20PA-058

Research and Development of a High Power Millimeter Wave Polarization Monitor

大電力ミリ波帯偏波モニターの開発研究

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New fast switching device at fixed frequency and new two types of polarization monitors for high power millimeter wave were proposed for an electron cyclotron current drive (ECCD) system. The principles and the results of numerical simulations about fast switching device and polarization monitors are reported.

1. Introduction

It is expected that the neo-classical tearing modes (NTMs) deteriorate energy confinement in tokamak fusion reactors [1]. Local current drive into the O-point of the magnetic island is effective in stabilizing the NTMs [2]. To take advantage of the 100% output of the gyrotron to current drive, the wideband diplexer for fast switching devices have been developed [3]. The switching operation of a wideband diplexer was confirmed by numerical simulations and by low power tests [4]. For improving performance, the new fast switching device at a fixed frequency and the new polarization monitor were proposed.

In this paper, the principles of new types of the fast switching device and the polarization monitor are reported .

2. Principle of Fast switching device at fixed frequency

In fast switching device that has been developed previously, assuming that P_1 is input power, output power is transmitted to port 2 when the frequency is not the resonant frequency of the diplexer. When the frequency is resonance frequency, electromagnetic wave accumulated in the diplexer is transmitted to port 4.

By attaching the vibrating plate installed in the miter bend of the first switching device as shown in Fig. 1 , the first switching device is a resonant state when the appropriate length for the input frequency, and electromagnetic wave is transmitted to port 4. At any other length, electromagnetic wave is transmitted to port 4. Theoretical formulas of output power P_2,P_4 are shown in Eqs.(1) and (2) [4].

$$P_2 = \frac{a\left|1+\{(1-a)\exp(i2\phi)-a\}\sqrt{\delta}\exp(i2\pi L/\lambda)\right|^2}{1+a^2\delta-2a\sqrt{\delta}\cos(2\pi L/\lambda)} \qquad (1)$$

$$P_4 = \frac{(1-a)^2 K}{1+a^2\delta-2a\sqrt{\delta}\cos(2\pi L/\lambda)} \qquad (2)$$

(R:Power reflection coefficient , L:Resonance length, λ:Wavelength, K:Loss coefficient of single pass from port 1 to port 4, δ: Loss coefficient of one turn pass in a ring resonator, φ: phase shift of passing through a half mirror)

Next, by attaching miter bend type directional coupler instead of another miter bend as shown in Fig. 1. , part of the electromagnetic wave of 170 GHz band high power millimeter wave accumulated in the device is taken out only a small amount. By measuring the power and polarization of the extracted electromagnetic wave, state of the electromagnetic wave in first switching device can be checked.

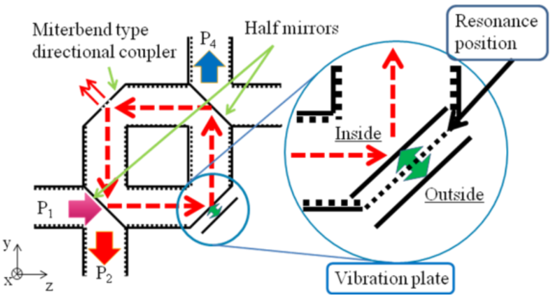
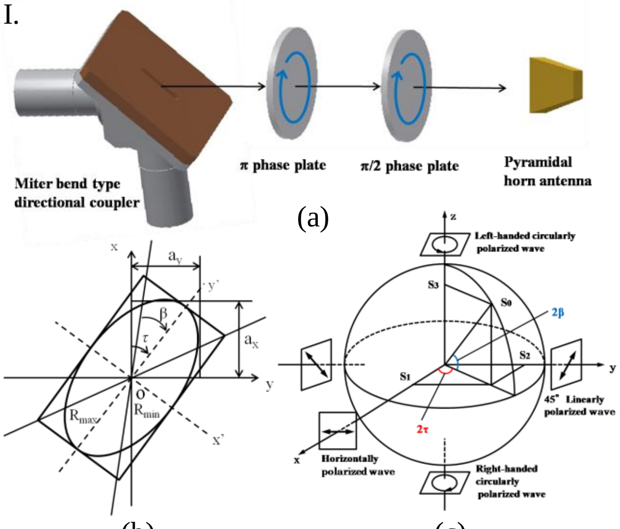


Fig. 1 First switching device at a fixed frequency.

3. Principle of polarization monitors

3.1 Phase plate type

The phase plate type polarization monitor consists of two phase plates (π phase plate and π/2 phase plate) as shown in Fig.3 (a). Phase plates are made of a-plane sapphire give a phase difference between two directions of the perpendicular and the c-axis to a parallel. By rotating these two phase plates, it was confirmed that the parameters of polarization can be obtained [5]. The thickness of these phase plates for 170 GHz are shown in Table I.



(a)

(b) (c)

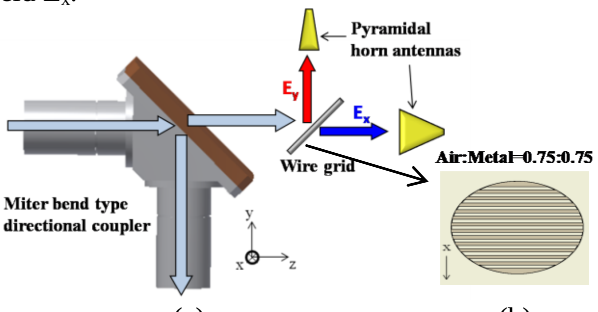
Fig. 3 Principle of the phase plate type polarization monitor. (a) Conceptual diagram, (b) Parameters of polarization, (c) Poincaré sphere.

Table I. The thickness of two phase plates.

π phase plate [mm]	π/2 phase plate [mm]
2.58	1.29

3.2 Wire grid type

The wire grid type polarization monitor uses a wire grid to separate x-direction component and y-direction component of the electric field as shown in Fig. 4. Slots were cut to cutoff y-direction electric field E_y and to transmit x-direction electric field E_x.



(a) (b)

Fig. 4 Principle of the half mirror type polarization monitor . (a) Conceptual diagram, (b) Magnified view of the wire grid.

4. Simulation by FDTD method

Reflectance of the wire grid has been simulated by our developed code. Main simulation parameters and results of the thickness dependence of the reflectance are in the following Table II and Fig. 5.

Table II. Main simulation parameters.

Cell size [mm]	0.15×0.15×0.15	Waveguide size [mm]	φ60
Total cell count	437×449×451	Air : Metal	0.75 : 0.75
Time step [s]	2.86×10^{-13}	Material of the mirror	C1020
Frequency [GHz]	170	Thickness of the mirror	0.636-2.76

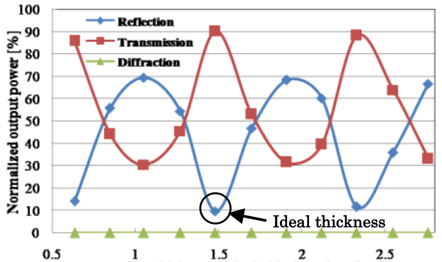


Fig. 5 The dependence of the reflectance on thickness.

The principle of separation of polarization was checked by numerical simulation using XFdtd. Main simulation parameters and result are in the following Table III and Fig. 6.

Table III. Main simulation parameters.

Thickness of the mirror	Material of the mirror	Frequency [GHz]	Size of the model
1.5	C1020	170	φ21 (1/3 model)

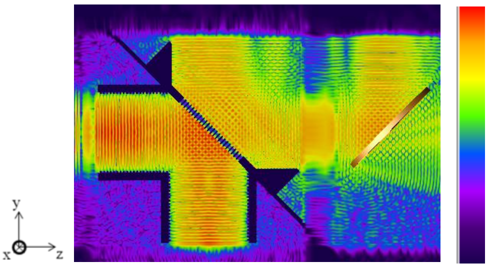


Fig. 6 Electric field distribution.

5. Summary

New first switching device at the fixed frequency and the two types of polarization monitors were proposed. In addition, the wire grid type polarization monitor was evaluated by numerical simulations.

Acknowledgments

This work has been supported by the Grants-in-Aid for Scientific Research (c) of 22560818.

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