§9. Improvement of Plasma Performance by Strong ECH with High Power Gyrotron

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An Electron Cyclotron Heating (ECH) is a key tool for electron heating and plasma control on magnetic confinement systems. It is, especially, important to get high ion confining potential and high electron temperature in tandem-mirror devices. For the purpose of the research of plasma potential physics and high power gyrotron development for LHD, power upgrade of 28GHz gyrotron to > 0.4MW have been explored on GAMMA 10 ECRH system, based on the unified scaling of potential formation[1] and high power gyrotron technology developed for ITER[2]. The first year of this program was to increase power of the central cell ECH and 350 kW from the central ECH gyrotron at MOU (Matching Optics Unit) was obtained. This year, further power up of the gyrotron by the tuning of the DC power supply control and installation of the efficient antenna and transmission line have been explored. Initial studies of the central ECH has been also performed.

The GAMMA 10 is a tandem-mirror device and axisymmetric mirror cells in both ends play important role to improve axial confinement of both ions and electrons through the formation of thermal barrier for electrons and plug potential for ions. The ECH power is a main tool to produce these confining potential in these plug/barrier in mirror cells and the electron heating in the central cell.

The power up test of the central system with the upgrade gyrotron was conducted by the improvement of the control circuits of the beam currents, since the power was limited by the beam current oscillation. After some fine tuning, it has delivered more than 400 kW power at MOU successfully, as shown in Fig. 1, where the performance of the upgrade gyrotron is compared with previous 200kW one[3,4]. During the initial ECH experiments uning this gyrotron in GAMMA 10, the beam instability often occurred. From the detailed observation of the waveforms of the beam currents, it was found that this instability was caused by the leakage magnetic field from GAMMA10. To reduce the effect of the leakage field, we installed magnetic shield near the gun and collector. As the result of these shields, the gyrotron works stably[5].

The wave launching angle is oblique incidence of 35.1° to the magnetic field, because of the ECH port configuration in GAMMA 10. Since the heating scheme is the X-mode (R wave) launch from the strong field side, the polarizer to optimize launching polarization of the waves is required. The polarizer of miter bend type with two grooved mirrors, which could generate almost all arbitral elliptical polarization was installed in the transmission line[6].

The initial heating experiment with the combination of the upgrade gyrotron, new antenna, and transmission line system has just started aiming to high central electron temperature which reduces electron cooling of high energy ions and hence improves the ion confinement of the tandem mirror. The result of the electron heating is shown in Fig. 2 with the previous electron heating before upgrade. More efficient central electron heating of T_e 500 ~ 750eV was obtained with the new central ECH system. The heating effect after upgrade seems to be larger than the previous one. One reason for this is the component of the R wave which efficiently couple to the electrons at the resonance surface increases by ~40% with the optimization of the polarizer.

As the outcome of these studies, new collaboration on the gyrotron development between NIFS and Tsukuba University has started to develop 1MW 77GHz gyrotron for LHD.

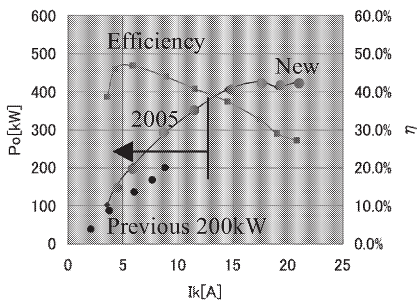

Fig. 1 Test results of output power vs beam current (Ik). Upgrade gyrotron (large closed circles) and previous (closed circle) are compared

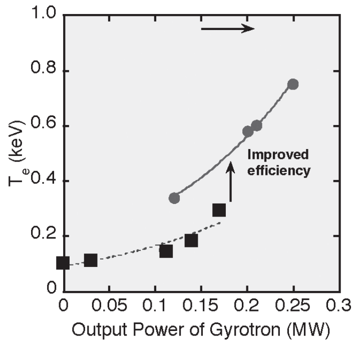

Fig. 2 Performance of Electron Heating with new Gyrotron, antenna and transmission line.

References

[1] T. Cho *et al.*, Phy. Rev. Letters,94(2005)085002.
[2] T. Imai, et. al., Fusion Eng. and Des. **55** , (2001) 281. .
[3] T.Imai, et al., Transac. of Fusion Sci. and Tech. 51 2T (2007) 208.
[4] Y.Kamata, et al., Transac. of Fusion Sci. and Tech. 51 2T (2007) 412.
[5] T.Kariya, et al., Transac. of Fusion Sci. and Tech. 51 2T (2007)397.
[6] R.Minami, et al Transac. of Fusion Sci. and Tech. 51 2T (2007)403.