§28. Influence of Hydrogen Ratio on Mode Conversion Heating in LHD

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Mode conversion heating was investigated in LHD. The ICRF loop antenna launches fast waves and they interact with plasma ions and cause ion heating by minority heating mode. This is a standard ICRF heating scheme in LHD. The other hand, electron heating is expected in mode conversion heating mode. Figure 1 shows the positions of resonance and cut-off layers in mode conversion heating scheme. The wave frequency and magnetic field strength is 28.4 MHz and 2.75 T, respectively. Hydrogen and helium mixture is used as a working gas. Ion cyclotron resonance layers of hydrogen ion are located at plasma peripheral region. Ion heating is expected to be week at these resonance layers. Two-ion hybrid layers are located at vicinity of ion cyclotron resonance layers and inside of plasma. Fast waves are mode-converted to ion Bernstein waves at these layers and couple with electrons through Landau damping theoretically. Thus, electron heating is expected by mode conversion heating. In steady state experiment, ion heating mode was used and we often suffer from iron impurity influx and local heating of divertor plates and so on. We anxious about bad influence of high energy ions accelerated by fast waves. Mode conversion heating is one of the feasible clue for steady state operation.

The location of two-ion hybrid resonance layer is changed by ratio of hydrogen and helium ions. If hydrogen ratio to helium is small, hybrid layers are located close to the ion cyclotron layers. The hybrid layers move inside as the hydrogen ratio increases. The hydrogen ratio is 60 % in Fig. 1.

Plasma sustain was tried by mode conversion heating with an assistance of ECH. Time evolution of plasma parameters are plotted in Fig. 2. Black line is a successful shot and gray line is a failed shot. Injected heating power is almost same in these shots. In failure shot, hydrogen ratio is smaller than a successful shot. Stored energy and density gradually decrease during the shot. Radiation loss power is higher than a successful shot. Electron temperature profile has a peak at plasma peripheral where the hybrid layers are located.

Repetitive hydrogen pellet injection was used for supply of hydrogen ions. The result is plotted in black in Fig. 2. Hydrogen ratio measured by a spectroscopy is higher in the case of repetitive pellet injection. Plasma is sustained during the RF pulse. Radiation loss power is kept in a low level. Electron temperature profile has a peak near the center of plasma. This result shows the possibility of longer pulse operation and steady state heating.

In mode conversion heating, plasma loading resistance is small. This means higher voltage of transmission line is required to inject the same power as a minority heating. High voltage at transmission line is not favorable because of a risk of breakdown of coaxial line. It is important to raise a plasma loading resistance in order to increase an injection power. Higher density operation and/or adoption of pre-matching stub are solutions for increase of plasma loading resistance.

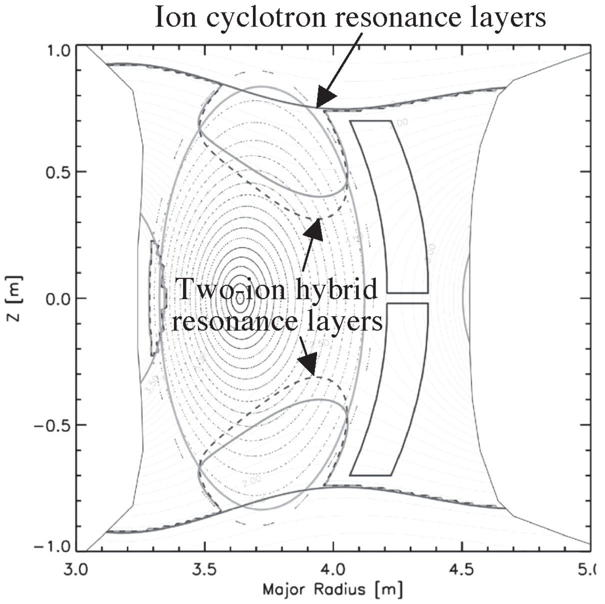

Fig. 1. Positions of resonance and cut-off layers. Ion cyclotron resonance layer, two-ion hybrid resonance layer, and R- and L-cutoff layers are shown.

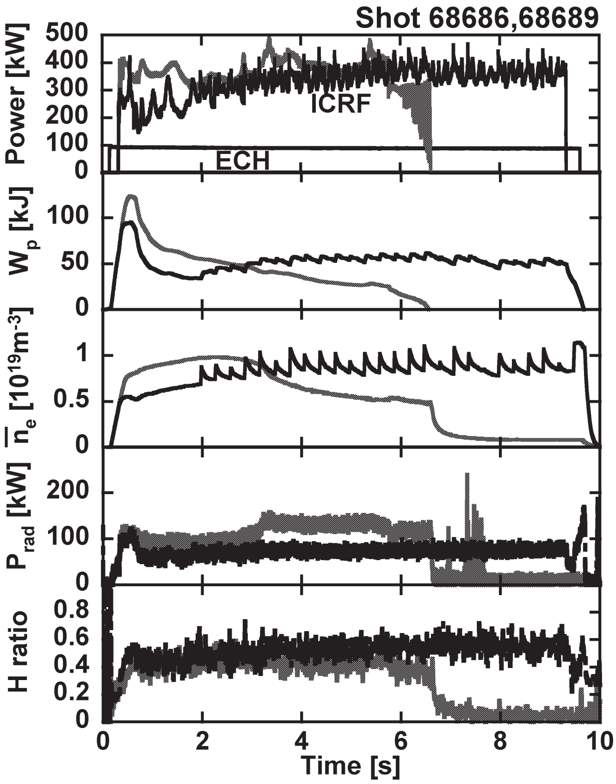

Fig. 2. Time evolution of plasma parameters of the mode conversion heating. Black and gray lines shows the discharges with and without a repetitive hydrogen pellet.