23P093-P

Improvement of the Central-cell ECRH Antenna in GAMMA 10
GAMMA 10セントラル部ECRHアンテナの改良研究

Hitomi AOKI[1)], Tsuyoshi IMAI[1)], Tsuyoshi KARIYA[1)],
Ryutaro MINAMI[1)], Yoshinori TATEMATSU[2)], et al.
青木瞳[1)]、今井剛[1)]、假家強[1)]、南龍太郎[1)]、立松芳典[2)]、沼倉友晴[1)]、飯泉英昭[1)]、
中林英隆[1)]、中澤和寛[1)]、江口濯[1)]、 河原崎遼[1)]、市村真[1)]、中嶋洋輔[1)]、吉川正志[1)]

1) Plasma Research Center, University of Tsukuba 1-1-1 Tennohdai, Tsukuba, 305-8577, Japan
2) Research Center for Development of Far-Infrared Region, University of Fukui
3-9-1 Bunkyo, Fukui, 910-8507, Japan
1)筑波大学プラズマ研究センター 〒305-8577 つくば市天王台1-1-1
2)福井大学遠赤外領域開発研究センター 〒910-8507 福井市文京3-9-1

The ECRH antenna system of the central cell in GAMMA 10 is newly developed for efficient electron heating. A new mirror for this system was designed for injecting waves directly to the resonance surface so as to improve microwave mode purity and the transmission efficiency is about 79%. The performance test was carried out outside the vacuum vessel and we got good agreement with it. This system was installed to GAMMA10 and obtained improved heating performance.

1. Introduction

In the tandem mirror plasma confinement device, GAMMA 10, the main plasma generated and heated by Ion Cyclotron Resonance Heating (ICRH) is confined in the central cell. Under this plasma condition, the low electron temperature in the central cell inhibits the ion temperature rise. Thus the electron heating is required and the central cell Electron Cyclotron Resonance Heating has been developed. This time a new C-ECRH antenna system is designed for better heating with high transmission efficiency and mode purity.

The central ECRH system consists of a gyrotron, a transmission line, polarizers and an antenna. The microwave from the 28GHz high power gyrotron propagates through corrugated waveguides as HE_{11} mode. The polarization control of the injected wave is done by the polarizers, which are two miter bends with twister polarizer and circular polarizer. Then the microwave is injected on the EC resonance layer via the mirror. In order to heat electrons by the ECRH, the microwave mode injected at the resonance is right-handed elliptically polarized. The extraordinary(X) mode couples this wave. 100 % X mode injection is thought to be the best mode for the ECRH.

The central ECRH antenna system has an ellipsoidal mirror for converging of the wave on the resonance near the axis. Figure 1(a) shows the previous ECRH antenna system of the central cell [1]. Though previous antenna system had the good transmission efficiency of 90 %, it couldn't achieve accurate X mode injection due to the first pass crossing the plasma, where the phase of the X and ordinary(O) mode shifted differently [2]. So new antenna system with accurate X mode control is designed in this report.

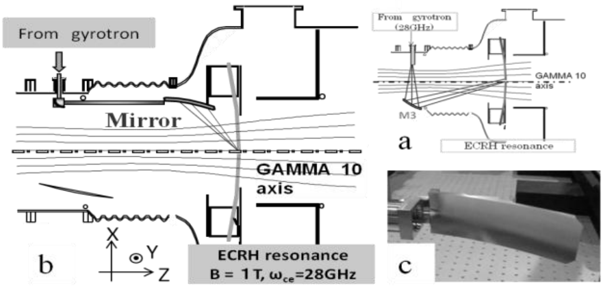

Fig.1. Schematic views of the ECRH antenna system of the central cell, (a) the previous system and (b) the new system. (c) The new mirror of the (b) system.

2. New antenna design

2.1 New ECRH antenna system

The directly injected antenna system is designed (Fig. 1(b)). The waveguide and the miter bend are installed in the vacuum vessel and the microwave is obliquely injected from the mirror (Fig. 3(c)) of the upper side of the vacuum vessel. Thus, the microwave doesn't pass in plasma before the final pass and the wave would have high mode purity.

2.2 Design

We use of elliptical mirror character that the microwave irradiated from the elliptical focal point converge to the other focal point. In order to obtain the axisymmetric converging radiated pattern at the resonance surface, we have used the electromagnetic code developed in Plasma Research Center, which directly solves the electric and magnetic field, E and H, at the resonance surface from the field at the mirror [3].

The best calculation result with high transmission efficiency is obtained when the mirror installed position is put close to the resonance as much as possible within the geometrical restriction. The projected size of the new mirror is 145 × 60 mm^2. Figure 2(a) shows spatial profile of power density. The 1/e folding radius along X and Y axis is 29.8 mm and 29.7 mm, respectively. The transmission efficiency to the resonance surface within the plasma radius of 200 mm is about 79 % (Fig. 2(b)), which a bit lower than that of the previous system. But the beam doesn't pass in plasma before the final pass for the accurate polarization this time, as seen in Fig. 1(b).

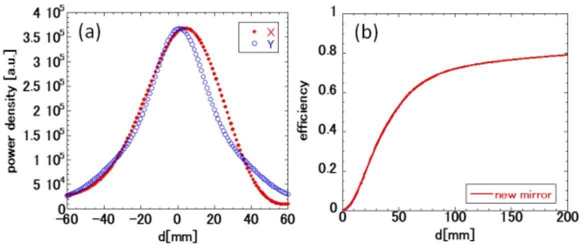

Fig.2. The calculation results. (a) Spatial profile of power density. Closed circles are X axis distribution and open circles are Y axis one. (b) Transmission efficiency.

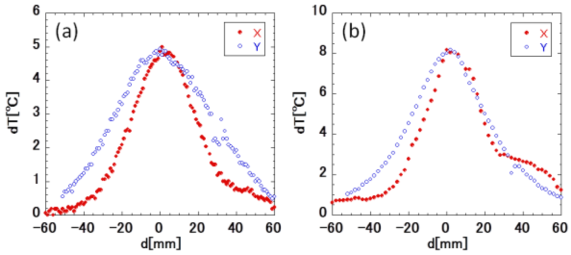

Fig.3. Spatial profile of temperature increment (dT) measured in (a) cold test and (b) hot test. Closed circles are X axis distribution and open circles are Y axis one.

3. Performance evaluation test

We performed tests for verifying performance of the designed mirror. The same configuration of the transmission system as that used in GAMMA 10 is mocked up outside. Radiated power distribution of the microwave at the absorber corresponding to the resonance surface is investigated by an infrared camera.

Figure 3(a) and (b) shows the results of the cold test with the power of 1 W and the hot test with 100 kW, respectively. Both test results are narrow along X axis and wide along Y axis. This cause is thought to be the measurement error of ±0.5~1.0 degree of temperature increment due to infrared camera. Thus these results give close agreement with calculation results within the error.

4. Plasma experiment

The new developed antenna system has been installed to the central cell of GAMMA 10, and the plasma experiment was performed. Figure 4 shows diamagnetism (DM) increment in the preliminary heating experiment using the new antenna system. In 150 – 152 ms, the DM decreases at first and then increases with the ECRH microwave injection of 100 kW. In 150 – 152 ms, vibrating SX radial profile is observed. However the cause is not obvious. This phenomenon was also observed in the previous antenna system. The DM increase is about 7 % compared to without the ECRH. It is not clear whether new antenna has better heating performance than before. We need more detail experiments in GAMMA 10.

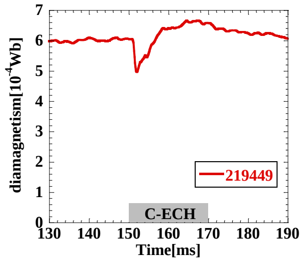

Fig.4. Time evolution of diamagnetism of the central cell. The C-ECH injection time is during 150 - 170 ms, with 100 kW and 100 % X mode.

5. Conclusions

The new antenna system of the central cell in GAMMA 10 is developed. In this system, the microwave with the accurate X mode purity by the direct injection to the resonance can be achieved with the transmission efficiency of 79 %.

The cold and hot test results give close agreement with calculation results. In preliminary plasma experiment, we obtained a slight increment of the DM with the C-ECH injection. More detailed studies will be done with the new antenna.

Acknowledgments

The author thanks the members of the GAMMA 10 group of the University of Tsukuba for their collaboration and discussion. This work is partially supported by National Institute for Fusion Science Collaborative program (NIFS11KUGM050 and NIFS11KUGM053).

References

[1] H.AOKI et al. 27th JSPF Annual Meeting, 02P84.
[2] H.KOUDOU et al. 27th JSPF Annual Meeting, 02P85
[3] Y.TATEMATSU et al. Jpn. Appl. phys. 44(2005) 6791-6795.