§8. Research of the Optimum Condition for ICRF Heating

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In the 18th experiment cycle (2014), the optimal condition for an ICRF heating was searched varying the magnetic field strength and the minority ratio. The ECH (Electron Cyclotron Heating) was the main experiment in this series of the experiment (#127427~127498), in which the magnetic field strength on the magnetic axis (R_{ax}=3.6m) was varied from 2.68T to 2.75T. The ICRF heating power of about 3MW was injected and the plasma of $n_e=3\sim4\times10^{19}m^{-3}$ was sustained for 6 seconds just after the main ECH plasma experiment.

A minority ratio is one of the important key parameters to decide the optimal condition of the ICRF heating together with the magnetic field strength. In this experiment the ICRF heated plasma consists of hydrogen ions (H^+) as a minority and Helium ions (He^{2+}) as a majority ions. The ratio is the number of H^+ to one of He^{2+}, i.e., n_{H+}/n_{He2+}. However 1t is very difficult to know the number of H^+ to He^{2+}, therefore in this research the ratio of H/(H+He) is employed as the one of their neutral density at the plasma periphery, measured using visible light intensity. Hereafter the minority ratio is employed as H/(H+2He), because $n_{H+}/(n_{H+}+2n_{He2+}) \sim n_{H+}/n_e$, which is the ratio of the number of the hydrogen ions to the one of the electrons in the impurity free plasma. H/(H+2He) was varied in the ranged from 0.055~0.07 as seen in Fig.1.

The confinement scaling of ISS04 is

$$\tau_E^{ISS04} = 0.079\cdot a^{2.21}\cdot R^{0.65}\cdot P^{-0.59}\cdot n_e^{0.51}\cdot B^{0.83}\cdot \iota_{2/3}^{0.4}$$

In this scaling when a=0.6m, R=3.6m, $\iota_{2/3}$=1.7, $P=\eta P_{ICH}$ and $W_P = \eta P_{ICH}\tau_E^{ISS04}$ are introduced, then the heating efficiency η

$$\eta = 649.9(W_P/1000)^{2.439}/n_e^{1.2439}/B^{2.02439}/P_{ICH}$$

Here W_p(kJ), n_e($10^{20}m^{-3}$), B(T) and P_{ICH}(MW). In the series of the experiment the ICRF heating efficiency was examined on the four different magnetic field strength, i.e., B=2.68(○), 2.705(△), 2.73(●) and 2.75T(◇) with varying the minority ratio, i.e., 0.055 < H/(H+2He) < 0.07 as seen in Fig.1. On the other hand the ICRF heating, η has been examined with ICRF power modulation method and then η is measured from 0.5 to 0.8, which agrees well with ones in Fig.1. As seen in Fig.1 the peak of η can be found at H/(H+2He) = 0.063 in B=2.73T. In B=2.68 and 2.705T it is expected that the higher η will be able to be obtained with the lower H/(H+2He). On the other hand in B=2.75T it is deduced that the higher η will be able to be obtained with the higher H/(H+2He). Here it should be noted that the antennas without Faraday shield was not used and that therefore η was measured relatively higher than the other experimental data.

The L cutoff condition is

$$N_{//}^2 = L = 1 - \frac{\Pi_m^2}{\omega^2}\frac{\omega}{\omega+\Omega_m} - \frac{\Pi_M^2}{\omega^2}\frac{\omega}{\omega+\Omega_M}$$

Here $N_{//}$, Π_m, Π_M, ω, Ω_m and Ω_M are a parallel refractive index to the magnetic field line of a fast wave, a minority ion plasma frequency, a majority ion plasma frequency, an applied radio frequency, a minority ion cyclotron frequency and a majority ion cyclotron frequency, respectively. When $k_{//}=N_{//}/c\omega$ =6m^{-1} (it is determined with a width of an ICRF heating antenna, and c is a light velocity), $\omega=2\pi\times38.5$MHz rad/s, m=1(Hydrozen), M=4(Helium) are adopted, the minority ratio of $H^+/(H^++2He^{2+})$ is calculated and plotted against the magnetic field strength from B=2.66T to 2.76T with a solid line in Fig.2. In B=2.73T the best condition is $H^+/(H^++2He^{2+})$=0.087. However the experimental data shows H/(H+2He)=0.063 at B=2.73T (here a varied range of the minority ratio indicated using a thin solid line at each magnetic field strength). There seems reasonable when it is taken into account that the hydrogen atom speed at the plasma peripheral is faster than that of helium atom.

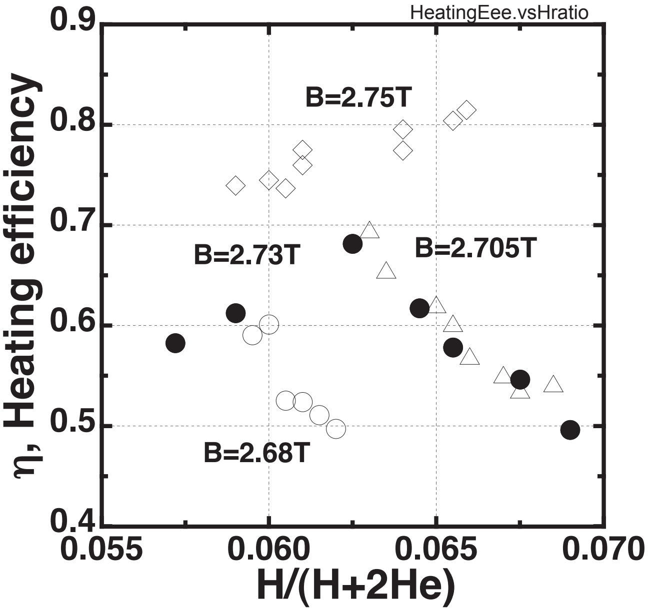

Fig.1 ICRF heating efficiency deduced from ISS04 scaling on minority ratio with various magnetic field strength.

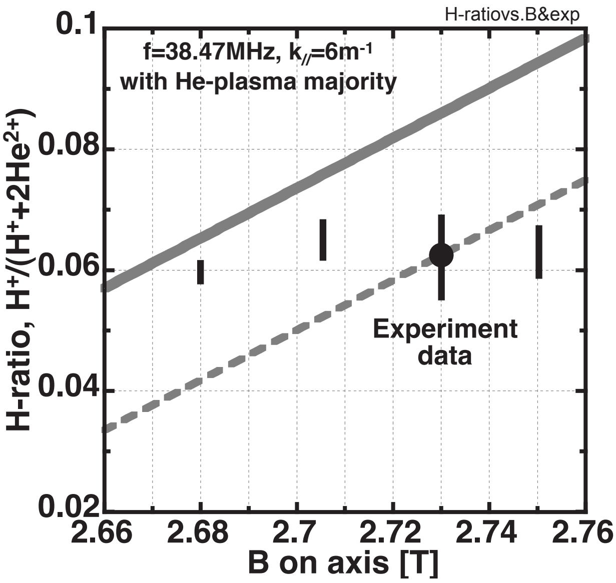

Fig.2 Minority ratio when the L cutoff layer is just located on the magnetic axis on the various magnetic strengths (solid line) and the experiment data.