen minority ratio ~ 0.1, electric kinetic energy ~ 320 kJ estimated by Thomson scattering measurements, radio-frequency heating power of 3.78 MW (P_{ICH} ~ 3.1 MW and P_{ECH} ~ 0.68 MW). As increasing the heating power, sustainable density was extended, and flat-top of electron density was stably demonstrated using gas-puffing. Profiles for ion temperature measured by charge-exchange spectroscopy (CXS) and electron temperature measured by Thomson scattering were similar profiles, which are shown in Fig. 2, and this stable and favorable plasma discharge suggests that high-density steady-state long-pulse discharge with electron density ~ 5x10^{19} m^{-3} and plasmas temperature > keV is one of the new candidate to study future target in steady-state experiment in LHD.

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1) Saito, K., et al., NIFS Annual Report (2014).

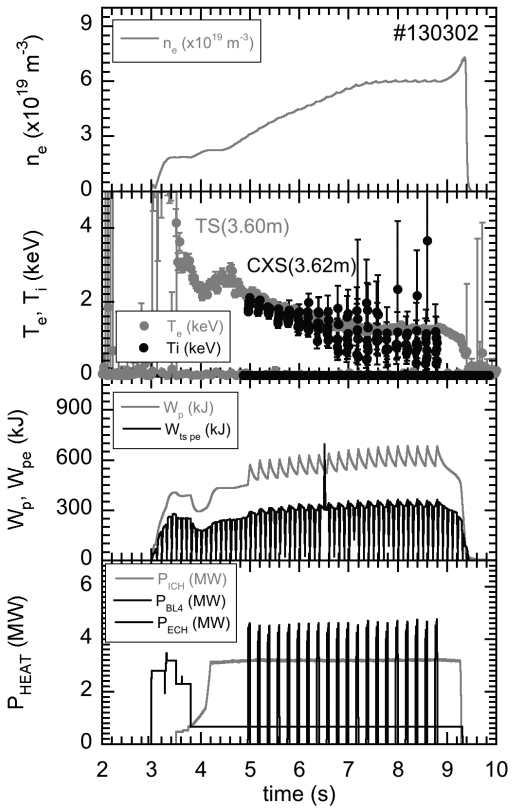

Fig. 1. Relative high-density plasma sustainment by radio-frequency heating.

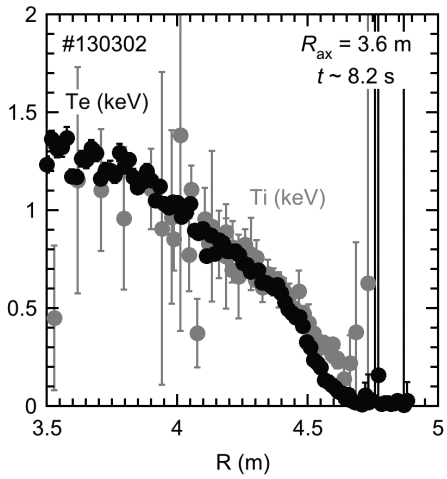

Fig. 2. Temperature profiles for ion and electron during radio-frequency heating at t ~ 8.2 s.