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Research and Development of High Power Wideband Diplexer for ECCD System
電子サイクロトロン電流駆動用ミリ波帯広帯域高速スイッチの開発研究

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A diplexer for high power millimeter wave has been developed as a fast switching device in ECCD system. It is an analogy of an optical ring resonator switch. The switching operation of diplexer with a frequency shift was confirmed with the FDTD code developed in our laboratory. The diplexer was made up of two cross circular corrugated waveguides, two miter bends and two half mirrors. The switching operations of designed diplexer in low power tests are reported.

1. Introduction

It is expected that the neo-classical tearing modes (NTMs) deteriorate energy confinement in tokamak fusion reactors [1]. Electron cyclotron current drive (ECCD) using high power millimeter wave could suppress NTMs [2]. It is useful that local current drive into O-point of a magnetic island of NTM for stabilization. Up to now, ECCD with pulse modulated gyrotron operation at duty of 50% have been done to drive current into only O-point. Recently, for improving the stabilizing efficiency of NTM, the diplexer like a fast directional switch has been developed [3]. It makes the duty of ECCD system to 100% by fast switching beam direction for tracking the rotating O-point of a magnetic island of NTM. For improving performance of fast switching devices, the new wide band diplexer as a fast switching device was proposed [4]. In this paper, the results of low power test of new diplexer are reported, firstly.

2. Principle of fast switching device

The proposed diplexer consists of two cross circular corrugated waveguides, two miter bends and two half mirrors as shown in Fig. 1.

Input power is divided into the reflected power to Output1 and the transmitted power to ring resonator by a half mirror. The transmitted electromagnetic waves are turned around the inside of a ring resonator and it is reached Output1. If it is in phase with the electromagnetic waves reflected in the first half mirror, most rf power go to Output1. And if it is out of phase, it got to Output2. So, power of output can be switched by shifting a frequency.

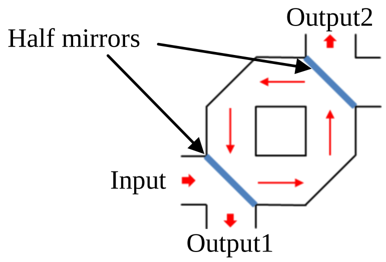


Fig.1. Principle of fast switching using a diplexer with shifting a frequency.

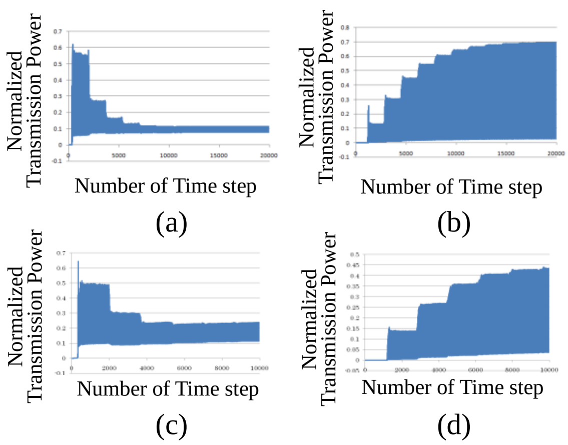


Fig.2. Normalized rf power of a fast switching device simulated by FDTD code. (a)Output1 using sapphire mirrors, (b) Output2 using sapphire mirrors, (c) Output1 using slotted mirrors, (d) Output2 using slotted mirrors.

3. Simulation by FDTD method

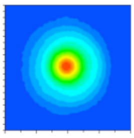
The electromagnetic field in the fast switching device has been simulated with our developed code using FDTD method.

The diameter of corrugated waveguides is 21.0 millimeters. The slotted metal half mirrors and the sapphire mirrors are used as the half mirrors in the ring resonator. The incidence HE_{11} mode is a fundamental mode of a circular corrugated waveguide. When sapphire disks are used as half mirrors, the input port must be shifted to take account of a shift of center axis due to refractive index. The characteristic of a fast switching device in the case of both half mirrors are shown in Fig.2.

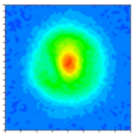
4. Low power test of a fast switching device

The diameter of a circular corrugated waveguide used in the low power test is 63.5 millimeters. The length of resonant ring is 650 millimeters.

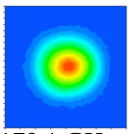
The diplexer with slotted metal mirrors (slot period:2 mm, slot width:1 mm, disk thickness:1.7 mm) was assembled as shown in Fig.1. The radiation patterns from Output1 and Output2 and the switching feature at a frequency band of 170 GHz are shown in Fig.3. The radiation patterns of peak power look like HE_{11} modes, while the higher mode was observed at minimum Output2 as shown in Fig. 3(d) because the slot period is longer than the wavelength.



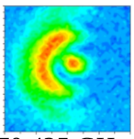
(a) 169.975 GHz



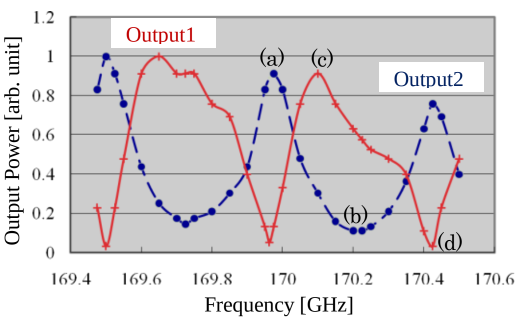
(b) 170.2 GHz



(c) 170.1 GHz



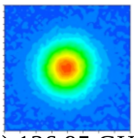
(d) 170.425 GHz



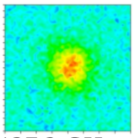
(e)

Fig.3. The result of low power test at 170 GHz band. (a) Radiation pattern of Output2 max, (b) Radiation pattern of Output2 min, (c) Radiation pattern of Output1 max, (d) Radiation pattern of Output1 min, (e) Frequency dependence of Output1 and Output2.

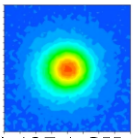
When a frequency band is 137 GHz, which is one of the planed frequencies in JT-60SA, the wavelength is shorter than a slot period. Therefore switching operation is clearly recognized without higher mode as shown in Fig.4.



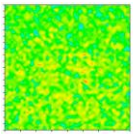
(a) 136.95 GHz



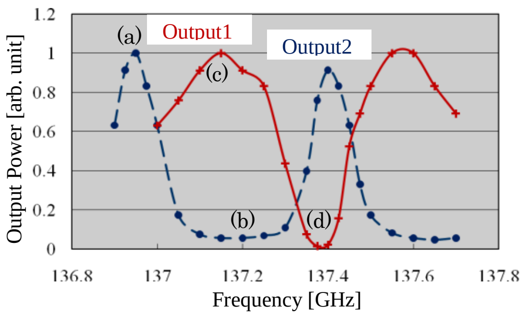
(b) 137.2 GHz



(c) 137.1 GHz



(d) 137.375 GHz



(e)

Fig.4. The result of low power test at 137 GHz band. (a) Radiation pattern of Output2 max, (b) Radiation pattern of Output2 min, (c) Radiation pattern of Output1 max, (d) Radiation pattern of Output1 min, (e) Frequency dependence of Output1 and Output2.

4. Conclusion

The high power wide band diplexer was designed and fabricated as a fast switching device for ECCD system. The switching operation was checked by numerical simulations and by low power tests. The switching operation of diplexer has been recognized clearly in the both cases of slotted mirrors and sapphire ones.

Acknowledgments

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References

[1] H. Zohm, Phys. Plasmas 4 (1997) 3433.
[2] H. Zohm, et al., Nucl. Fusion 39 (5) (1999) 577.
[3] W. Kasparek et al., Fusion Eng. Des. **84** (2009)1002.
[4] M. Saigusa, et al., Proc. of 13th AMPERE Toulouse (2011), p. 285.