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Propagation and Absorption Properties of ICRF Wave in Finite Beta Plasma of LHD

LHD型ヘリカルプラズマにおけるICRF共鳴帯の伝搬・吸収特性

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We analyzed the propagation and the absorption property of the ICRF wave in the plasma consisting of the helium as a majority ion and the hydrogen as a minority ion by using the cold plasma approximation. As a result, the minority ratio with the maximum absorption power is about 30% and the maximum absorption power rarely changes by changing the density

1. Introduction

The heliotron type device such as the Large Helical Device (LHD) is suitable for the steady operation because the poloidal magnetic field, which is required for the plasma confinement, is made by the helical coil. With the Ion Cyclotron Range of Frequencies (ICRF) and Electron Cyclotron Heating (ECH) the low density discharges with 1×10^{19} m^{-3} are done for more than 3000 second in the LHD. In the helical plasma, the plasma confinement performance makes improvements with the increase in the density. On the other hand, when the density increase and is more than density limit, plasma confinement performance become very low, and the discharge stops due to the density collapse. Therefore, it is necessary to systematically investigate the heating property of the ICRF and the ECH in the relatively high density for the long discharge with the high confinement performance. In this study, we investigate the propagation and the absorption property of the ICRF wave in the LHD plasma with the relatively high density.

2. Analyses of ICRF wave with the cold plasma approximation

In this study, the propagation and the absorption property of the ICRF in the plasma consisting of the helium as a majority ion and the hydrogen as a minority ion, is investigated by using the TASK3D/WM [1], which is developed in the Kyoto University. The standard vacuum magnetic field with magnetic axis R_{ax} =3.6 is used and its field strength at magnetic axis is assumed to be 2.75 T. The propagation of the ICRF wave is analyzed by using the cold plasma approximation and the absorption is calculated with the collision dumping on resonance layers. The collision dumping is assumed to be $\nu=0.003\times i\omega$. Then the absorption process of the ICRF wave does not directly depend on the plasma parameter.

First, we investigate the absorption property by changing the ICRF wave frequency from 32 to 42 MHz in the 5% minority ion ratio. Figure 1 shows the change of the absorption power due to the frequency. In the Fig. 1, the vertical axis show the absorption power when the antenna current is 1 A. In the Fig. 1, the absorption power to the minority ion (H) is the largest than others and the absorption power to helium and electron is one tenth and one hundredth of the minority ion's absorption power, respectively. The absorption power near 39 MHz is the largest in each particle species.

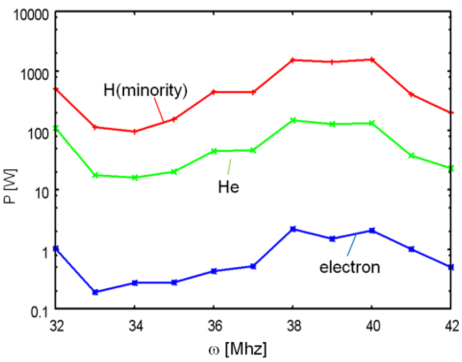


Fig. 1 The dependence of the absorption power on the ICRF wave frequency. The vertical axis show the absorption power when the antenna current is 1 A. Red, green and blue lines are the absorption powers to H, He and electron, respectively.

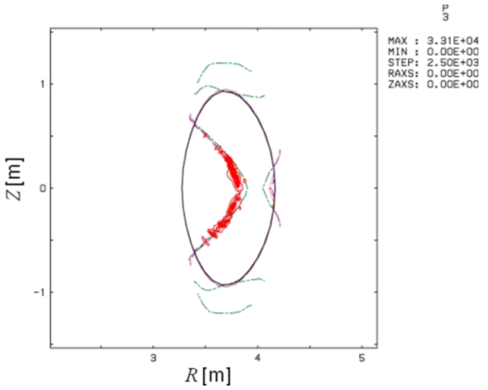
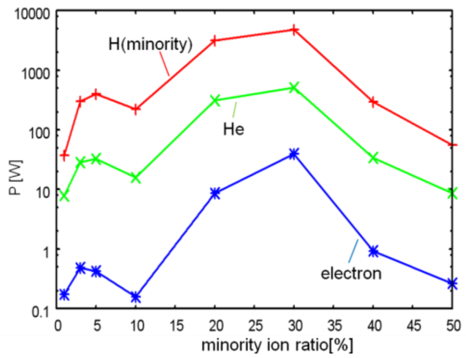
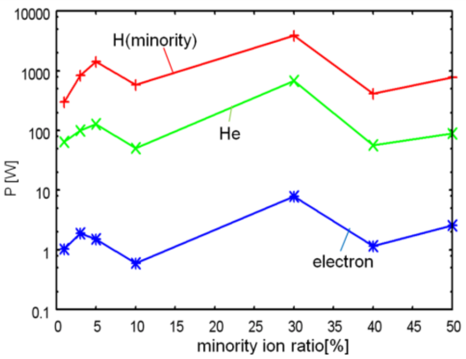


Fig. 2 The contour of the absorption power profile (red) and resonance layer (green). In addition, Purple lines show two-ion-hybrid resonance.



(a) n_e=2x10^{19} m^{-3}



(b) n_e=5x10^{19} m^{-3}

Fig. 3 The dependence of the absorption power on the minority ion ratio. Red, green and blue lines are the absorption powers to H, He and electron, respectively.

Figure 2 shows the absorption power profile of ICRF wave in the 39 MHz. In the Fig. 2, the resonance layer in the 39 MHz is near the saddle point of magnetic field strength where the gradient of the magnetic field strength is zero. ICRF wave is found to be absorbed only near the resonance layer.

Next, we investigate the dependence of the absorption power on the minority ion ratio in the low density (electron density n_e = 2x10^{19} m^{-3}) and relatively high density (n_e = 5x10^{19} m^{-3}). Figure 3 shows the dependence of the absorption power on the minority ion ratio in the 39 MHz case. In the analyses with the cold plasma approximation, the minority ratio in the maximum absorption power is 30% in both n_e = 2x10^{19} m^{-3} and n_e = 5x10^{19} m^{-3}. The maximum value of the absorption power in the two case is alomst same. On the other hand, except for near the minority ratio (30%) in the maximum absorption power, the absorption power dependent on the density. In the higher density case, the dependence of the absorption power on the minority ion ratio is smaller than that in the low density case.

3. Summary

We analyzed the propagation and the absorption property of the ICRF in the plasma consisting of the helium as a majority ion and the hydrogen as a minority ion by using the cold plasma approximation. As a result, the minority ratio with the maximum absorption power is about 30% and the maximum absorption power rarely changes by changing the density in the analyses with the cold plasma approximation. In the actual ICRF experiments, plsamsa tempearture is expected to enormously change due to the change of the density when the heat power of ICRF is constant. To analyses the effect of the plasma temperture on the propagation and the absorption property of the ICRF with "hot plasma model" is an issue in the near future.

We will investigate the effect of the plasma temperuter by using the ray tracing model as a first approach. In addition, the strike points of the divertor change by periodically changing the magnetic configuration and the average heat load decrease in the LHD long discharge. Thus, we will investigate the effect of the magnetic configuration on the propagation and the absorption property in the future.

[1] A. Fukuyama and T. Tohnai, in *5th IAEA Technical Committee Meeting on Alpha Particles in Fusion Research*, IAEA, Vienna, 1997.