Study on Beam Phase Correcting for Gyrotron Quasi-optical Mode Converter

Guohui Zhao
[1]College of Physics and Electronic Engineering
Taishan University
Taian, Shandong Province, China,271021
zhaogh2006@163.com

Yong Wang
[2]Key Laboratory of High Power Microwave Sources and Technologies
Institute of Electronics, Chinese Academy
[3]University of Chinese Academy of Sciences
Beijing, China,101407
wangyong3845@sina.com

Qianzhong Xue
[2]Key Laboratory of High Power Microwave Sources and Technologies
Institute of Electronics, Chinese Academy
[3]University of Chinese Academy of Sciences
Beijing, China,101407
qianzhong_xue@mail.ie.ac.cn

Abstract: *In this paper, the Katsenelenbaum–Semenov Algorithm(KSA) of beam phase correcting for gyrotron quasi-optical mode converter is introduced. Based on KSA, two models with one phase-correcting mirror and two phase-correcting morrors are designed respectively. Five Gaussian beams at 170GHz with different ellipticity and astigmatism are studied base on above two models. A phase correcting mirror is designed for 170GHz, TE32,9-mode gyrotron quasi-optical mode converter by using KSA. After adding phase correcting mirror into the mirror system, the scalar and vector correlation coefficient on the output window increased by 1.02% and 9.72% respectively.*

Keywords*:* KSA; phase correcting; Gyrotron; quasi-optical mode converter

Introduction

Motivated by International Thermonuclear Experimental Reactor(ITER), the Gyrotron calls for higher operating frequency and output power. Quasi-optical mode converters (QOMC) are mainly used to transform high-order cylindrical waveguide modes generated by high power gyrotrons in millimeter and submillimeter wave range into linearly polarized fundamental Gaussian-like beams which can be directly used for low-loss transmission in free space[1]. Improving the efficiency of mode converter is of great significance for saving energy, reducing the design difficulty of heat load and prolonging the working life of gyrotron. There are several methods to increase the efficiency of QOMC, one of which is to design phase correction mirror[2]. The beam radiated from the launcher generally has a large ellipticity and astigmatism[3], and the wave-front phase of the beam is not in the same plane. Adding a phase correction mirror in the mirror system can adjust the beam parameters, and the beam with the wave-front phase almost in a plane can be obtained at the output window finally[4]. Based on KSA, the beam adjusted by phase correcting mirror is studied, and the output beam parameters of the 170GHz,TE32,9-mode quasi-optical mode converter are analyzed in this paper.

Correction of Gaussian Beams

The theoretical deduction of KSA can be found in many literatures[5], which will not be repeated in this paper. The two numerical models are shown in Fig. 1 and Fig. 2. Five Gaussian beams with different parameters are simulated respectively. The results are summarized in Table I and Table II. Table I corresponds to model 1 and Table II corresponds to model 2. The results show that the Gaussian mode content on the output window of 5 Gaussian beams are increased. While the astigmatism of the input Gaussian beam is small, the result of model 1 is better; while the astigmatism of the input Gaussian beam is large, the result of model 2 is better. However, when the ellipticity of the incident Gaussian beam is large, the results of the two models are not good.

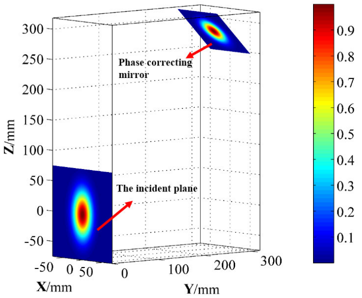


Figure 1. Model 1 for correcting Gaussian beams.

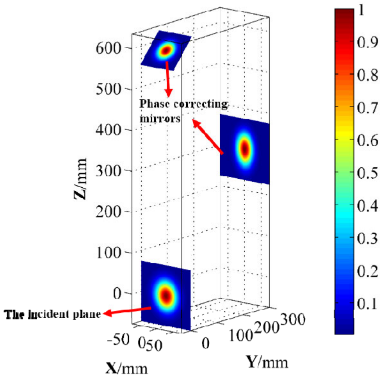


Figure 2. Model 2 for correcting Gaussian beams.

Table 1. Simulation results for model 1

Waist radius in two directions and astigmatism of incident Gaussian	Waist radius of target Gaussian beams in two directi-	scalar and vector correlation coefficient before correcting (%)	scalar and vector correlation coefficient after correcting (%)

978-1-5386-8288-3/20/$31.00 ©2020 IEEE

beams (mm)	ons (mm)		
20,25,50	28,28	96.37,91.64	98.26,95.13
20,25,50	26,26	97.96,94.84	99.08,97.20
20,24,50	22,22	99.77,98.91	99.79,99.23
20,24,500	22,22	99.50,97.13	99.95,99.77
20,24,800	22,22	99.31,93.32	98.77,96.72

Table 2. Simulation results for model 2

Waist radius in two directions and astigmatism of incident Gaussian beams (mm)	Waist radius of target Gaussian beams in two directions (mm)	scalar and vector correlation coefficient before correcting (%)	scalar and vector correlation coefficient after correcting (%)
20,25,50	28,28	99.75,90.03	98.69,93.74
20,25,50	26,26	99.79,90.15	98.68,93.73
20,24,50	22,22	99.07,90.83	99.73,97.74
20,24,500	22,22	97.13,88.45	99.76,97.83
20,24,800	22,22	96.93,90.55	99.92,99.44

Simulation Results for Phase Correcting Mirrors

One phase correcting mirror is designed for 170GHz, TE32,9-mode gyrotron quasi-optical mode converter by using KSA. Fig.3 gives out the variation of correlation coefficient with iteration numbers. When the iteration number is 20, the scalar correlation coefficient and vector correlation coefficient converge to 99.45% and 98.12% respectively. The field amplitude (dB) distribution and phase pattern distribution on the window after phase-correcting are shown in Fig.4 where the red circle represents the window boundary. Fig.5 shows the beam width of the output beam in X and Z directions, respectively. The waist radius of the output beam in the X and Z directions is 28.56mm and 28.85mm, respectively. The coordinates of the two radius on the propagation axis are Y0x=-340mm and Y0z=-390mm, respectively. The ellipticity is 1.01 and the astigmatism is 50mm for the output beam.

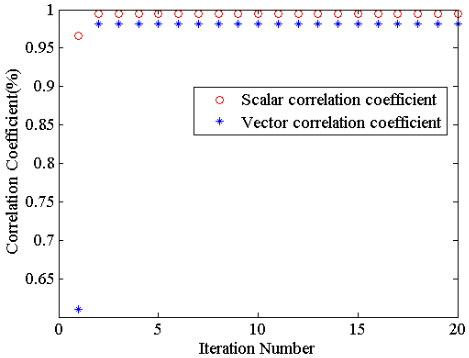
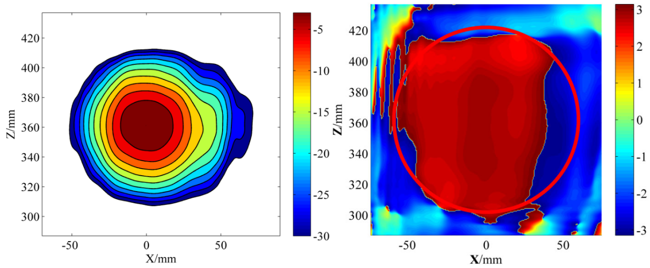
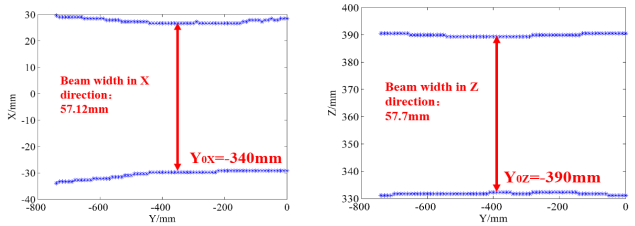


Figure 3. The variation of correlation coefficient with iteration numbers.



(a) (b)

Figure 4. (a) Field amplitude (dB) distribution (b) phase pattern distribution on the window after phase-correcting



(a) (b)

Figure 5. (a)The beam width of the output beam in the X direction, (b) the beam width of the output beam in the Z direction.

Conclusion

The KSA can improve the Gaussian mode content on the output window and reduce the beam ellipticity. However it cannot eliminate the beam astigmatism. Iterations of the KSA consume a significant amount of time resources, and this method is not the appropriate choice as the operating frequency and mode order increase.

Acknowledgments

This work was supported in part by the National Science Fund of China under contract 11475182.

References

1. Wang, Wei , et al. "Quasi-Optical Mode Converter for a 0.42 THz TE17, 4 Mode Pulsed Gyrotron Oscillator." IEEE Transactions on Electron Devices PP.99(2017):15.
2. D. S. Tax et al., "Experimental results on a 1.5 MW, 110 GHzgyrotron with a smooth mirror mode converter," J. Infr., Millim. Terahertz Waves, vol. 32, no. 3, pp. 358–370, 2011.
3. J. Jin, G. Gantenbein, J. Jelonnek, M. Thumm, and T. Rzesnicki, "A new method for synthesis of beam-shaping mirrors for off-axis incident gaussian beams," IEEE Trans. on Plasma Sci., vol 42, no. 5, pp. 1380- 1384, may2014.
4. Guohui, Zhao, et al. "Design of Phase Correcting Mirror for Gyrotron Quasi-optical Mode Converter." 2019 International Vacuum Electronics Conference (IVEC). IEEE, 2019.
5. J. B. Jin, B. Piosczyk, M. Thunmm, T. Rzesnicki, and S. C. Zhang, "Quasi-optical mode converter/mirror system for a high-power coaxial cavity gyrotron," IEEE Trans. Plasma Sci., vol. 34, no. 4, pp. 1508–1515,Aug.2006.