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Research and Development of Wide band Polarizer for High Power Millimeter Wave
大電力ミリ波帯広帯域偏波器の開発研究

Takuma Sai, Fumiaki Matsubara, Yoshitaka Ishida, Mikio Saigusa,
Takayuki Kobayashi[1)], Shinichi Moriyama[1)]
佐井拓真, 松原史明, 石田義貴, 三枝幹雄, 小林貴之[1)], 森山伸一[1)]

College of Engineering, Ibaraki University
4-12-1, Nakanarusawa-cho, Hitachi 316-0036, Japan
茨城大学工学部 〒316-8511 日立市中成沢町4-12-1

1) Japan Atomic Energy Agency,
801-1, Mukayama, Naka 311-0193, Japan
日本原子力研究開発機構 〒311-0193 那珂市向山801-1

A wide band polarizer were developed for an electron cyclotron current driving system in JT-60SA. The wide band polarizer consists of a twister and a circular polarizers. The polarization properties of the twister was confirmed in cold tests. A high power test of the twister was carried out at an input power of 0.25 MW, 3 s at a frequency of 110 GHz . The reducing cost and size of the polarizer was proposed from the results of the thermal stress analysis.

1. Introduction

An electron cyclotron current drive (ECCD) system is one of the methods of controlling a plasma current profile in fusion plasma. In ECCD system, it is necessary that the electromagnetic wave are injected with specific elliptically polarization at the angle that is most suitable for a line of magnetic force with an incident electromagnetic wave to maximize current drive. The step tunable dual frequency gyrotrons at the frequency of 110 GHz and 138 GHz have been developed for ECCD system in JT-60SA [1]. Therefore, it makes the ECCD system to be simple and low cost by developing a wide band polarizer and installed in a waveguide transmission line. It was confirmed that the polarizer correspond to the frequency of 110 GHz and 138 GHz. In this paper, it was reported that an examination was carried out to obtain the guidance of the solution and the extraction of the problem. The results of high power and cold tests of prototype twister were reported.

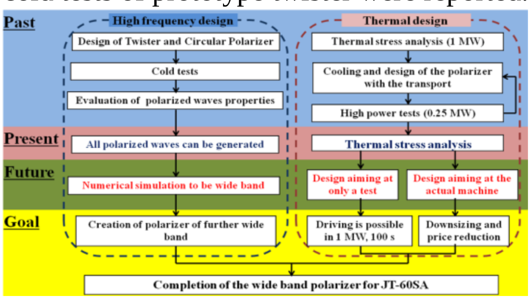


Fig. 1. A research flowing.

2. Principle of polarizer

The linearly polarized wave can be divided into the two polarizations. The one is the fast polarization: FP and the other is slow polarization: SP, where the z component of magnetic field of FP and the z component of electric field of SP must be zero, so that FP is reflected on top of the groove, SP is reflected on its bottom. In order to propagate the zeroth-order mode, the period a must be given by

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

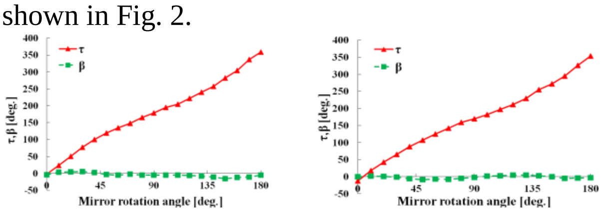
where θ is a incident angle, ϕ is a mirror rotation angle, and λ is a wavelength [2].

The groove depth of twister is about 1/4 wavelength, so that the phase difference between two reflected polarization waves is about 180 degrees. On the other hand, the groove depth of circular polarizer is about 1/8 wavelength, so that the phase difference between FP and SP is about 90 degrees. Arbitrary elliptical polarized wave can be generated by rotating these two grooved mirrors.

3. Experiments

3.1 Test results of twister in cold test

The cold test results of the prototype twister are shown in Fig. 2.



(a)110 GHz (b)138 GHz

Fig. 2. Polarization properties of twister.

It was confirmed to play a role to turn a plane of polarization because τ : a rotation angle of the longest axis of an ellipse turned 360 degrees at dual frequency in twister.

3.2 Test results of twister in high power test

The high power tests of the prototype twister had been carried out at an input power of 0.25 MW, 3 s at a frequency of 110 GHz. The ohmic loss of the twister and the miter bend with arc sensors were measured. Table I shows the result of the measurement.

Table I. Ohmic loss of the twister and miter bend.

	Twister			Miter bend		
Mirror rotation angle [deg.]	**0**	**45**	**90**	**0**	**45**	**90**
Ohmic loss [%]	**0.45**	**0.63**	**1.1**	**0.23**	**0.28**	**0.23**

The ohmic loss of the twister agree with the theoretical prediction qualitatively. The ohmic loss of the miter bend can be explained by the surface roughness and the diffraction loss generated in miter bend. The difference of the miter bend loss between the result and the theory(0.07 %(0°, 90°), 0.13 %(45°)) could be expressed by assuming the offset loss of 0.16%, which is estimated to be the part of the diffraction loss by one miter bend: 0.53%.

4. New polarizer design

The development of the polarizer corresponding to the dual frequency is carried out. This polarizer was designed to be able to endure the consecutive driving in 1MW, 100 s (Fig. 3.). As coolant leak measures, a plane cut was given for flange middle and Swivel Joint was connected.

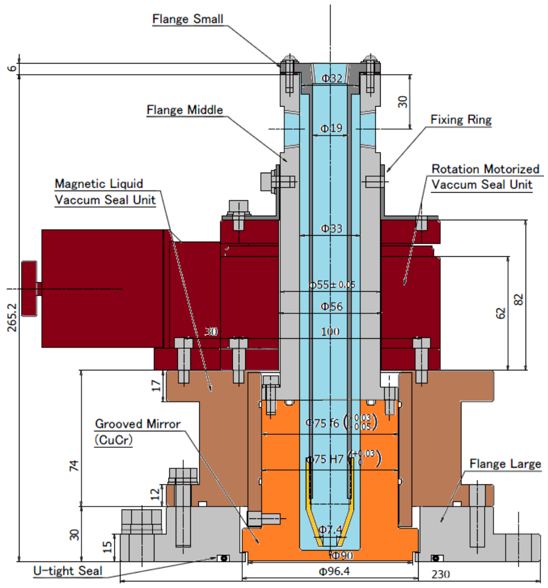
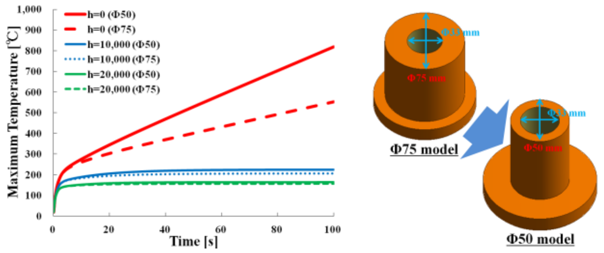


Fig. 3. Schematic view of the polarizer for high power tests.

The thermal stress analysis of the polarizer was carried out in examining downsizing (Fig. 4(a).). As a result, it was confirmed that the influence was small if the outer diameter of the polarizer was considered to be ϕ 50 from ϕ 75(Fig. 4(b).). Therefore, to reduce the inside diameter of the magnetic liquid vacuum seal unit lead to a price reduction and downsizing.

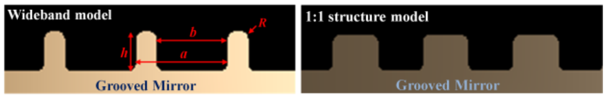


(a) (b)

Fig. 4. Maximum temperature:(a) and the two analysis models: (b).

5. Numerical simulations

Now the parameters of simulation model, where *a*, *b*, *h*, and *R* are a groove period, a groove width, a groove depth and a fillet of groove edge are designed *a*=1.17, *b*=0.91, *h*=0.49, *R*=0.1 mm to make wide band in comparison with *a*=1.17 mm and *b*=0.585 mm (Fig. 4.). In that case, the groove period: *a*=1.25 mm is simulated because the loss of *a*=1.25mm is smaller than the loss of *a*=1.17 mm.



(a) Wide band model (b) 1:1 structure model

Fig. 4. The parameters of simulation model.

6. Summary

The polarization properties of twister was confirmed from the cold test results. The ohmic loss of the twister and miter bend was evaluated from the high power test. New polarizer was designed for the next high power test. The downsizing of the polarizer was proposed from the results of the thermal stress analysis. In future plans, further wide band examination is carried out by numerical simulations because the polarizer correspond to the frequency of 110 and 138 GHz.

Acknowledgments

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