§17. ICRF Heating Experiment in Heliotron J

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The formation and confinement experiment for fast ions is performed using the ICRF minority heating scheme with a proton minority and a deuteron majority in Heliotron J, a low-shear helical-axis heliotron (R_0 = 1.2 m, a = 0.1-0.2 m, $B_0 \leq 1.5$ T). The effect of the magnetic configuration on the fast ion confinement is one of the most important issues in helical devices. In this report, the effect of the bumpiness on the trapped fast ion confinement is clarified by using ICRF minority-heating. The role of one of the Fourier components, the bumpiness, is a key issue for the design principle of the magnetic filed of Heliotron J, where the particle confinement is controlled by the bumpiness. The proper bumpiness causes deeply trapped particles to be confined in the small grad-B region. The fast ion confinement was studied using tangentially injected fast ions by using NBI in the previous work. However, trapped particles were not sufficiently investigated in the NBI experiment.

The ICRF loop antennas are installed on the low-field side of the corner section of the Helitoron J. The high energy ions are produced up to 10 keV by injecting an ICRF pulse into an ECH target plasma where $T_i(0)$ = 0.2 keV, $T_e(0)$ = 0.8 keV and $\overline{n}_e = 0.4 \times 10^{19}$ m^{-3}. Figure 1 shows the time traces of the line integrated density, the ion temperature and the hydrogen flux of 3.9 keV. Hydrogen and deuterium fluxes are measured by a charge-exchange neutral energy analyzer (CX-NPA). During the ICRF pulse, the ion temperature measured by the CX-NPA is almost doubled and the fast neutral flux is observed.

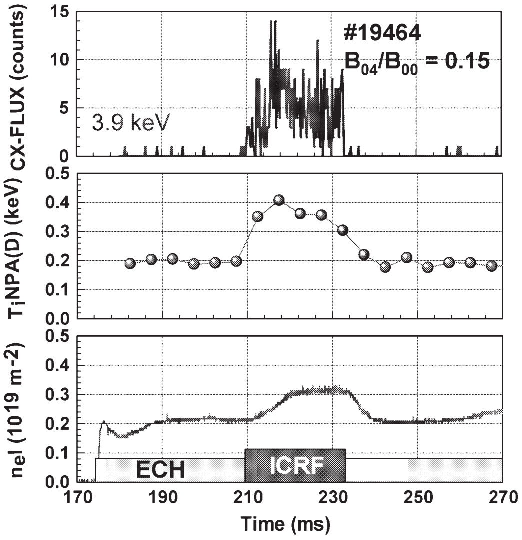

Fig. 1 Time traces of the charge-exchange flux (H), the ion temperature and the electron density.

The amplitude modulation of the ICRF power is also performed for estimating the confinement of the fast ions. The injection power is modulated with the frequency of 100 Hz, and then the CX flux is modulated as well. The phase delay of the CX flux to the injection power is caused through the acceleration by RF wave and collision damping. Fokker-Plank equation with the loss term is used for estimation of the fast ion confinement. From this experiment, the confinement of the fast ions for the high bumpy ripple is longer than that for the medium. It is considered that the bumpy control is effective for the fast ion confinement in Heliotron J as expected from the calculation using the DKES code and the discussion of the field structure that the grad-B drift is smallest in the configuration with the largest bumpy ripple.

The ion temperature increases with P_{ICRF}/n_el in this power range for two cases as shown in Fig. 2. Here, P_{ICRF} is the injected ICRF power and n_el is the line integrated density. The increment of the ion temperature in the high bumpy case is larger than that in the case of B_{04}/B_{00} = 0.06. Therefore, the heating efficiency is better in the high bumpy case. The bulk ion heating in this heating scheme is caused through the Coulomb collisions with the high energy minority ions produced by the ICRF heating. It is considered that the energy transfer from the minority ions is larger in the high bumpy case since the high energy tail is larger. The global energy confinement time in target ECH plasmas is almost same for three configurations except the improved confinement mode.

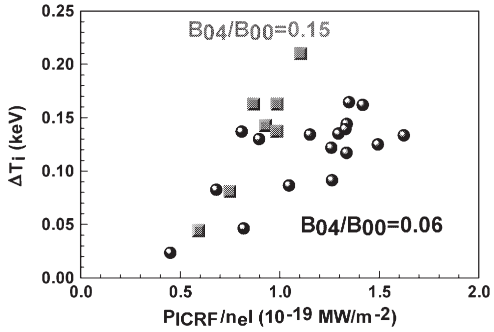

Fig. 2 Increase of the bulk ion temperature vs. the injected ICRF power for two cases of the bumpy ripples.