23P086-P

ICRF Heating Experiments in the Minimum-B Anchor Configuration on GAMMA10

GAMMA10 極小磁場アンカー部における ICRF 加熱実験

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On GAMMA10, ICRF waves produce and heat initial plasmas and keep MHD stability. MHD stability is supplied by the high-β plasma in the minimum-B configuration at the anchor cell. This plasma is formed by ICRF waves propagated from the central cell. Because these waves are also used for the production of initial plasma, it is difficult to change only the effect of the anchor heating. Then, an independent system from the plasma production is needed for the anchor heating. In this study, we report direct anchor heating experiments with antennas installed in the anchor cell.

1. Introduction

GAMMA10 is the largest tandem mirror device in the world and consists of five magnetic mirror configurations, which are a central cell, two anchor cells connected to both sides of the central cell and two plug/burrier cells at both ends. The main plasma is produced in the central cell with magneto-hydrodynamic (MHD) stability attained by the high-β plasma in the anchor cells with minimum-B configuration. The anchor plasma is heated by Ion-Cyclotron Range of Frequency (ICRF) waves (around 10MHz). In the standard discharge, ICRF waves which have resonance layers near the anchor midplane are excited in the central cell and propagate to the anchor cell. Since these waves are also used for the plasma production in the central cell, it is difficult to control only the heating effects in the anchor cell. In order to enhance anchor heating, an antenna is installed in the anchor cell. In this study, we replaced the anchor antenna so as to improve its coupling with the facing plasma and confirmed its validity by the experiment and the computer simulation.

2. Experimental setup

Figure 1 shows the schematic drawing of magnetic field configuration and ICRF systems on GAMMA10. There are three ICRF systems, which are RF1 with the Type-Ⅲ antennas for producing initial plasma and heating anchor plasma, RF2 with Double Half Turn (DHT) antennas for heating main plasma in the central cell and RF3 with the anchor antenna for heating anchor plasma.

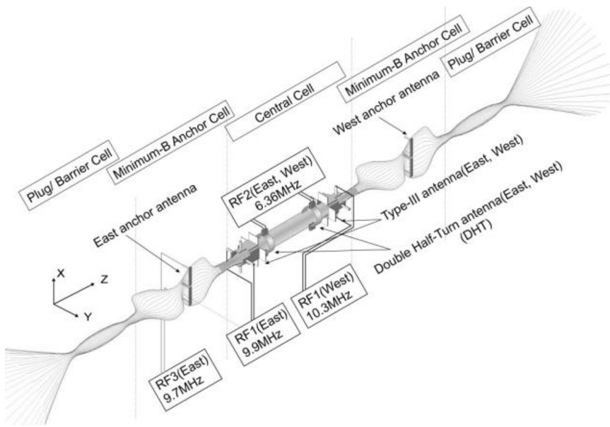

Fig.1. GAMMA10 tamdem mirror device

The anchor heating experiments have been proceeded by using two types of antenna. Figure 2 shows (a) a bar-type antenna, which has been used previously, and (b) a new type antenna, which has double elliptic arcs so as to surround the facing plasma. The experiment with the bar-type antenna has been performed and the stabilization of the whole plasma has been confirmed[1]. The loading resistance of the bar-type antenna and the new antenna are calculated by a three-dimensional full wave numerical code, which is developed by one of the authors (A. Fukuyama).

(a)Bar-type antenna (b)New antenna

Fig. 2. Schematic drawing of two type antennas

This code solves the Maxwell's equation for the wave electric-field as a boundary-value problem using the finite element method. The model assumes that cold and inhomogeneous plasma is surrounded by a conducting wall. The power absorption with the collisional damping is described by introducing effective collisions in the dielectric tensor. According to the result of this calculation, the loading of the bar-type antenna has been found to be very small and that of the new antenna is three times larger than that of the bar-type antenna.

3. Experimental results

We have performed anchor heating experiments using two types of anchor antenna. The results are shown in Fig. 3. In these experiments, ICRF waves of 9.7MHz are used. The diamagnetism and the line-integrated density in the central cell are shown on top graphs of Figs.3 (a) and (b). The input and net powers of RF3 with the anchor antenna are shown on bottom graphs of them. These effects on the diamagnetism and the line-integrated density in the central cell are larger in case of using the new antenna than the bar-type antenna. This is partly due to the difference of the radiated power to the plasma. In the case of the bar-type antenna, although the input power is about 130kW, only one-sixth of power is radiated to the plasma. In other words, less than five-sixth of the power is used on the circuit including the antenna, which indicate weak coupling to the plasma. On the contrary, in the case of the new antenna, more power is radiated from the antenna although the input power is much less than that in the case of the bar-type antenna. From this result, we confirmed that antenna loading is clearly improved with the modification of the antenna shape from simple bar-type to the double elliptic arcs type.

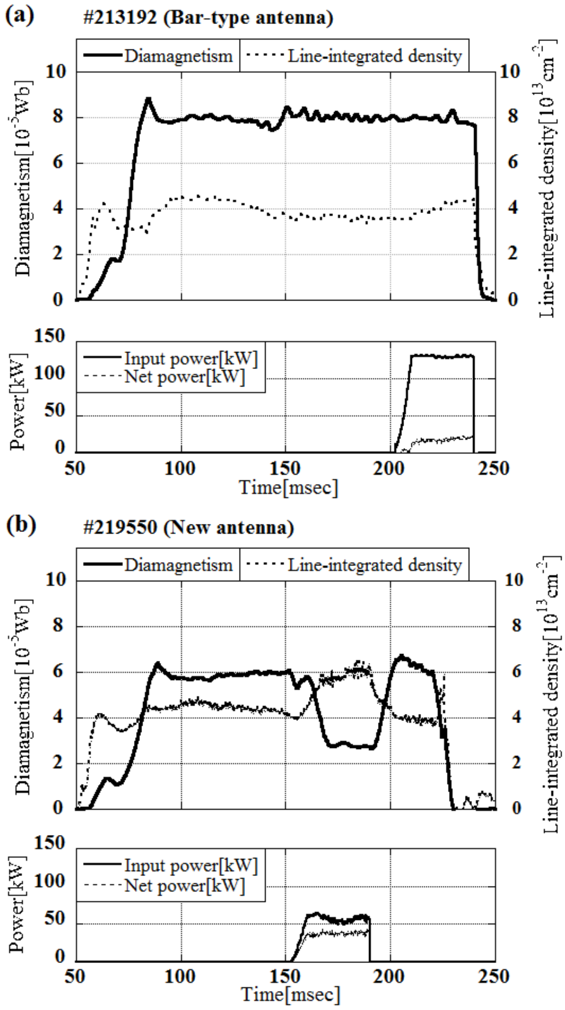

Fig. 3. Temporal evolution of plasma parameters by applying RF3 with (a) the bar-type and (b) the new antenna

4. Summary

In order to heat plasma effectively in the anchor cell, the bar-type antenna was replaced to the new designed antenna. In the experiment, we have confirmed that the plasma in the central cell is affected more effectively by ICRF waves from the new antenna than the bar-type antenna, which reflects the improvement of antenna loading.

Acknowledgments

This work is partly supported by the bidirectional collaborative research program of National Institute for Fusion Science, Japan (NIFS11KUGM055).

Reference

[1]Y.Yamaguchi et al., Fusion Science and Technology, 59, No.1T(2011)250-252.