§13. Three-Dimensional Analysis of the Propagation of ICRF Waves in the GAMMA10 Anchor Cell

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Magneto Hydro Dynamic (MHD) stability of confined plasmas is improved on tandem mirror devices with minimum-B field. A concept of magnetic well stabilization was first proposed and demonstrated by Ioffe's group. Following mirror machines have achieved the sustainment of high performance plasmas with minimum-B stabilization. The GAMMA10 tandem mirror also has two minimum-B anchor cells at both sides of the central cell to eliminate the MHD instability. So far, high-β plasmas with the electron density of ~10^{18} m^{-3} and the ion-temperature higher than 10 keV have been sustained in a steady state with the help of the anchor stabilization. The anchor stabilization is given by producing a high pressure plasma in the minimum-B well. In GAMMA10, radio-frequency (RF) waves in the Ion-Cyclotron Range of Frequency (ICRF) are used for ion heating of the minimum-B plasmas. In the standard discharge, the RF power is coupled to the fast Alfvén wave by Nagoya Type-III antennas in the central cell. The fast wave excited in the central cell propagates to the anchor cell. In the flux tube with an elliptical cross section which is located between central and anchor cells, a part of the fast wave is converted to the slow wave and heats ions in the anchor cell. In order to produce higher performance plasmas in the central cell, it is essential to sustain higher pressure plasmas in the minimum-B well.

In this study, direct heating of the minimum-B plasma without mode-conversion is investigated by use of a three-dimensional full wave code (TASK/WF3). This code solves Maxwell's equations as a boundary-value problem using the finite element method. In the calculations, it is assumed that the cold and inhomogeneous plasmas surrounded by the conducting walls. The effect of the collisions is taken into account in the dielectric tensor. Figure 1 shows the generated finite element mesh. The calculation region is finely-divided around the core plasma region, which includes the ion-cyclotron resonance layer and the RF antenna. A bar-type antenna is installed near the minimum-B well, where the flux tube has a vertically long elliptical cross section. The excited wave with the frequency of 9.7 MHz has a resonance layer with the ellipsoidal closed surface in the magnetic well. The profiles of the magnetic field and the plasma density, and the structure of ICRF antennas are precisely set as shown in Fig. 2. The calculated electric field and absorbed power are also shown. The radial electric field profile is plotted on the z-x plane. In the beach heating regime, it is found that the absorbed power concentrates near the ion cyclotron resonance layer. It is suggested that more effective ion-heating can be expected by the optimization of the antenna configuration [1].

1) Yamaguchi, Y., 26th Annual Meeting of JSPF, Kyoto International Community Hole, (1-4/Dec./2009) 4pD23Ps

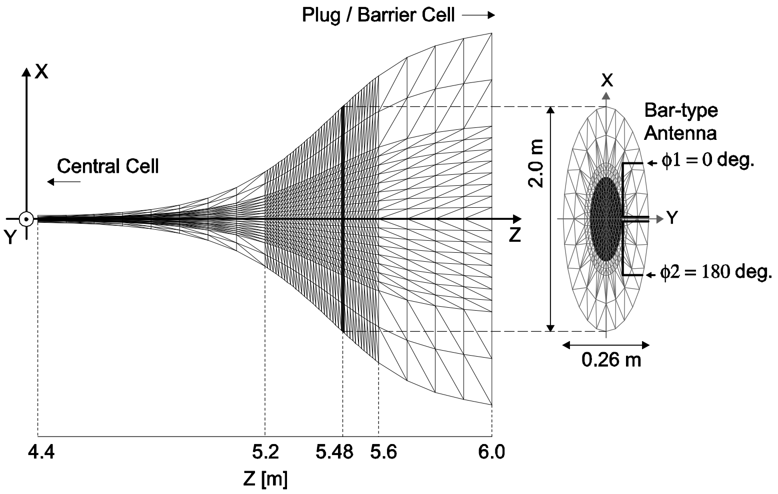

Fig. 1. Generated three-dimensional mesh structure for the finite-element analysis is shown.

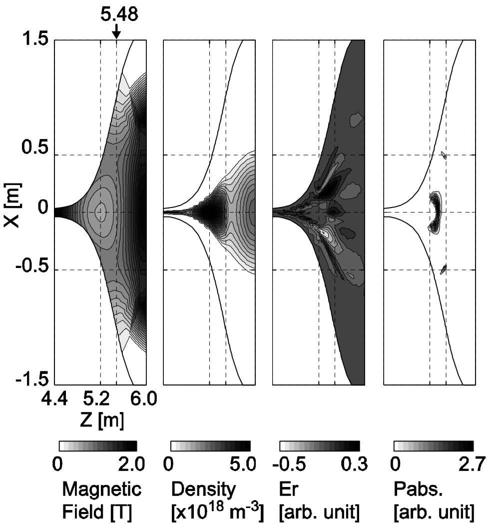

Fig. 2. Experimental parameters used for the calculations, and the results of the calculations are shown. It is clearly seen that the waves are absorbed near the resonance layer.