§66. Development of High Beta Plasma Production by Using Higher Harmonic Fast Wave in ICRF

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The purpose of this collaborative research is to develop a radiofrequency heating method that can be used at low magnetic fields for high beta plasma research on LHD. In particular, electron heating by Landau damping and transit time damping of the fast wave at relatively high harmonics of the ion cyclotron frequency can be explored using the existing ICRF transmitters which can provide power in the frequency range of 30 to 80 MHz. The fast wave in this frequency range is called the high-harmonic fast wave (HHFW).

Development of heating scenarios is carried out on both LHD at NIFS and the TST-2 spherical tokamak at the University of Tokyo, which share the same objective of studying high beta plasmas. On LHD, existing ICRF loop antennas are used. On TST-2, two transmitters in the frequency range of 10 to 30 MHz will be used. TST-2 has the advantages of ample experimental time and flexibility with short turn-around time for hardware modifications.

In LHD, HHFW experiments were performed using the 38.4 MHz ICRF system. In order to operate in the HHFW regime, Helium plasmas were used at lower magnetic fields, 1.5 T and 1 T. Plasma was initiated by ECH and NBI. Since the ion cyclotron frequency for helium at 1.5 T is 11.4 MHz, the fast wave frequency is around the third harmonic. The fast wave propagates in the density range exceeding the right-hand (R) cut-off density. At high harmonics of ion cyclotron frequency, ion cyclotron damping becomes weaker, and electron damping by Landau damping and transit time damping is expected to become dominant. The harmonic number is not very high in the present experiment, absorption by energetic ions may not be negligible in neutral beam heated plasmas. The formation of energetic ions is observed experimentally in LHD, but it is not know how much power is absorbed by ions.

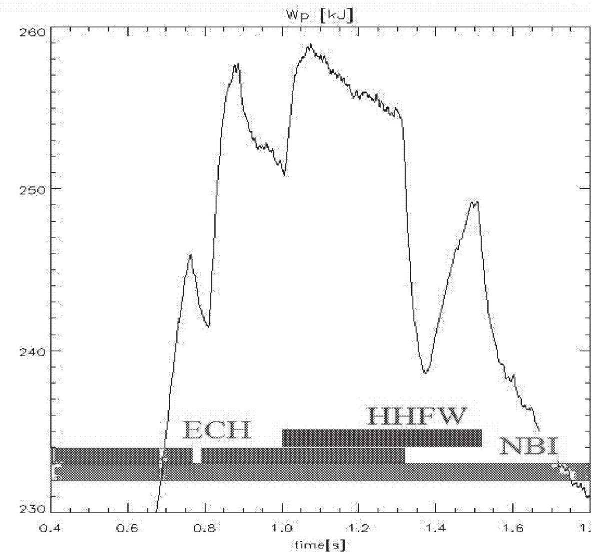

Fig. 1. Evolution of the stored energy (SN50490).

The time evolution of the plasma stored energy for shot number 50490 is shown in Fig. 1. In this discharge, plasma was formed by NB (2.5 MW) and EC (1.6 MW). Application of FW (1.2 MW) into this discharge raised the central electron temperature from about 2.5 keV to 3 keV, and the stored energy from about 250 kJ to nearly 260 kJ at an electron density of $3 \times 10^{19}\text{m}^{-3}$. There was no change in the ion temperature. EC injection was terminated first, then FW injection was terminated 0.2 s later. At this time, the electron density did not change at 2 keV, but the ion temperature decreased from 1.475 keV to 1.45 keV. This result indicates that it is possible to obtain more electron heating than ion heating near the plasma center provided the electron temperature is sufficiently high (greater than 2.5 keV in this case), even in the presence of energetic ions from NB injection

When ECH works effectively, the central electron density is pumped out by localized electron heating. The rate of decrease of electron density is smaller when HHFW heating was applied. This result suggests that HHFW is absorbed when the cenral electron temperature and beta are high enough and that parallel heating of electrons by HHFW reduces electron density pump out caused by perpendicular electron heating by ECH.

TST-2 has been moved to the Kashiwa Campus of the University of Tokyo, and is ready to start electron heating experiments using the HHFW in FY2005.

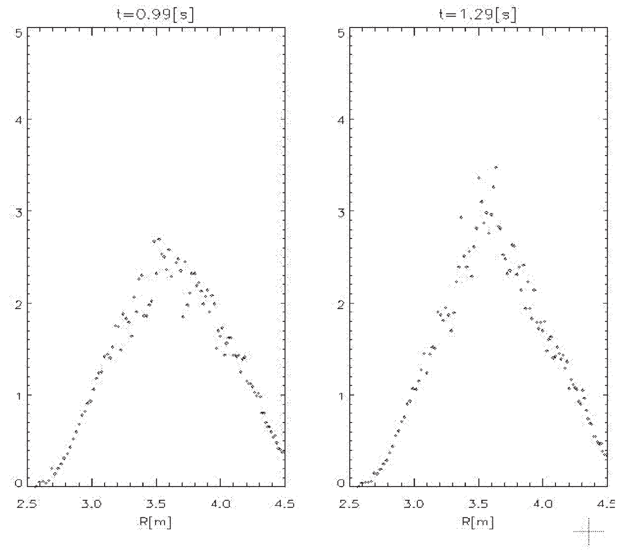

Fig. 2. Electron temperature profiles at 0.99 s (NB 2.5MW + EC 1.6MW) and 1.29s (NB 2.5MW + EC 1.6MW + FW 1.2MW).