§8. Development of Efficient Microwave Transmission System for GAMMA 10

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The GAMMA 10 is a tandem-mirror device and the mirror cells in both ends play important role to improve the axial confinement of both ions and electrons through the formation of thermal barrier for electrons and plug potential for ions. An Electron Cyclotron Heating (ECH) is a main tool to produce these confining potential in these plug/barrier cells. In addition, the ECH plays a quite important role of electron heating in the central cell plasma to reduce electron drag of hot ions to increase the stored energy. In the ECH scheme of the central cell, a linearly-polarized wave from a 28 GHz Gyrotron was launched from the upper port near the mirror throat and focused on the center of the EC resonance surface through two reflecting mirrors. To get efficient electron heating, it is important to design the transmission line and the antenna capable to control wave polarization and absorption profile. In this work, the studies of heating performances of the developed transmission line (polarizer) and the antenna (movable mirror) are discussed.

Since the wave launching angle of the central cell ECH in the GAMMA 10 is oblique to the magnetic field and it is required to employee the X-mode launch from the strong field side to get high single path absorption rate, it is indispensable to optimize the launching polarization of the waves for pure X-mode wave excitation. The central cell ECH system has 3 miter bends in the transmission line. The two of them near the GAMMA 10 port are used as the polarizers. The flat mirrors of the two miter bends are replaced by the corrugated mirror having the depth of $\lambda/4$ (a twister polarizer) and $\lambda/8$ (a circular polarizer). The combination of these two provide an arbitrary polarization. Using this system, we controlled the ratio of the X-mode of the injected microwave power. The figure 1 shows the time evolutions of the diamagnetism of plasma in the central cell with the different polarizations of the EC waves[1]. The central ECH was from 160 ms. It is seen that the diamagnetic signal increases with the high X mode fraction but decreases with the low X mode fraction. As expected from theory, it is clearly confirmed the wave which contains more X mode shows better heating. It is seen high O mode fraction deteriorates the confinement. This is the first result which shows clearly the importance of the pure X mode excitation in the design of the fundamental ECH system injecting from high field side in mirror devices

It is also important to control the power absorption region, especially in case of highly localized ECH. To optimize the ECH power deposition region of the central cell plasma, we have introduced the movable mirror[2]. Because of the restriction of the vacuum vessel, we designed the first mirror movable, just after the waveguide mouth. It can move vertically, about from d= +10 to -10 mm and it enables the change of deposition region about from + 5 to -5 mm vertically at the resonance surface. The d = 0 means the position of the previous fixed system. The figure 2 shows the time evolutions of the diamagnetism of ECH plasma with different d. As the d is set lower, the diamagnetism becomes higher. In case of $d < 0$ setting, it increases. But for $d > 0$, it oscillates up and down and then decreases and the visible camera indicates the plasma column shifts outward. The effective heating is obtained only in $d <$ 0. It is found the clear difference of heating effect by the relatively small absorption region change.

It is found that both the wave polarization and the absorption position clearly affect the X mode ECH from the strong field side in the tandem mirror plasma, which suggests the importance of the axisymmetric heating and adequate one path absorption.

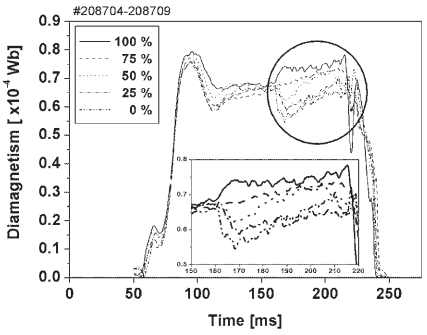

Fig. 1 Time evolutions of the diamagnetism of ECH plasma with the different polarizations of the ECH waves. The numbers indicate the percentage of X-mode. ECH power is applied from 160 ms.

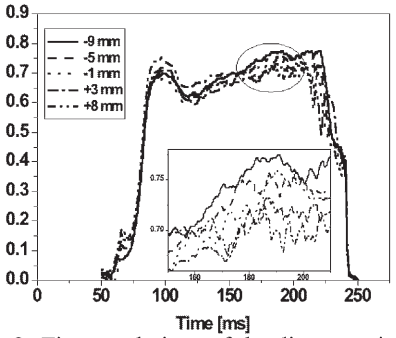

Fig. 2 Time evolutions of the diamagnetism of ECH plasma with different positions of movable mirror 1.

[1] M.Harigae, R.Minami, T.Imai, et al., Transac. of Fusion Sci. and Tech. 55 2T (2009) 136.
[2] H. Shidara, Y. Sakagoxhi, T. Imai et al., Transac. of Fusion Sci. and Tech. 55 2T (2009) 131.
[3] Y. Sakagoshi, T. Imai, et. al.,The 25th annual meeting of Jap. Soc. of Plas. Sci. and Nucl. Fus.(2008) 3aB06P.