§58. Helium-3 Minority Ion Heating by ICRF Waves in LHD

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When a future fusion reactor is considered, a fusion reaction using deuterium and helium-3 as a fuel is one of the attractive methods. ICRF heating using helium-4 as a majority ion and helium-3 as a minority ion was investigated in order to obtain knowledge about a heating scheme in which ^{3}He minority ion heating is expected in deuterium majority plasma. Figure 1 shows the positions of cyclotron resonance layers in ^{3}He minority ion heating scheme in LHD. The wave frequency and magnetic field strength is 51 MHz and 2.75 T, respectively. A ^{4}He and ^{3}He mixture is used as a working gas. Second harmonic ion cyclotron resonance layers of ^{3}He ion are located at saddle point of a magnetic configuration. Acceleration of ^{3}He ions by second harmonic heating is expected in this condition. Ion cyclotron resonance layers of hydrogen ion and two-ion hybrid resonance (mode-conversion) layers are also located at a plasma peripheral region if hydrogen ions exist in the plasma. The heating related with these resonance layers at plasma peripheral is possible to occur though there is little probability theoretically. An output power of 1.6 MW per a transmitter was achieved in a pulse length of 5000 sec in R & D experiment using 50 MHz.

In the experiment, NBI plasma was used as target plasma. A ^{4}He and ^{3}He mixed cylinder is utilized and its volume ratio is four to one. The existence of ^{3}He ions in plasma was confirmed by spectroscopy measurement. The ratio of ^{3}He ions to ^{4}He ions measured by the spectroscopy was about one fifth. The measured ratio is almost same as the volume ratio of the mixed cylinder which is used for the experiment. The wave frequency of 51 MHz was used for the first time in LHD experiment and the maximum injected power was about 1.1 MW because conditioning of ICRF antennas and transmitters was not sufficient. Density scan was conducted to find an effective heating condition and rise of plasma stored energy was observed in several shots. In figure 2, an ICRF power of 0.8 MW was injected from 1 to 1.5 sec. Stored energy increased during the ICRF pulse. Line-averaged electron density is also changed. Vertical axis of the stored energy and electron density is enlarged in order to look into the detailed behavior accompanied by a RF injection. Radiation loss power is also increased during RF pulse and it means that conditioning of the ICRF antenna is insufficient. Ion temperature measured by crystal spectroscopy of argon line emission did not show a clear increase.

The experiment has been just started and preliminary result was obtained. Further investigation is required for the heating optimization by using higher power and changing the density and ^{3}He minority ion ratio widely involving selection of the wave frequency and the magnetic field strength.

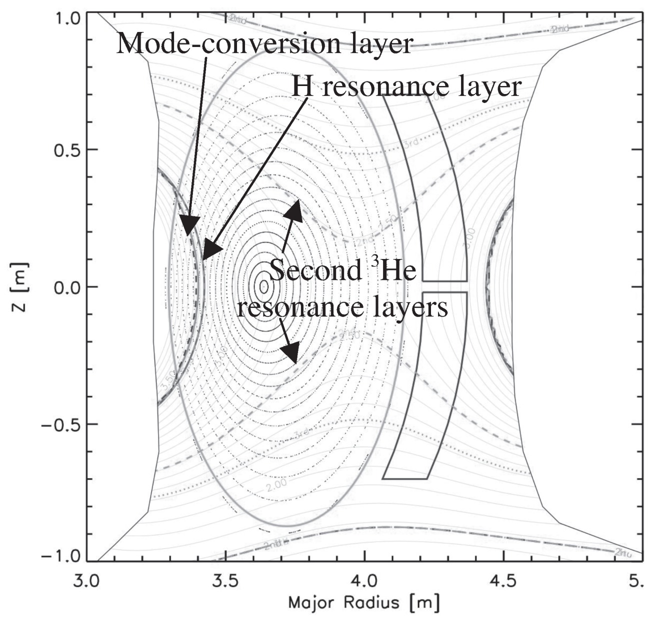

Fig. 1. Positions of cyclotron resonance layers. Second harmonic ^{3}He cyclotron resonance layers, H cyclotron resonance layer, and two-ion hybrid resonance (mode-conversion) layer are shown.

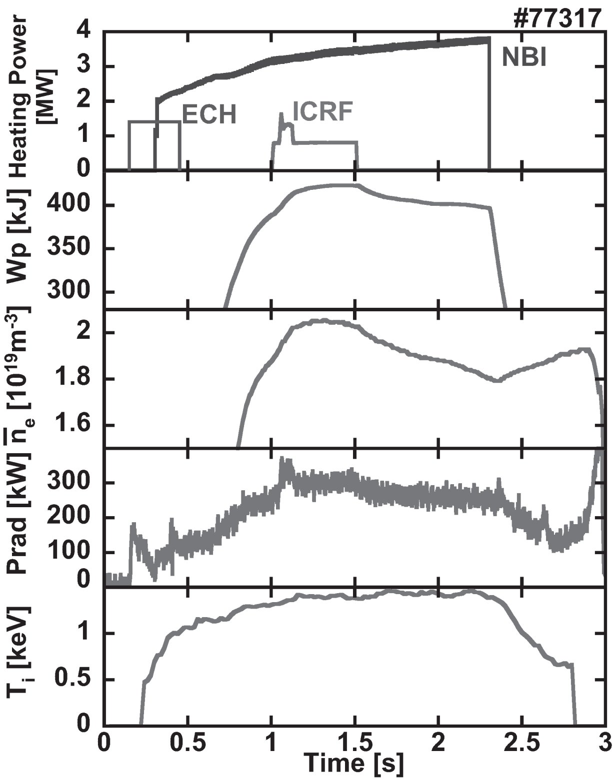

Fig. 2. Time evolution of plasma parameters of the ^{3}He minority heating. Heating power, stored energy, line-averaged electron density, radiation loss power, and ion temperature are shown from the upper column.