§22. ICRF Heating Experiment in Heliotron J

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Fast ion velocity distribution is investigated using ICRF minority heating 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), with special emphasis on the effect of the toroidal ripple of magnetic field strength. The effect of the bumpiness, which is the toroidal field ripple, on fast ion confinement and heating efficiency are discussed in the previous studies[1, 2, 3]. The good confinement of fast ions and the high efficiency of ICRF heating in the high bumpy case are reported. Here, the pitch angle dependence of energy spectra for high bumpy case is measured for the first time and compared with the medium bumpy case, then, the fast ions up to 34 keV are observed during ICRF heating in Heliotron J. The configurations used in this study are as follows; the bumpiness (B_{04}/B_{00}, where B_{04} is the bumpy component and B_{00} is the averaged magnetic field strength) are 0.15 (high) and 0.06 (medium) at the normalized radius of 0.67. The configuration of B_{04}/B_{00} = 0.06 corresponds to the standard configuration in Heliotron J.

The ICRF loop antennas are installed on the low-field side of the corner section of Helitoron J. An ICRF pulse of 23.2 MHz is injected into an ECH target plasma where $T_i(0)$ = 0.2 keV, $T_e(0)$ = 0.8 keV and $\overline{n}_e$ = 0.4 x 10^{19} m^{-3}. ICRF injection power is about 270 kW. The majority species is deuterium and the minority is hydrogen. Figure 1 shows measured minority hydrogen energy spectra for various pitch angles by changing toroidal angle of a charge exchange neutral energy analyzer (CX-NPA) for two bumpy cases. In high bumpy case, the ion flux is measured up to 34 keV at the pitch angle of 120 deg. Such high energy particles cannot be observed in the medium bumpy configuration. In both cases, the higher energy flux is measured near 120 deg in pitch angle although the ions are considered to be accelerated in the perpendicular direction by ICRF heating.

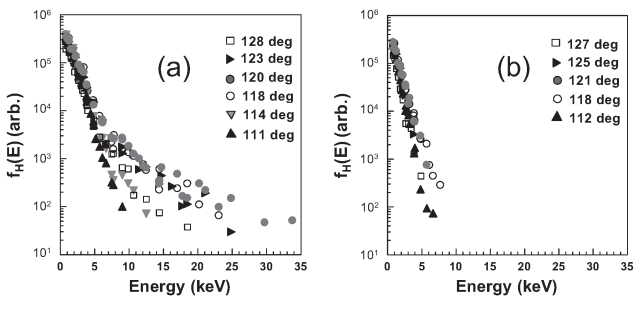

Fig. 1 Minority hydrogen energy spectra for various pitch angles in the high bumpy configuration (a) and in the medium bumpy configuration (b).

To understand experimental results, Monte Carlo calculation is performed. The numerical model consists of orbit tracing, Coulomb collisions and acceleration by the ICRF heating. Minority protons are regarded as test particles and the heating is simulated by the velocity kick in the perpendicular direction in velocity space when ions cross the cyclotron layer. The initial distribution of test ions is uniform in the toroidal and poloidal directions, and parabolic in the radial direction. The energy is chosen randomly due to the Maxwell distribution of bulk ions. Figure 2(a) shows the relation of calculated energy spectra to the pitch angle in the high bumpy case. The high energy ions are generated near 60 deg and 120 deg in pitch angle. There are high energy ions at 90 deg; however they are not so large. The property is almost same in the medium bumpy case shown in Fig. 2 (b). The calculation results using Monte Carlo method represents that the accelerated ion distribution has its peak in the range between 20 deg and 30 deg from the perpendicular direction. This result is considered to be caused mainly due to the existence of the loss region around the perpendicular direction [3].

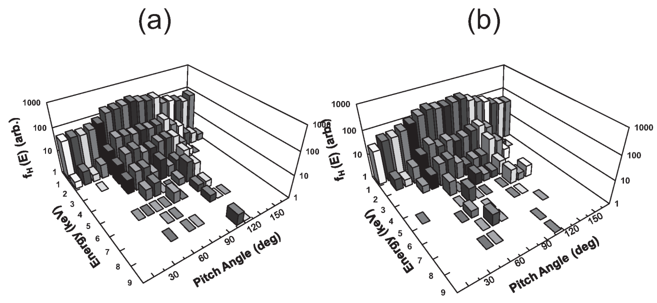

Fig. 2 Calculated pitch angle dependence of energy spectra in the high bumpy case (a) and the medium bumpy case (b).

1) Kobayashi, S., et al., IAEA-CN-116/EX/P4-41 (2004).
2) Okada, H., et al., Fusion Sci. Technol. **50** (2006) 287.
3) Okada, H., et al., Nucl. Fusion **47** (2007) 1346.