T-shape Vane Slow-wave Structure for 220 GHz Sheet Beam Traveling-wave Tubes

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Abstract: *In this paper, a T-shape vane slow-wave structure (SWS) for 220 GHz sheet beam traveling-wave tube (TWT) is proposed. The high frequency characteristics and transmission characteristics of T-shape vane SWS are analyzed by using eigenmode solver of HFSS and the frequency domain solver in CST 2016 Microwave Studio. The results indicate that the interaction impedance of T-shape vane slow-wave SWS has improved about 5% than rectangular vane's at 220 GHz, and the reflection coefficient S_{11} is below -15 dB and the transmission coefficient S_{21} is above -5 dB in the frequency range from 213 GHz to 230 GHz. The T-shape vane SWS has laid a good foundation of physical experiment about 220 GHz sheet beam TWT in the future.*

Keywords: T-shape vane slow-wave structure, high frequency characteristics, transmission characteristics, 220 GHz sheet beam TWT

Introduction

Terahertz (THz) wave is an electromagnetic wave with the frequency between 0.1 THz and 10 THz. It has the advantages of strong penetration and high resolution, and would enable numerous applications in the field of medical detection, imaging and industrial production [1]. As the most widely used vacuum electron devices, the traveling-wave tubes (TWTs) are widely applied to radar, communication and various fields [2, 3]. As slow-wave structure (SWS) is one of the core components of TWT, the performance of TWT is determined by the performance of SWS. However, the size of the device becomes small in THz band and complicate the processing.

In this paper, a simple metal structure T-shape vane SWS is proposed. It can be realized by modern microfabrication techniques [4]. In order to illustrate its performance, the high frequency characteristics of T-shape vane SWS are given and compared with the rectangular vane SWS in Section II. The transmission characteristics simulation results of T-shape vane SWS with input and output couplers are also discussed in Section III.

High Frequency Characteristics

The beam-wave interaction performed in the slow-wave systems, but the electron beam must be synchronized with the traveling-wave in the SWS for continuous and effective energy exchange. The dispersion characteristics of the SWS represent the operating bandwidth that the device can synchronize, while the strength of the beam-wave interaction is represented by another parameter—the interaction impedance.

Based on the normal rectangular vane SWS, we add ridges on the vane tips in order to enhance the axial electric field intensity [5]. The optimum parameters of the structure are obtained by using eigenmode solver of HFSS. The 3-D model of the T-shape vane SWS is shown in Fig. 1, and the parameters are listed in Table I.

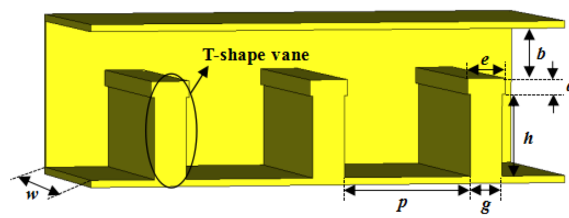

Fig. 1. 3-D model of the T-shape vane SWS.

Table I. Parameters for the T-shape vane SWS

Symbol	*p*	*g*	*h*	*w*	*b*	*e*	*d*
Value (mm)	0.5	0.1	0.23	0.78	0.14	0.12	0.045

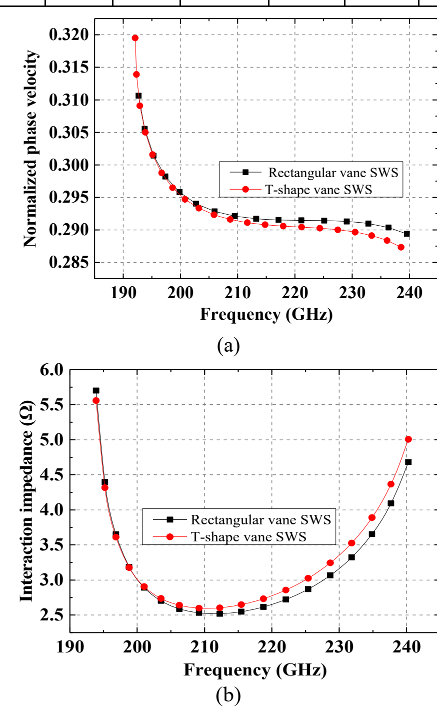

Fig. 2. (a) Normalized phase velocity versus frequency and (b) interaction impedance versus frequency.

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The results show that the operating bandwidth of T-shape vane SWS and rectangular vane SWS are similar but the interaction impedance of T-shape vane SWS is higher than rectangular vane SWS, it improved about 5% at 220 GHz.

Simulation of Transmission

We add a ridge on the bottom of the input and output couplers in order to match the T-shape vane SWS [6]. So that the electron beam can pass through the electron beam channel. Meanwhile, decreasing the height of channel to achieve a signal cut-off.

The length of the T-shape vane is 60 periods, and there are transition structures of 6 periods on the left and right sides. Considering the influence of surface roughness in reality, the conductivity of the background material is set as 2.2×10^7 S/m. The waves are inserted at port 1, extracted from port 2, port 3 and port 4 are reserved electron beam channels. The T-shape vane SWS with input and output couplers are shown in Fig. 3.

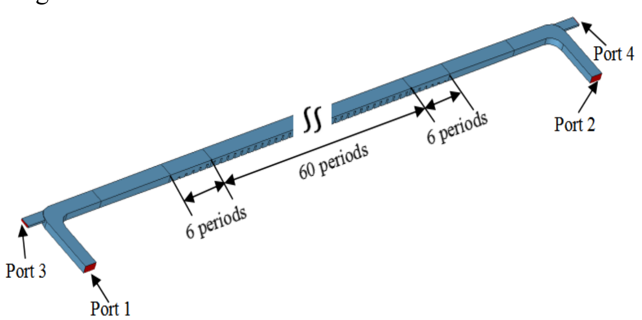

Fig. 3. Vacuum models of T-shape vane SWS with input and output couplers.

Under perfect boundary conditions, the transmission characteristics of T-shape vane SWS with input and output couplers are investigated by using the frequency domain solver in CST 2016 Microwave Studio. The simulation results of S-parameters are shown in Fig. 4.

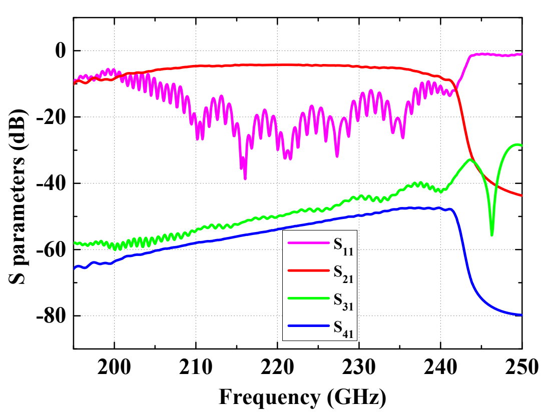

Fig. 4. S-parameters of the SWS with input and output couplers versus frequency.

The simulation results show that from 213 GHz to 230 GHz, the reflection coefficient S_{11} is below -15 dB, the transmission coefficient S_{21} is greater than -5 dB, and the transmission coefficient S_{31} and S_{41} are lower than -40 dB. Basically no wave is transmitted to port 3 and port 4, achieving good isolation. The whole T-shape vane SWS has good transmission.

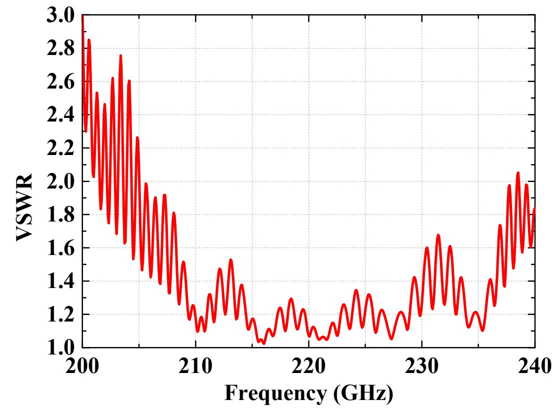

Fig. 5. Simulated voltage standing wave ratio versus frequency.

Furthermore, it is observed that the frequency range of VSWR less than 1.4 is 213 GHz to 229 GHz in Fig. 5, it illustrates that the SWS is well matched with the input and output couplers.

Conclusion

A T-shape vane SWS applied to 220 GHz sheet beam TWT is proposed, and its high frequency characteristics are analyzed. The transmission characteristics of the T-shape vane SWS with input and output couplers are simulated. The results show that the transmission coefficient S_{21} is higher than -5 dB, and the reflection coefficient S_{11} is lower than -15 dB from 213 GHz to 230 GHz. It indicates that the T-shape vane SWS has low transmission loss. The T-shape vane SWS proposed in this paper provides a good foundation for the following research on 220 GHz sheet beam TWT.

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