

Optimization of Millimeter-Wave Components using FDTD Simulation

FDTDシミュレーションによるミリ波コンポーネントの最適化
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In order to improve the shape of waveguide to transport with lower-loss energy than the present waveguide, we built up finite-difference time-domain (FDTD) simulation system for the waveguide. In our code, the time evolution of electromagnetic field in corrugated waveguide is simulated in two-dimensional (r, z)-coordinates calculation with perfect matched layer (PML) boundary condition. According to this simulation, it is confirmed that the total energy of the electromagnetic fields in the waveguide is conserved.

1. Introduction

It is necessary to provide low-loss transmission of electromagnetic wave for electron cyclotron heating (ECH) system to realize the nuclear fusion generation. To achieve this purpose, a lot of researches have been being done (see Refs. [1,2]). As one of the brilliant successes, it was found that corrugating the walls reduces the loss further not only in straight runs but also at bends (Fig.1) and that the corrugation makes the waveguide robust against small deformations [1]. Moreover theoretical calculations, which are based on a space-harmonic analysis of electromagnetic waves, contribute for these properties to be maintained over very wide bandwidths [1]. According to their work [1], the theoretical calculations were validated by the measurements on waveguides.

In order to improve the waveguide to transport with lower-loss energy than the previous design in Ref. [1], we challenge to optimize the waveguide structure by simulating the time evolution of electromagnetic fields in the waveguide by finite-difference time-domain method (FDTD) method (see Refs. [4-6]).

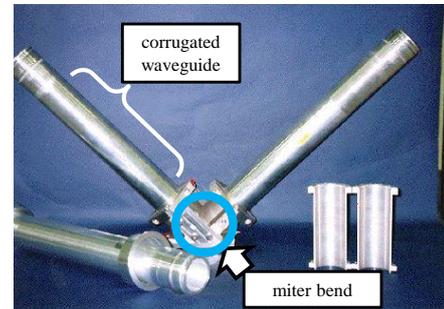


Fig.1. Milli-meter transporting components, which are designed for Large Helical Device (LHD) in NIFS.

2. FDTD Simulation

In FDTD method, the three-dimensional Maxwell equation is solved numerically, in the perfect matched layer boundary condition [7], for the same situation as the experimental configuration (Fig. 2).

Because the corrugated waveguide has the cylindrical symmetry, (*i.e.*, continuous rotational symmetry) for the azimuthal angle φ , the three dimensional simulation can be reduced to the two-dimensional (r, z)-coordinates calculation, where the electromagnetic fields are proportional to a function $\exp(im\varphi)$, where m is an integer (related to the angular momentum of the field).

The simulation parameters are as follows: the

wave length is 3.57 mm (the frequency 84 GHz), the spatial mesh is 0.025 mm, and the time step $\Delta t = 0.33 \times 10^{-11}$ sec. As the initial configuration, the electromagnetic fields are set to zero in the whole space.

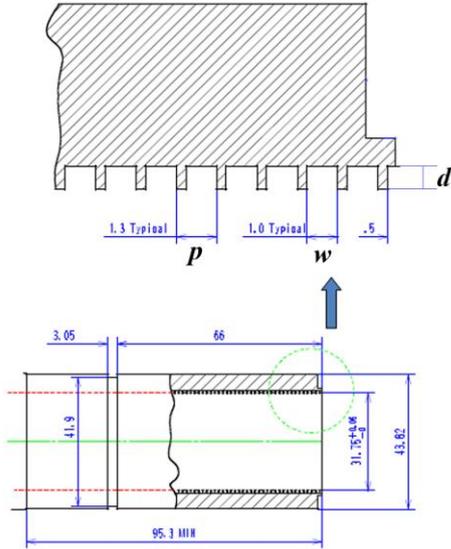


Fig. 2. Cross section diagram of the geometry in our 3D computer simulations for the corrugated waveguide (p denotes the period, w is the width and d the depth of the corrugation geometry).

3. Results

In Fig. 3, we draw the isosurfaces of the r component of the magnetic field for the two types of the cylindrical waveguides, that is, (a) “normal” waveguide and (b) corrugated waveguide. In the z direction, the shape of the electromagnetic field seems to the plane wave, *i.e.*, $\exp(ik_z z)$, where k_z is the wave number in the z direction. We plot the total electromagnetic energy v.s. time t whose unit is Δt in Fig. 4. When the time t is less than 100 step, the total energy is increasing. Around $t \sim 100$, there is a peak. After it, the total electromagnetic field is stabilized. This property denotes the energy is conserved in the simulation.

4. Conclusion

We performed FDTD simulation with PML boundary condition for cylindrical corrugated waveguide in two-dimensional coordinates. The conservation of the total electromagnetic field in the waveguide is confirmed. In the next step, it is expected to optimize the shape of the waveguide using this simulation.

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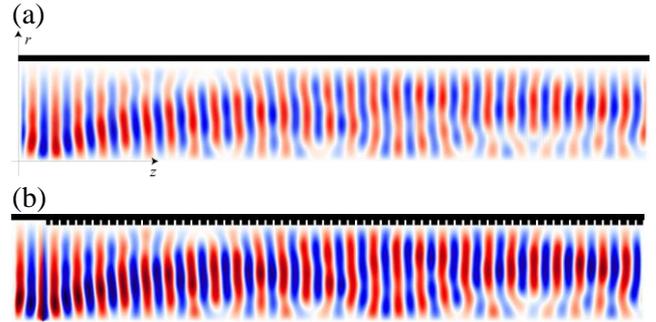


Fig. 3. The r component of magnetic field in (r, z) plane at time $700 \times \Delta t$. (a) The normal waveguide: The corrugated waveguide.

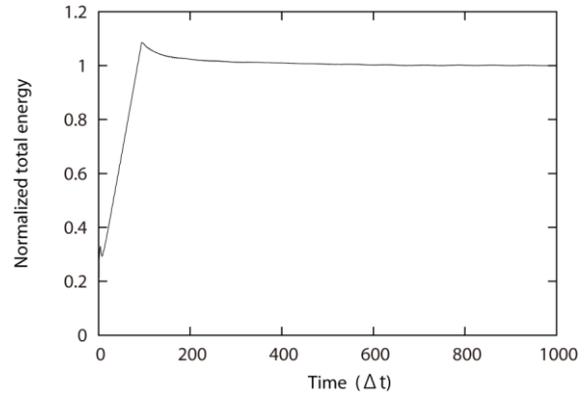


Fig. 4. Time dependence of the total energy for electromagnetic field in the corrugated waveguide. The energy is normalized by the saturated total energy.

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