§17. 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 0.4-0.5MW have been explored on GAMMA 10 ECRH system, from 200kW to push high confining potential formation and high power central electron heating, based on the unified scaling of potential formation[1] and high power gyrotron technology developed for ITER[2]. Main subject of the first year of this program is to increase power of the central cell ECH. Despite of the restrictions of present system, the gyrotron of central cell ECH delivered 400-500 kW as expected from design. The ion confining potential of 3kV was obtained with high power plug ECH. The electron heating of the central cell plasma using high power gyrotron has started.

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. In last 20 years, ECH power source of the GAMMA 10 was 200 kW gyrotrons at 28 GHz and the ECH power produced 0.7 kV ion confining potential and electron temperature of the central cell was less than 100 eV. Much higher potential formation and electron heating would be expected corresponding to the ECH power upgrade.

New high power gyrotron of 500kW level at 28GHz has been developed for this ECH system upgrade. $TE_{4,2}$ mode is selected to reduce wall ohmic loss and beam current density for the new gyrotron. The major specification is listed in the table 1, comparing with previous one. The output mode is Gaussian like mode using quasi-optical mode converter, which couples efficiently to $HE_{1,1}$ mode transmission line.

Parabolic mirror was designed to make transmission efficiency high and power profile at resonance surface axisymmetric in both plug and central antennas using newly developed code[3]. Using these new high power gyrotron and efficient antenna, high power ECH experiment is going on.

As the base plasma experiments, the maximum ion confining potential of 3kV was obtained, which is four times higher than the previous value before the gyrotron upgrade. As for the central ECRH, the new antenna was tested before installing the new gyrotron and remarkable electron heating from tens eV to hundreds eV was obtained. An upgrade of the central ECH system is being made, with the DC power supply of JFT-2M ECH system. The output power test of this upgrade central system with the upgrade gyrotron was conducted and ~ 400 kW power at MOU (Matching Optics Unit) was successfully obtained as shown in Fig. 1, where the performance of the upgrade gyrotron is compared with previous 200kW one. It is seen that the output power is 2 times higher than previous one. The combination of this gyrotron, new antenna, and transmission line system will be experimented in the next campaign aiming to high central electron temperature which reduces electron cooling of high energy ions and hence improves the ion confinement of the tandem mirror.

Table 1 Comparison of specifications of 28GHz gyrotrons

	Upgrade tube	Previous
Frequency	28 GHz	28GHz
Output power	500kW	200kW
Cavity mode	TE42	TE02
Output mode	Gaussian	TE02
Pulse length	0.1	0.075
Efficiency	40%	34%

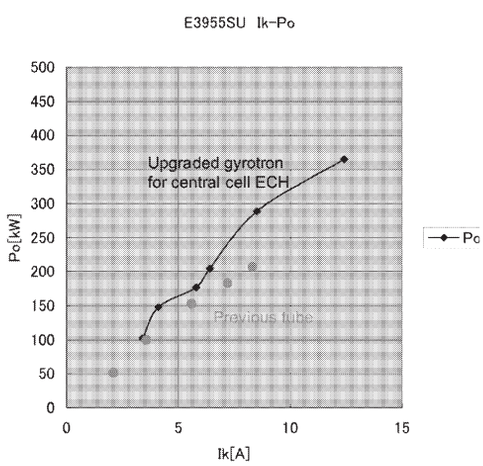

Fig. 1 Test results of output power vs beam current (Ik). Upgrade gyrotron (diamond) and previous (closed circle) are compared.

References

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