§16. Preliminary Experiment of High Frequency Second Harmonic ICRF Heating in LHD

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Second harmonic heating experiment using high frequency ICRF waves has been carried out in LHD preliminarily. Advantage of use of high frequency is that the experiment is carried out at the magnetic field strength of 2.75 T and performance of the target plasma is higher than that of the second harmonic experiment performed by reducing the magnetic field. The experiment does not require the helium species and the experimental condition is suitable for various other experiments. High harmonic heating works well with the high temperature and high density plasmas. The launched waves couple with the perpendicular high energy ions. The perpendicular NBI is suitable for making the target plasma. The second harmonic heating is expected to contribute to the high ion temperature experiment.

On the other hand, there are some problems in hardware for operating in the high frequency. Adjustment of the transmitter is required for the frequency. The transmission lines are necessary to be changed. Control of impedance matching and stable operation for operating with the antenna is not easy. Then, we use one transmitter and one antenna (3.5L antenna) in 2012 experiment as a preliminary experiment.

Figure 1 shows the time evolution of the plasma parameters. The magnetic field strength is 2.75 T and the working gas is pure hydrogen. The plasma is produced by the perpendicular NBI beam. The wave frequencies for the second harmonic and the fundamental heating are 77 and 38.47 MHz, respectively. The power of 200 kW of the second harmonic heating is injected from 5.8 to 6.7 seconds. The fundamental wave is injected from 6.4 seconds as a comparison and NBI heating is started from 7.5 seconds. During the second harmonic heating, the line-averaged electron density and the plasma stored energy increased slightly. The density increased but the stored energy decreased in the fundamental heating though the injected power in the fundamental heating is about five times higher than that of the second harmonic heating. Central ion and electron temperatures keep constant during the second harmonic heating but they are reduced in the fundamental heating. This worse result of the fundamental heating is expected theoretically. The observed effect of the second harmonic heating is very small because of the low injected power. Figure 2 shows the enlarged plasma parameters during the second harmonic heating. Injected RF power is modulated and the stored energy responds to the power modulation, while the density is kept almost constant. The ion and electron temperatures at the plasma center fluctuate slightly. These results suggest that the some power of the second harmonic heating couples with the plasma. The preliminary rough analysis of the heating efficiency is estimated to 50 - 60 %. Relatively good results are obtained in the preliminary experiment so far. We have the plan to increase the heating power and obtain the better heating results for the second harmonic heating.

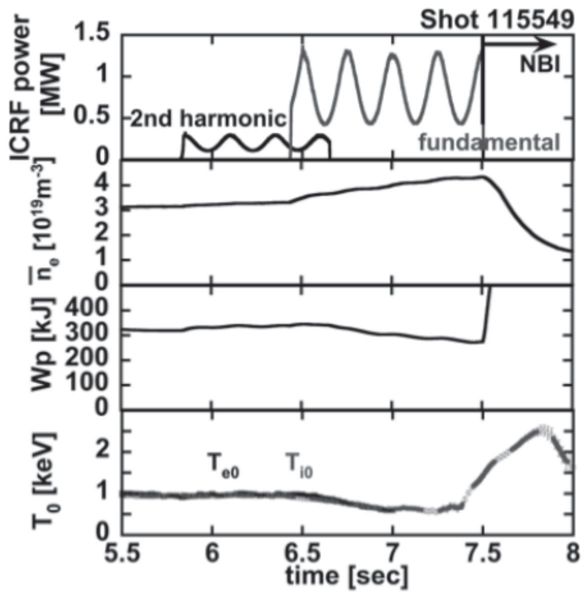

Fig. 1. Time evolution of plasma parameters for the second harmonic heating. Injected ICRF power, line-averaged electron density, plasma stored energy, and central ion and electron temperatures are plotted from the top column.

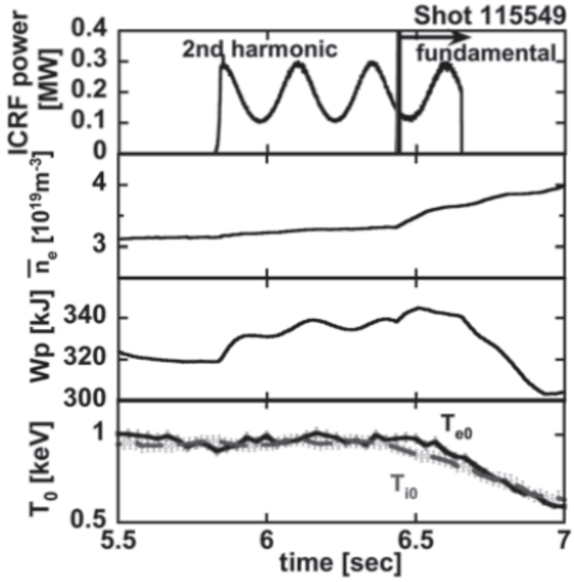

Fig. 2. Time evolution of enlarged plasma parameters during the second harmonic heating. Injected ICRF power, line-averaged electron density, plasma stored energy, and central ion and electron temperatures are plotted from the top column.