Simulation Design of TWT Based on CNT Cold Cathode

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Abstract: *Beam-wave interaction system of a Ka-Band traveling wave tube (TWT) based on carbon nanotube (CNT) cold cathode is theoretically researched in this paper. Based on the electron beam parameters of a truncated-cone carbon nanotube cold-cathode electron gun, a high-frequency system for coupled-cavity TWT is designed. Simulation results show that the maximum output power of the TWT can reach 313 W at 33.5 GHz with an input power of 500mW, corresponding to the maximum gain of 28 dB, when the electron beam voltage and current are 28 kV and 300 mA. The 3dB bandwidth of the TWT is about 0.6 GHz.*

Keywords: Ka-Band; carbon nanotube; coupled-cavity traveling wave tube.

Introduction

As key parts of radar space, military electronic system and space communication, vacuum electronic radiation source (VERS) have been developed rapidly. The electron gun is the central component of VERS device, with most commercially available modern electron guns employing thermionic cathodes. The thermionic cathode electron gun has some disadvantage, such as easily broken, high temperature and slow reaction, which limits the range of application. On the contrary, field emission cold cathodes can be operated at room-temperature, and respond almost instantaneously to local fields, allowing for facile and inexpensive integration alongside aggressive miniaturization.

TWT as the core device for microwave power amplification is characterized by high gain, large dynamic range and low noise coefficient. Coupled-cavity TWT with all-metal structure has the characteristics of strong heat dissipation ability, high power and reliability. Carbon nanotube has good thermal stability, high strength and high toughness, so it can be used as ideal field emission material in the electron gun. A circular electron beam based on a truncated-cone carbon nanotube cold-cathode electron gun was obtained [1], and the beam-wave interaction system of a large-diameter electron beam channel was designed in this paper.

Results and Discussion

Figure.1 shows slow wave structure (SWS) and input-output structure of TWT. Among them, the SWS uses a uniformly distributed three-hole coupling cavity structure, and the input-output structure uses a rectangular waveguide. The parameters are optimized by CST, so that the slow wave structure and the input-output structure can be better matched.

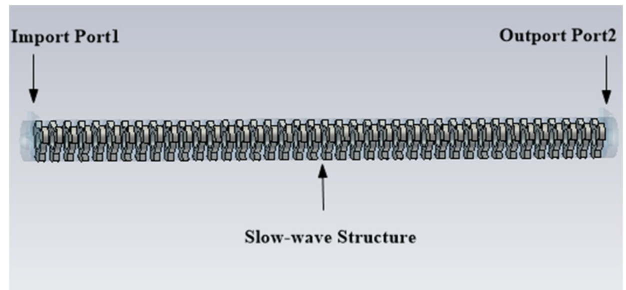

Figure 1. Slow wave structure

The SWS is uniformly distributed three-hole coupling cavity structure. Figure.2 bottom right corner shows the SWS single-cycle vacuum model. The radius of cavity is 3.1 mm; the period of coupled-cavity is 2.2 mm; three uniformly distributed coupling holes are fan shaped, the angel is 70°; the radius of drift tube is 1.3 mm, the length of drift tube is 0.9 mm. This coupling cavity slow wave structure is very simple and easy to process.

In the simulation, cold-cavity dispersion curves of SWS characteristics of the operating mode and electron beam line are shown in Figure.2. The work point is set at 33.5 GHz in this paper, which the voltage is set at 28 kV. The working point will affect the electronic efficiency and bandwidth of TWT. Where the phase shift is lower, the coupling impedance and electron efficiency are higher, but the bandwidth is narrower.

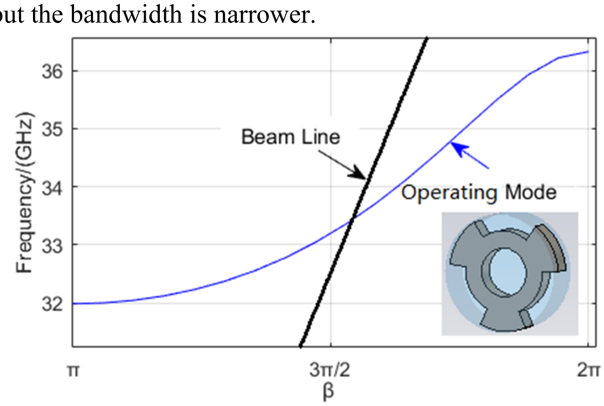

Figure 2. Dispersion characteristics diagram. Inset: single-cycle vacuum model of the SWS

Figure.3 shows the high-frequency system transmission characteristics of 40-cycle. In the range of 33GHz to 35GHz, S11 is less than -15dB, and S21 is stable at about 0dB. It can be seen from the figure that the high-frequency system has good transmission characteristics.

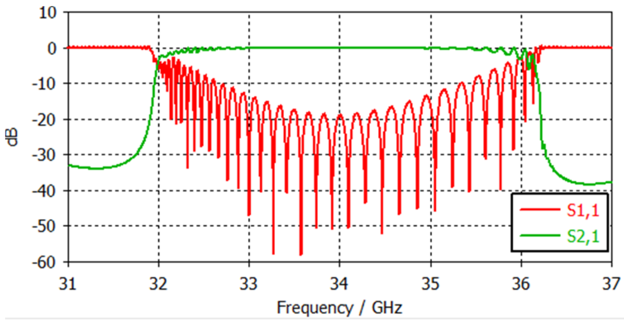

Figure 3. High-frequency system transmission characteristics of 40-cycle

Figure.4a shows the output power versus frequency and 3-dB bandwidth of TWT is about 0.6 GHz. Figure.4b shows simulation results of beam-wave interaction at 33.5 GHz. The simulation parameters are as follows: the electronic beam current is 300mA, the voltage is 28kv, and the average input power is 500mW. After 4 ns, the average output power is stable to 313W, corresponding to a gain of 28dB.

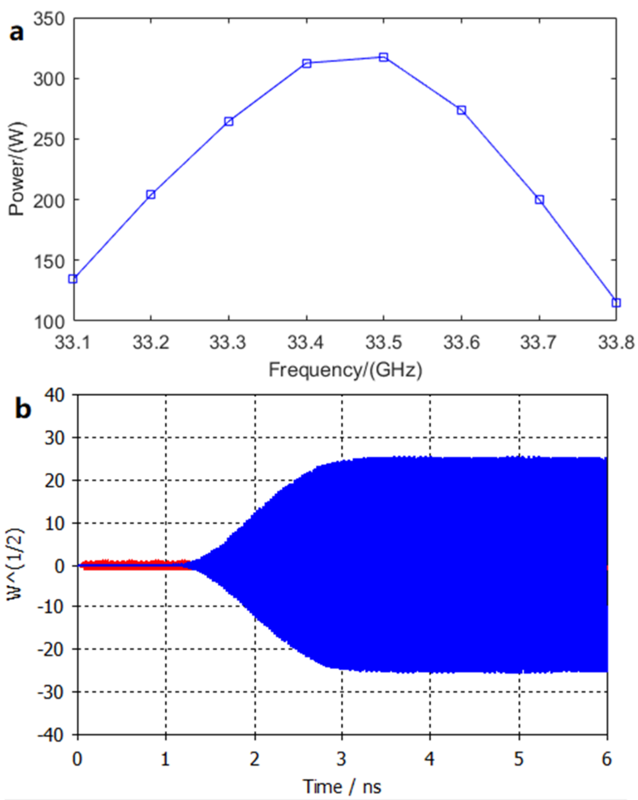

Figure 4. (a) Output power versus frequency. (b) Output signal amplitude diagram at 33.5GHz

Figure.5 shows the electronic phase space diagram and density modulation diagram. It can be seen from the figure that the electron beam and the input signal have a good interaction.

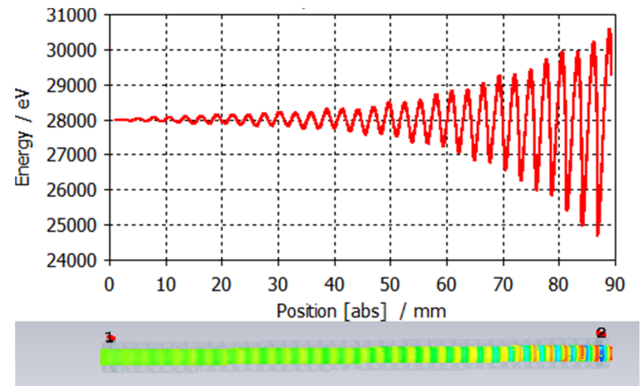

Figure 5. Electronic phase space diagram and the electron bunching diagram

Conclusions

Based on the electron beam parameters of a truncated-cone carbon nanotube cold-cathode electron gun, the high frequency system of a large-diameter electron beam channel is designed in this paper. Simulation results show that the maximum output power of the TWT can reach 313 W at 33.5 GHz with an input power of 500mW, corresponding to the maximum gain of 28 dB, when the electron beam voltage and current are 28kV and 300 mA, respectively.

Acknowledgements

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