Effect of the Position Variation of the Launcher Cut on the Conversion Efficiency of the Gaussian Beam in a Denisov-type Mode Converter

Chen Yang[1, 2], Wenqi Li[1, 2], Zhiqiang Zhang[1], ZhiXian Li[1, 2], Menglong Jiao[1, 2], Min Zhu[1], Wei Guo[1], Jirun Luo[1, 2]

[1]Key Laboratory of High Power Microwave Sources and Technologies, Institute of Electronics,
Chinese Academy of Sciences, Beijing China, 100190
[2]University of Chinese Academy of Sciences, Beijing China, 100049

Abstract: *In this abstract, the position variation of the launcher cut was slightly adjusted for decreasing the effect of the diffraction on the launcher conversion efficiency of the Gaussian beam from the $TE_{28,8}$ mode in Denisov converter, which shows that the Gaussian beam content can be improved indeed.*

Keywords: Gyrotron; quasi-optical mode converter; Gaussian beam content; Denisov-type launcher

Introduction

High power output gyrotron generally works in high-order cavity mode, which has less loss in the cavity, but has strong diffraction and polarization loss in free space. To solve this problem, Russian scientists proposed quasi-optical mode converter technology in 1974 to transform the operating cavity mode into a fundamental Gaussian wave beam in order to reduce losses in the transmission of the gyrotron output power [1]. A general quasi-optical mode converter consists of a cylindrical waveguide with a spiral opening, i.e., a launcher and a set of mirrors system. The launcher is the core of the design of the converter system, which greatly affects the conversion efficiency of the cavity mode to the Gaussian beam at the aperture of the launcher, that is, the Gaussian component content.

In order to reduce the diffraction of the edge of the launcher, Russian scientist Denisov et al. proposed a periodic spiral corrugated waveguide structure in 1992 [2]. The irregular perturbation of the waveguide wall realized the pre-focusing process of the beam in the launcher, making the current on the inner wall of the waveguide represents a quasi-Gaussian distribution, which reduces the diffraction loss at the edge of the cut, thereby improving the conversion efficiency of the Gaussian beam to about 95.7% [3].

Design of Denisov-type launcher

For the Denisov-type launcher with an operating frequency of 140GHz and an operating mode of $TE_{28,8}$, the perturbation on launcher wall can be described as follows:

$$r(\phi,z)=R_0+\tau z+\delta_1(z)\cos(0.1499z-\phi)+\delta_2(z)\cos(0.0153z-3\phi) \quad (1)$$

where R_0 is the radius of the launcher, τ represents the slope of the wall, and δ_1, δ_2 represents the perturbation amplitude. The perturbation amplitude and length selected here is shown as Figure1. Figure 2 shows the wall profile of Denisov-type launcher obtained by expression (1).

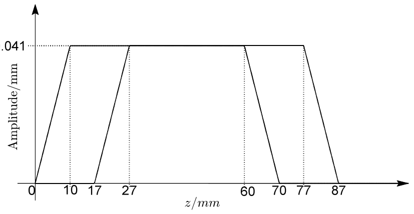

Figure 1. The perturbation amplitude and length

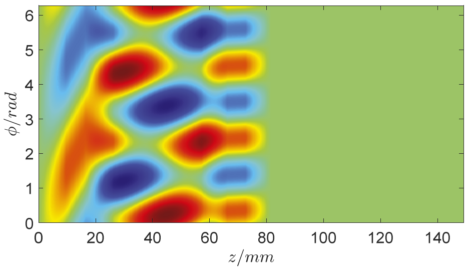

Figure 2. Amplitude distribution of wall profile of Denisov-type launcher

Firstly, the influence of the launcher cut is not considered, and the field distribution on the launcher wall is obtained and shown in Figure 3. The cut and radiating aperture edges are indicated by solid and dotted lines in Figure 3, respectively.

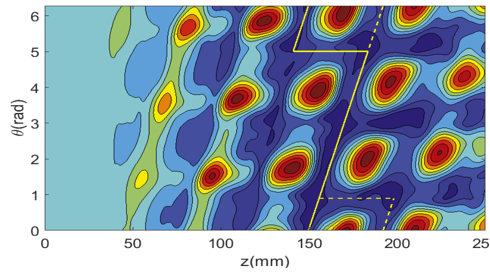

Figure 3. Field distribution on the wall of the launcher. The radiating aperture edges are shown as dashed lines and the cut as solid lines

Numerical calculation

A. Impact of radiating aperture center

If taken the effects of the launcher cut into consideration, the radiating aperture field would deform in some degree due to the diffraction effect of the cut, as shown in Figure 4. In this case, the fundamental Gaussian mode content (FGMC) of the aperture field obtained is 96.21%, which is higher than 95.65% when the launcher cut is not considered. This improvement of FGMC may be due to the change of the center of the radiating aperture field, which caused by the introduction of launcher cut, so that the aperture field and the target Gaussian field are better matched. Therefore, by adjusting the center of the aperture field to change the position of the launcher cut (ensure that the size of the aperture remains the same), the vector correlativity between the aperture field and the target Gaussian field is obtained by numerical calculations, and it can be used to judge whether the setting of the cut at this case can gain the maximum Gaussian mode content of the aperture field. Table 1 represents the FGMC of the aperture field for different position of aperture center. The calculation results show that the choice of the center position of the aperture field can indeed affect the FGMC of the final aperture field.

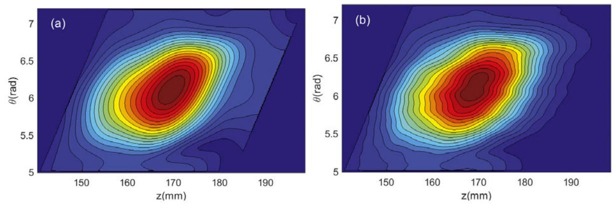

Figure 4. Field distribution of radiating aperture. (a) represents the radiating aperture field without launcher cut and (b) with launcher cut

Table 1. Gaussian mode content for different radiating aperture center

Position of aperture center (z_c,ϕ_c)	Vector correlation coefficient	Scalar correlation coefficient
(169.541,6.098)	96.21%	97.68%
(168.471,6.029)	96.58%	97.99%
(168.899,6.088)	96.93%	98.40%
(168.471,6.020)	96.33%	97.75%

B. Impact of radiating aperture size

On the other hand, the FGMC of the aperture field is also relative to the size of the launcher cut. For the cut shown in Fig. 3, the aperture of the launcher is shown in Fig. 4. It can be seen that the position of the cut is not at the smallest field value. Therefore, the position of the cut can be adjusted to make the cut through the smaller value of the aperture field, in order to reduce the effect of the cut on the aperture field. Figure 5 is shown the aperture field distribution after the adjustment of cut shown in figure 3. The FGMC of aperture field is 96.67%，compared to the unadjusted cut of 96.21%. The calculation results show that by properly setting the size of the aperture field, the Gaussian mode content of the aperture field can be improved.

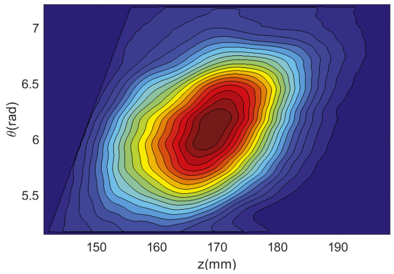

Figure 5. aperture field distribution after the adjustment of launcher cut shown in Figure 3

Finally, by combining these two methods of optimizing the position of the launcher cut, the optimal cut position is obtained and the aperture field FGMC of is up to 97.26%. Figure 6 shows the field of aperture and the target Gaussian mode.

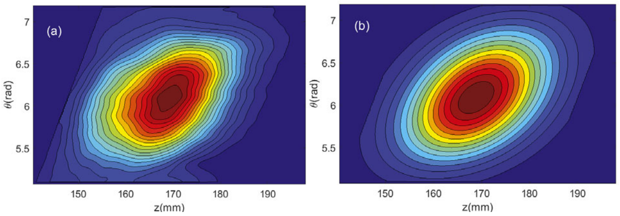

Figure 6. Field distribution of radiating aperture. (a) represents the radiating aperture field with launcher cut and (b) the target Gaussian field

Conclusion

The diffraction effect brought by the cut of the launcher will affect the aperture field distribution, and then its Gaussian mode content. Through quantitative analysis of the aperture center position and aperture size to the aperture field Gaussian content, a higher FGMC (97.26%) of aperture field is obtained under a suitable launcher cut.

Acknowledgements

This work has been supported by National Key R&D Program of China, contract numbers 2017YFE0300202 and 2017YFE0300200.

References

[1] S. N. Vlasov, I. M. Orlova. Quasioptical Transformer Which Transforms the Waves in a Waveguide Having a Circular Cross Section into a Highly Directional Wave Beam[J]. Radiophysics & Quantum Electronics, 1974, 17(1):115-119.

[2] Denisov G, Kuftin A, Malygin V, et al. 110 GHz Gyrotron with a Built-in High-Efficiency converter[J]. International Journal of Electronics., 1992,72(5-6):1079-91.

[3] Thumm M, Yang X K, Arnold A, et al. A high-efficiency quasi-optical mode converter for a 140-GHz 1-MW CW gyrotron[J]. IEEE Transactions on Electron Devices, 2005, 52(5): 818-824.