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Research and Development of High Power Wide-band Polarizer for ECCD System
電子サイクロトロン電流駆動用ミリ波帯広帯域偏波器の開発研究

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A high power wide-band polarizer has been developed for ECCD system using step tunable gyrotrons, The polarizer has been designed at frequency bands of 110,130 and 140 GHz has been analyzed with the finite differential time domain method. The wide-band polarizer was designed for low-power experiments.

1. Introduction

Electron Cyclotron Current Drive (ECCD) system is one of the most promising method for heating and stabilization of fusion plasmas. Incident wave from gyrotron was needed to convert linearly polarized wave into specific elliptically polarized wave in order to excite the suitable wave at high mode purity. The polarizer is used for generating the specific polarization. Until now, the polarizer corresponding to single frequency has been used. However, it may be able to let the electromagnetic waves of different frequency on the same transmission line pass if wide-band polarizer which can be installed in a waveguide transmission line can be developed. Therefore, transmission line composition can be simplified sharply.

In this paper, the possibility of development of wide-band polarizer for ECCD system is reported.

2. The principle of polarizer

The linearly polarized wave, which is injected at right angles to a grooved mirror, can be divided into a electric field and a magnetic field component parallel to a groove direction. The former is reflected on the top of the grooved mirror, because of cutoff in groove, the latter is reflected at a bottom of it as long as the cycle *a* is less than half wavelength, as shown in Fig.1. Phase difference between fast polarization: FP and slow polarization: SP can be controlled by the groove depth of *h*.

In order to suppress high order diffraction waves, the cycle *a* must be given by

$$a < \lambda/(1+\sin\psi\ \cos\phi) \qquad (1)$$

where ψ is a incident angle, ϕ is a rotation angle, and λ is a wavelength [1].

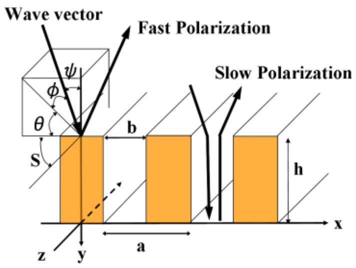
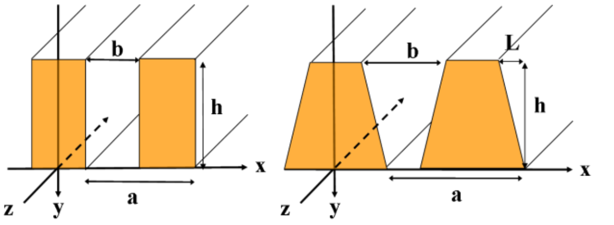


Fig. 1. A schematic view of grooved mirror.

A universal polarizer generally consists of a pair of grooved mirrors. The groove depth of the one mirror is about quarter wavelength, so that the phase difference between two reflected polarization waves is about 180 deg. The groove depth of the other one is about 1/8 of the wavelength, and the phase difference between two reflected polarization waves is about 90 deg. Arbitrary elliptical polarized wave can be generated by rotating these two grooved mirrors.

3. Analysis by the FDTD method

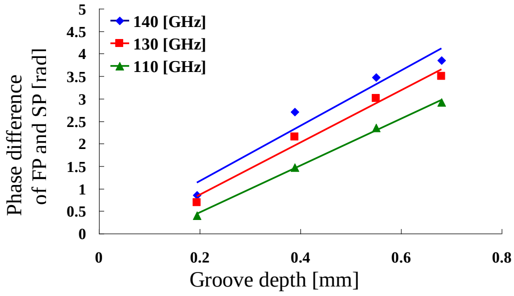
The polarizer has been analyzed by finite differential time domain (FDTD) method. The models of grooved mirror for analysis were defined as shown in Fig. 2. The dependence of phase difference between FP and SP on the depth and width of groove have been analyzed. The groove period: *a* was assumed to be 1.1664 mm from Eq. (1).



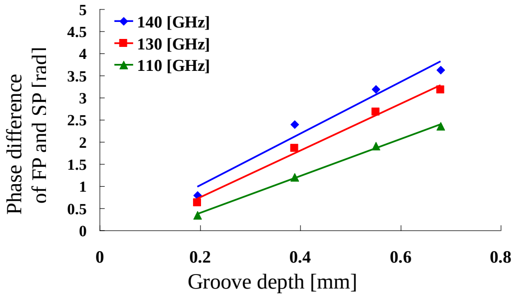
(a) (b)

Fig.2. Modeling of the grooved mirror used for analysis: (a) rectangle type and (b) trapezoid type.

The analysis results in ψ =*45* deg. and *S*=0 deg. of grooved mirror rotation angles at 110,130 and 140 GHz are shown in Fig. 3.



(a)



(b)

Fig. 3. Phase difference between FP and SP on the groove depth; (a) rectangle groove, (b) trapezoid groove, at the both grooved mirror form ratios: b/a=0.78.

4. The design of the wide-band polarizer

On the assumption the groove period is 0.467λ and the ratio of the width of a slot to ridge is 1 to 1, the depth with optimal diffraction grating is 0.25λ and 0.149λ [2]. At 110 GHz, these are 0.681 mm and 0.406 mm, respectively.

As shown in Fig.4, if they are substituted for x_1, the phase difference y_1 will be set to 3.618 rad and 1.791 rad. Further, they are substituted for y_2, the depth of the slot x_2 will be set to 0.804 mm and 0.454 mm. As shown Table I, in order to use electric power-proof, by deleting the angle at the tip of a diffraction grating, phase difference decreased by 0.21 rad at the maximum.

The depth of the slot is set to 0.85 mm and 0.49 mm as a result of taking these all into consideration.

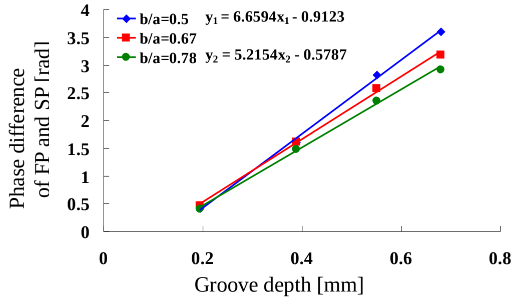


Fig. 4. Phase difference between FP and SP on the groove depth in various groove shapes at 110 GHz.

Table I. Maximum electric fields and the reduction of phase differences in various groove shapes at 110 GHz.

	Efp	Esp	Phase difference (rad)
Rectangle Type	2.78	2.60	2.92
Roundish Type 1	2.40	2.19	2.86
Roundish Type 2	2.31	2.08	2.79
Roundish Type 3	2.25	2.10	2.71

The grooved mirror and the flange attached to a mitre-bend was designed for a low power test as shown in Fig. 5.

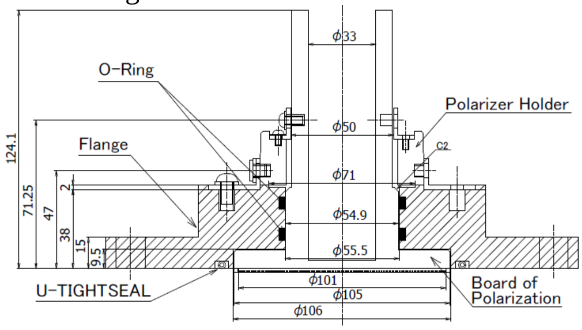


Fig.5. The erection diagram of the polarizer

5.Conclusion

The wide-band polarizer has been investigated in numerical calculations. It appears that the large ditch ratio rectangular grooved mirror is suitable for wide-band. The rectangular wide ditch grooved mirror installed in a miter bend was designed for a wide-band polarizer.

Acknowledgments

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References

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[2] M. Harigae, et al., Fusion Sci. and Technol. **55** (2009) 136.