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ICRF wave analysis in the minimum-B configuration on GAMMA 10 with three-dimensional full wave code

3次元波動コードを用いたGAMMA 10極小磁場配位おけるICRF波動解析

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On GAMMA 10, the diverter simulation experiments progress with high temperature plasmas produced by waves in ion-cyclotron range of frequency. In these experiments, it requires to produce and control high temperature and high density plasmas. On GAMMA 10, ICRF waves are used for producing high pressure plasma. In order to enhance the ion-heating and producing plasmas, the experiments with phase-control between two antennas are introduced. In these experiments, high density plasmas have been produced more effectively. In order to analyze the propagation of ICRF waves, three-dimensional full wave code is introduced.

1. Introduction

On GAMMA 10, the diverter simulation experiments progress with high temperature plasmas. Ion-cyclotron range of frequency (ICRF) waves are used for producing plasmas, heating ions, and keeping the Magneto Hydro Dynamics stability on GAMMA 10. In a standard discharge, ICRF waves excited from the Type-III antennas are used for producing plasmas in the central cell and ion-heating in the minimum-B anchor cells. In order to enhance the ion-heating in the anchor cell, the phase-control experiments[1] with Type-III and the anchor antenna is introduced. In order to analyze the propagation of ICRF waves in the phase-control experiments, three dimensional full wave code (TASK/WF) [2] is introduced.

2. Experimental device

Figure 1 shows (a) the axial profiles of the magnetic field strength and the location of ICRF antennas, (b)the values of ω/Ω_{ci} as 10.0MHz and 6.36MHz from the midplane of the central cell to the west plug/barrier cell ($\mathbf{0 \le z \le 10}$). The anchor cells are minimum-B field configuration with 0.6T in the magnetic field strength at the midplane. In order to enhance ion-heating in the anchor cell, Double Arc Type (DAT) antennas are installed in the anchor cells as indicated in Fig. 1(a). In the west anchor cell, the antenna located near the central cell is so-called WAI-DAT, and another is WAO-DAT. In order to heat more effectively, the phase-control experiments are introduced with Type-III, WAI-DAT, and WAO-DAT antennas. The resonance layer of 10.3MHz waves are near the midplane (z=5.2m) of the anchor cell. In the case of the Type-III and WAI-DAT antenna, the resonance layer is out of two antennas. On the other hand, in

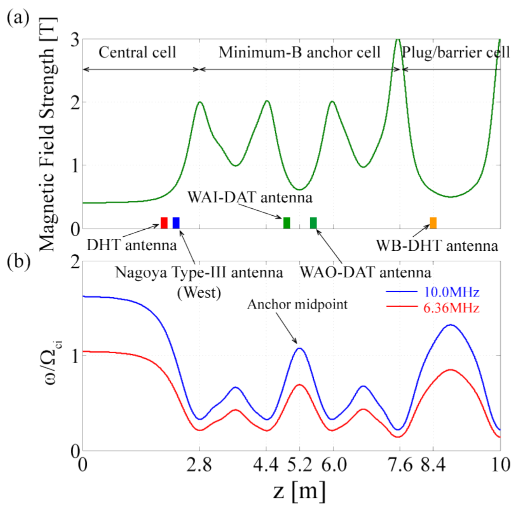

Fig. 1. (a)Axial profile of the magnetic field strength and the location of ICRF antennas, (b)the value of ω/Ω_{ci} as 10.0MHz and 6.36MHz between the midpoint of central cell and the west plug/barrier cell.

the case of Type-III and WAO-DAT antenna, the resonance layer exists between two antennas.

3. Three dimensional full wave simulation

In order to analyze the wave excitation on phase-control experiments, the three dimensional full wave code, TASK/WF[2], has been introduced. In this code, Maxwell's equation is solved as a boundary-value problem using three-dimensional finite elements method (3D-FEM). Waves in the anchor cell can be analyzed with this 3D code. The profile of the density and the magnetic field strength, and the configuration of the ICRF antennas are decided based on the standard setting and the result of measurement in phase-control experiments.

4. Result

In the experiments, the line-integrated density in the central cell and the secondary electron detector (SED) signal are considered to show the propagation of the ICRF waves. Figure 2 shows the phase dependence of the SED signal and the line-density in cases of (a) Type-III and WAI-DAT antennas, and (b) Type-III and WAO-DAT antennas. It is clearly observed that the ion-heating in the anchor cell becomes effective with phase difference $\delta = \pi/2$ in the case of Type-III and WAI=DAT antennas, and becomes effective with phase difference $\delta = 0$ in the case of Type-III and WAO-DAT antennas. In order to analyze ICRF

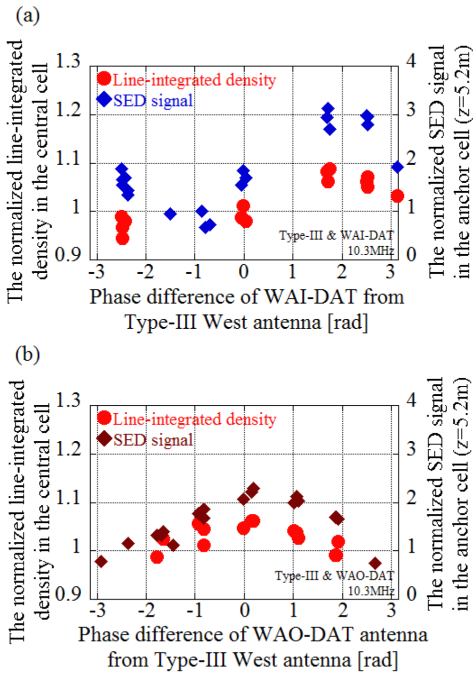

Fig. 2. The phase dependence of line-integrated density and SED signal in case of (a)Type-III and WAI-DAT antenna, and (b)Type-III and WAO-DAT antenna in the phase-control experiments.

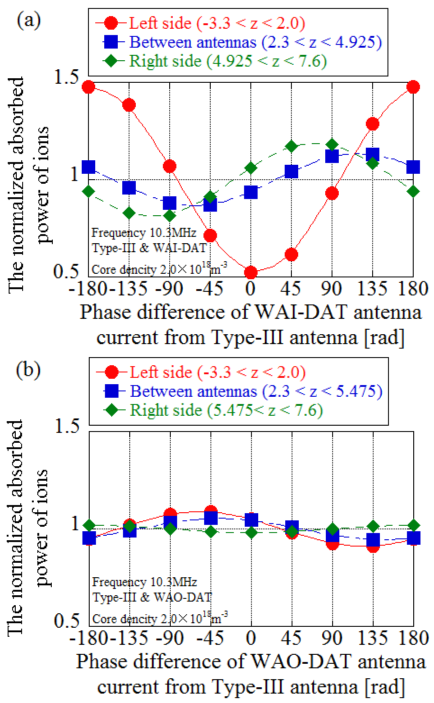

Fig. 3. The phase dependence of the absorbed power in case of (a)Type-III and WAI-DAT antenna, and (b)Type-III and WAO-DAT antenna in the numerical simulation.

wave propagation, the absorbed power of ions are calculated in phase-control experiments by TASK/WF. Figure 3 shows the absorbed power at the left side of two antennas, between two antennas, and the right side of two antennas, in cases of (a)Type-III and WAI-DAT antenna and (b)Type-III and WAO-DAT antenna in TASK/WF. In Fig. 3(a), the anchor cell is the right side of two antennas. In Fig. 3(b), it is between antennas. The absorbed power becomes big with phase difference $\delta = 45\sim90$ in Fig. 3(a), and with phase difference $\delta = -45\sim0$ in Fig. 3(b). The propagation of ICRF waves are the same way as the experiments.

5. Summary

In order to enhance ion-heating in the anchor cell, the phase-control experiments are introduced. It is performed that the optimization of ion-heating and controlling ICRF wave propagation with phased antennas.

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References

[1] T. Watari, et al., Nucl. Fusion, 22, 1359 (1982).
[2] A. Fukuyama et al., Proc. 20th Int. Conf. on Fusion Energy, TH/P2-3 (2004).