§34. Electromagnetic Analysis in Corrugated Waveguide Using 3D-FDTD

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i) Introduction The Electron Cyclotron Heating (ECH) system is used for the plasma heating in the Large Helical Device (LHD). In ECH, the electrical power that is made by the gyrotron system transmits to LHD by long corrugated waveguide. The corrugated waveguide is bent by miter bend because it cannot be connected directly through the wall separating the gyrotron system and LHD. The miter bend is primary cause of the transmission loss. The optimum shape of the corrugated groove is not sufficiently verified.

In the previous study, the transmission efficiencies of the corrugated waveguide and miter bend have been investigated. In order to investigate the transmission efficiencies, the perfect electric conductor (PEC) was adopted as the metal. However, the Joule heating was not generated because PEC has no electric resistance. It is known that the Drude model can be substantiated the complex dielectric constant for the metal as a waveguide wall.

The purpose of the present study is to develop the numerical code for analyzing the wave propagation phenomena in the corrugated waveguide by FDTD with induced current density on the waveguide wall. In addition, the influence of the miter bend on the mode transfer is also investigated.

ii) Results and Discussions The electromagnetic wave that propagated corrugated waveguide is bent at a right angle by 45 degrees tilted mirror by the miter bend. A corrugated grooves digs periodically in waveguide wall perpendicular to the propagating direction of wave.

In ECH experiments, HE_{11} mode that is an eigenmode of the corrugated waveguide is adopted as the source wave. The effect of the waveguide wall is suppressed in the HE_{11} mode because the electric field is highest concentration at the center of the waveguide. In order to implement experiment fact on the numerical simulation, following assumptions are employed: the input wave is HE_{11} mode, the input frequency is 84 GHz, $l_{\rm in} = 3.6$ mm, $l_{\rm out} = 108$ mm, the waveguide consists of the aluminum and inside of the waveguide is vacuum. In addition, assuming the waveguide extends to infinity, Perfect Matched Layer (PML) that is the absorbing boundary condition is placed at both ends of the waveguide.

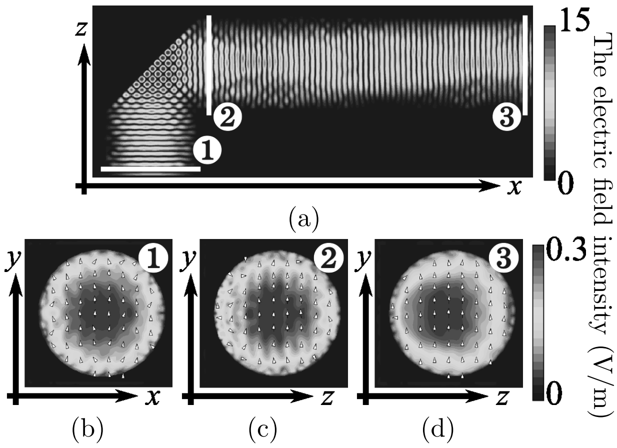

Fig. 1: The distribution of the electric field intensity at the miter bend. Here, (a) is cross-section of the miter bend, (b) is input plane, (c) is middle of the cross-section and (d) is output plane. In addition, (a) is $|\boldsymbol{E}|$, (b), (c) and (d) are $\langle|\boldsymbol{E}|\rangle_t$, respectively.

The distribution of the electric field intensity in the miter bend is shown in Fig. 1 for $p = 1.4$ mm, $w = 1.0$ mm and $d = 0.8$ mm [1]. The electric field intensity of the input plane was affected by reflection from the mirror (see Fig. 1(b)). Similarly, the electric field intensity of the middle cross-section was affected by reflection (see Fig. 1(c)). On the other hand, the input mode that is HE_{11} mode was observed at output plane (see Fig. 1(d)). The distribution of the electric field intensity in the middle cross-section is converted to the eigenmode of corrugated waveguide.

Additionally, the wave propagation simulations are implemented by means of meshless based method. Meshless Time-Domain Method (MTDM) is adopted for the wave propagation shimulation in complex shaped waveguide because MTDM does not requires meshes of geometrical structure [2, 3].

1) Y. Fujita, S. Ikuno, S. Kubo and H. Nakamura, "Electromagnetic wave propagation in waveguide considering influence of induced current", 24nd International Toki Conference, Gifu, Japan, Nov. 2014

2) Y. Ohi, Y. Fujita, T. Itoh, H. Nakamura, S. Ikuno, "Faster Generation of Shape Functions in Meshless Time Domain Method", Plasma and Fusion Research, 9, 3401144 (2014).

3) T. Itoh, Y. Hirokawa, and S. Ikuno, "High-Performance Computing of Electromagnetic Wave Propagation Simulation using Meshless Time-Domain Method on Many Integrated Core Architecture", IEEE Trans. on Magnetics, in press.