# Design of G-band Folded Waveguide Traveling-wave Tube

***Ping Han[1], Zugen Guo[1], Zhixin Yang[1], Rujing Ji[1], Ruifeng Zhang[1], Huarong Gong[1]***
[1]National Key Laboratory of Science and Technology on Vacuum Electronics
School of Electronic Science and Engineering, University of Electronic Science and Technology of China
Chengdu, China, 610054
hrgong@uestc.edu.cn

**Abstract:** *When it comes to the terahertz band, it is a challenging task to design traveling-wave tube. In this paper, the design of G-band folded waveguide traveling-wave tube (FWGTWT) is introduced in detail. The simulation results show that the folded waveguide circuit can produce over 27.5dB gain and over 15W output power within 10GHz bandwidth, when the beam current of the electron optical system (EOS) is 40 mA and the beam transmission rate is 100% with cathode voltage -19.25kV and the first anode -3kV.*

**Keywords:** G-band, electron optical system, folded waveguide

## Introduction

At present, many research institutions in the world have done a lot of research on terahertz TWT. In 2012, Northrop Grumman successfully developed a 0.22THz folded waveguide TWT, with the emission current of 277mA, electron beam flow rate of 75-80%, and output power exceeding 30W [1]. In 2019, the Institute of Applied Electronics China Academy of Engineering Physics successfully developed a G-band continuous waves FWGTWT, which can reach over 10W output power with 10GHz -3dB bandwidth at 3% duty cycle. The maximum output power is about 18W at frequency 216GHz and the maximum gain is 28.2dB [2].

In this paper, a G-band folded waveguide TWT is designed. Folded waveguide with wide bandwidth is very suitable for slow wave structure of traveling-wave tube. Since the electron channel radius is only 0.1mm, focusing electron beam is difficult, so that uniform magnetic field of permanent magnet block is applied to the focusing system of G-band travelling-wave tube. By optimizing the design of electron optical system and high frequency system, the G-band FWGTWT, operating at -19.25kV and with electron beam current 35mA, can reach over 15W output power with 15GHz -3dB bandwidth.

## Eletron optical system

The electron beam channel radius is only about 0.1mm, making it difficult for the beam to pass through. Therefore, it is necessary to optimize EOS to make the electron beam wave and beam radius as small as possible. Electron Gun: *The initial structure parameter is calculated by Vaughan theory. The radius of electron beam channel is 0.1mm. Because the cathode is small, which makes it difficult to fabricate curved surface, the planar surface cathode is adopted. The structure model of electron gun and electron optical system are shown in Fig. 1 and Fig. 2, respectively.*

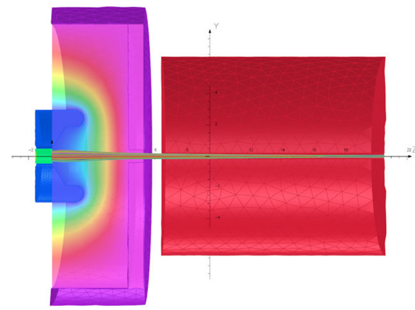

**Fig. 1.** The structure of electron gun

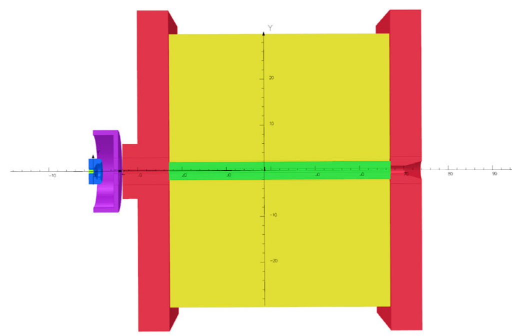

**Fig. 2.** The structure of EOS

*Magnetic Focusing System:* In that the electron beam radius is small and the space charge force is strong, the traditional periodic permanent magnet focusing system is difficult to focus the electron beam. Therefore, this design adopts the uniform magnetic field of permanent magnet block. The axial field distribution of uniform magnetic is calculated by CAD, the result is shown in Fig. 3. The axial magnetic field intensity of magnetic system is about 0.7T with its length of 50mm.

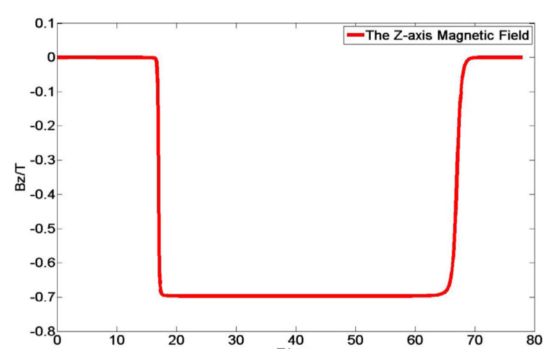


**Fig. 3.** The axial magnetic field intensity of magnetic system

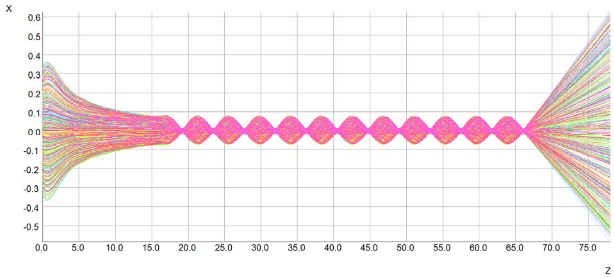

**Fig.4.** The beam trajectory with magnetic field

By matching the magnetic focusing system with the electron beam, the simulation results show that the transmission rate of electron beam reaches 100% with the current of 40mA. The beam trajectory of the electron optical system is simulated by Opera-3D as shown in Fig. 4.

## High frequency system

The attenuator structure is so small that is very complicated to be processed and assembled when the frequency is in the terahertz band. Due to the need for concentrated attenuator in the multi-section structure, in this paper, the whole high frequency system of TWT adopts single segment structure. However, in order to prevent self-excited oscillation, the gain is not too high. Fortunately, terahertz solid-state amplifier has been able to provide 100mW output power, so that the gain requirements of terahertz traveling-wave tube can be properly reduced.

The slow wave circuit adopts folded waveguide whose material is copper with its relative permittivity of 5.7. Considering the actual machining conditions and loss, the dispersion and coupling impedance obtained are shown in Fig. 5 by adjusting the structural parameters.

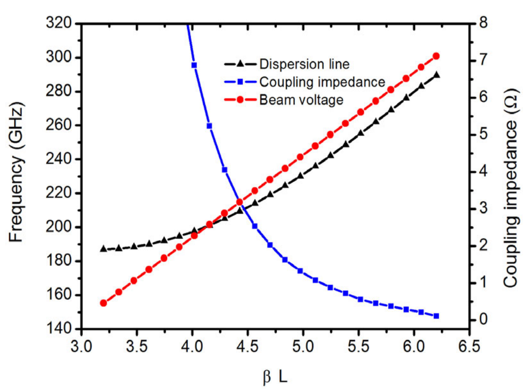


**Fig.5.** The dispersion and coupling impedance of slow wave circuit

The beam-wave interaction was calculated by the 2.5-dimensional signal analysis program FWGTWT [3]. The results show that the circuit can produce over 27.5dB gain and over 15W output power within 10GHz bandwidth from 214GHz to 224GHz. The output power growth curve is shown in Fig. 6.

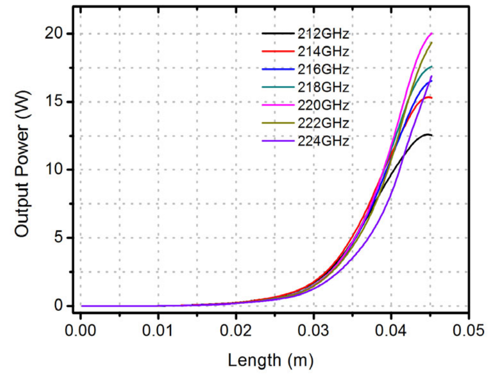


**Fig.6.** The output power growth curve with circuit length

## RF Window

A beryllium oxide pill-window a diamond pill-window for 0.22THz FWG TWT have been designed. The simulation predicts the VSWR of beryllium oxide pill-window is less than 1.15 and the VSWR of diamond pill-window is less than 1.1. As is shown in Fig. 7.

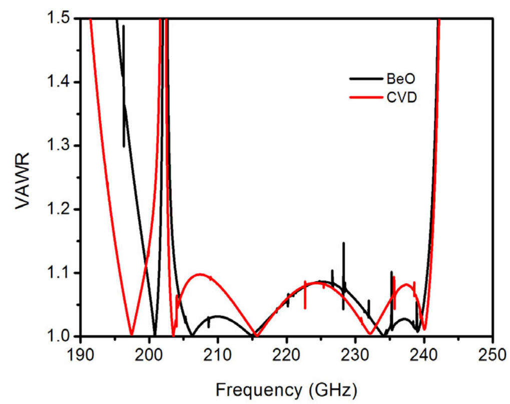


**Fig.7.** The VSWR of beryllium oxide pill-box window and diamond pill-box window

## Conclusion

The G-band folded waveguide traveling-wave tube has been designed by the University of Electronic Science and Technology of China. Fabrication and testing are about to be carried out soon.

## References

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