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Study of the Heating Characteristics by the Central ECH Antenna in GAMMA 10/PDX

GAMMA 10/PDXにおける
セントラル部ECHアンテナによる加熱特性の研究

Makoto Uehara, Tsuyoshi Imai, Tomoharu Numakura, Ryutaro Minami, Tsuyoshi Kariya, Takaki Kato, Kohei Tsumura, Reona Goto and Makoto Ichimura
上原　真、今井　剛、沼倉友晴、南龍太郎、假家　強、
加藤敬輝、津村康平、後藤礼於奈、市村真

Plasma Research Center, University of Tsukuba, University of Tsukuba, Tennodai, Tsukuba, Ibaraki, 305-8577, Japan
筑波大学プラズマ研究センター　〒305-877　茨城県つくば市天王台1-1-1

The ECH antenna system of the central cell in GAMMA 10/PDX has been developed for efficient electron heating. The previously used antenna system with two mirrors was the transmission efficiency of about 95% and the power profile is highly peaked. In the plasma ECH experiment, efficient heating was observed in lower power of less than 100 kW, however the diamagnetism signal tends to decrease when the heating position slips off from the center of the vessel or the ECH power increases to 150kW. Since it is appeared that these results were caused by highly localized heating of the previous antenna system, the broad antenna system has been newly designed to enlarge the radial heating profile. In the experiment using the broad antenna, the broad heating profile has been obtained, but the heating efficiency seems to be less effective.

1. Introduction

In the GAMMA 10/PDX, the ion temperature in the central cell is much higher than the electron temperature. In order to reduce the electron drag in the central cell plasma and form the plasma confining potentials in the plug/barrier cell, Electron Cyclotron Heating (ECH) has been used.

The central ECH (CECH) system consists of a 28GHz gyrotron, a transmission line, polarizers and antenna system. In the CECH system, the antenna system is used to radiate microwave to the resonance layer. The CECH antenna systems have been improved in terms of the transmission efficiency, the control of wave polarization, and power density profile.

2. The antenna systems

Figure 1 shows schematic drawing of the CECH antenna systems in the central cell in GAMMA 10.

The antenna system with two mirrors (M1&M2) was designed in 2012 [1]. The transmission efficiency of this antenna system is about 95% and the power profile is peaking in the center of the axis. The calculated radii that the power density becomes 1/e are 16.8 mm in vertical direction and 11.7mm in horizontal direction [2.3]. This system can control the heating position (vertically ±7.2 mm on resonance layer) by moving the M1 position *d* mm (-12 mm ≦ *d* ≦ 12 mm). The ion confinement seemed to be degraded due to the local heating resulted from the peaking power profile. The new antenna system was planned to enlarge the power density profile.

The new antenna system (M5) was designed in 2013. This system also has high transmission efficiency (95%). The 1/e radii of the power profile along the vertical and horizontal direction using M5 are 81 and 83mm. This value is about six times as large as M1&M2. The new antenna has broad power density profile.

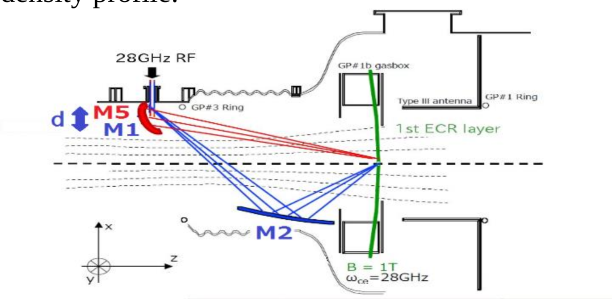

Fig. 1. Schematic views of the CECH antenna system

3. Plasma experiment

3.1 *Antenna system with two mirrors (M1&M2)*

In the plasma experiment using M1&M2, when we change the M1 position vertically from -12 mm to 12 mm, the heating effect becomes less and even decreases. In case of the lowest position of the M1, the peak position of Soft X-ray (SX) signal profile is near the center of the axis. However the SX peak position of other cases oscillate approximately 2 cm.

Figure 2 shows the time evolutions of Diamagnetism (DM) signal with 50, 100 and 150 kW cases when *d* is -12 mm and X-mode is 50%. The CECH power was injected during 160 – 190 ms and those of plug ECH (PECH) were from 180 to 195 ms. The DM signal increases in case of 100kW and decreases in the 150kW case while electron temperature (Te) increases in both cases. In the case of 150kW, the counterclockwise rotation of the SX profile is measured as seen in Fig. 3. From these results, the highly localized heating profile brings about the non-axisymmetric plasma, which appeared to degrade the ion confinement.

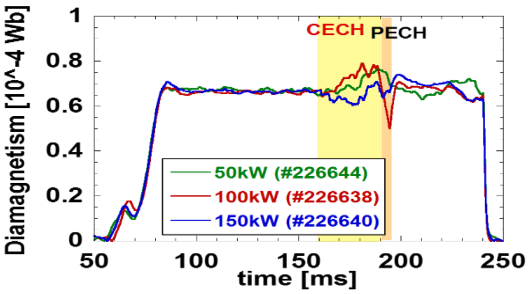

Fig. 2. Experimental results of time evolutions of the diamagnetic signals with three injection powers using the M1&M2 antenna.

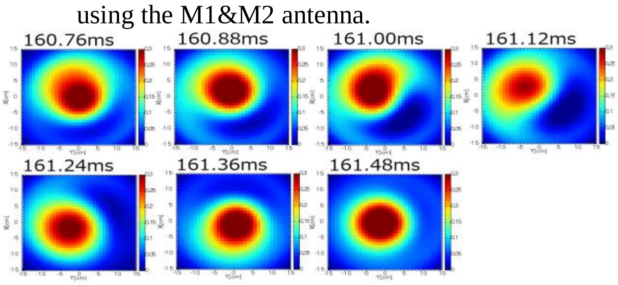

Fig. 3. Time evolution of the SX profiles during CECH 150kW shot (M1&M2) [4]

3.2 *Broad antenna system (M5) experiment*

The time evolutions of DM of three different CECH power cases using M5 are shown in Figure 4. The DM increases in the case of 200 kW when X-mode is 100%. DM doesn't decrease even with high CECH power of 200kW and the peak position of SX during CECH doesn't move with 200kW (Fig. 5). However the DM signal during CECH using M5 doesn't increase as M1&M2. The DM increase with CECH using M5 is about 10% compared to without the CECH. This value is smaller than 20% of M1&M2.

The radial ECH power density profile of M5 is much broader than that of M1&M2, as described in the section 2. The SX profile during CECH with M5 is expected to be broader than with M1&M2. The Full Width at Half Maximum (FWHM) of radial SX profile using M5 is 2 cm larger than M1&M2, as expected. Since the plasma potential is usually proportional to the Te in open and linear devices, the localized electron heating by the ECH could easily modify the radial Te profile and hence the potential profile. Before CECH, the shape of radial potential profile is concave. Although the value of central potential rises by CECH and the shape of potential profile changes largely. In contrast, the shape of radial potential profile of M5 with CECH is kept similar, and shifts upward in whole radial position. The increment of potential becomes higher as CECH power rises. These indicate the broad heating, too.

It is found that the heating effect (DM increment) changes in accordance with the radial profiles of the SX and the potential change through the different antenna experiments, which indicates that the change of radial profile affects ion confinement.

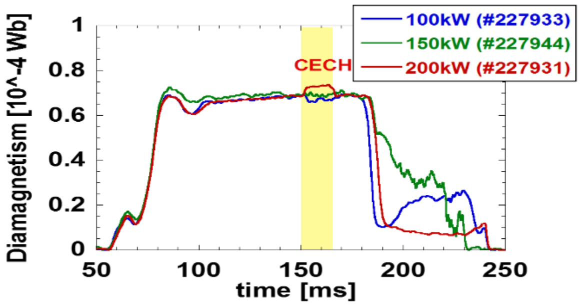

Fig. 4. Experimental results of time evolutions of the diamagnetic signals with three injection powers using the M5 antenna.

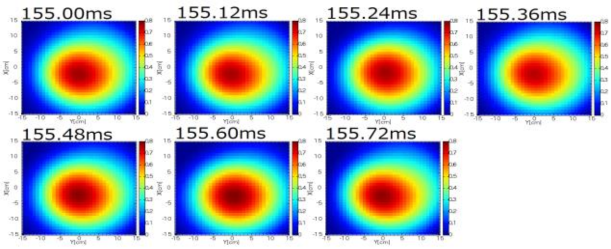

Fig. 5. Time evolution of the SX profiles during CECH 200 kW shot (M5)

4. Acknowledgment

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