W-Band 30W Continuous Wave wide band Folded Waveguide TWT

Fei Li, Liu Xiao, Tianjun Ma, Yuhui Sun, Jiandong Zhao, Jian Wang, Linlin Cao, Hongxia Yi, Xinwen Shang and Mingguang Huang

Key Laboratory of Science and Technology on High Power Microwave Sources and Technologies, Aerospace Information Research Institute, Chinese Academy of Sciences, Beijing, 100190, China

Abstract: *A W-band 30W wideband continuous wave folded waveguide TWT (CW FWTWT) with 15kV operation voltage was designed and fabricated. The measured results showed that beam transmission was over 98.5% at dc and better than 97% at the highest peak RF power. Measured saturated output powers were higher than 31W within frequency range of 90-99GHz. The maximum output power was 58.1W and the maximum saturated gain was 37.7dB at center frequency point of 94GHz.*

Keywords: W band CW TWT, Folded Waveguide, Operation voltage, Beam transmission, Oscillation suppression.

I. NTRODUCTION

W-band TWT has a wide application prospect in satellite-ground communication, high-resolution radar, precise tracking, electronic countermeasures and deep-space exploration [1]. At present, the United States, France, Germany and China have developed W band TWT[2,3]. It is believed that folded waveguide has become a research hotspot and a preferred TWT interaction circuit in W and terahertz band[4]. In this paper, A W-band 30W wideband continuous wave folded waveguide TWT (CW FWTWT) with 15kV operation voltage and 9Hz bandwidth was developed.

II. SIMULATION AND DESIGN

Folded waveguide is a kind of periodic slow wave circuit. Key parameters *a, b, p, h* and r_0 stand for dimensions of wide side, narrow side, half period, straight waveguide wall and radius of electron beam channel for folded waveguide, respectively. Considering processing feasibility, dimensions of optimized folded waveguide were selected as: a=1.9mm, b=0.28mm, p=0.55mm, h=0.6mm, r_0=0.21mm and operation voltage was U=15kV.

In this work, phase stepping method was adopted to improve interaction efficiency and 0.01mm was selected as stepping length of p variation. Considering convenience of actual fabrication, three half period lengths p_1, p_2 and p_3 were introduced into interaction circuit. The first stage had N_1 gaps of pitch p_1 with sever length S, the second stage had N_2 gaps of pitch p_2 and the third stage had N_3 gaps of pitch p_3 and pitch distribution was shown in Fig. 1. MTSS software was used to simulate the beam wave interaction of W-band 30W CW TWT. The total length of the interaction circuit was 98.28mm, in which p_1=0.55mm, p_2=0.54mm, p_3=0.53mm. The corresponding number of gaps were N_1=167, N_2=7, N_3=5, respectively.

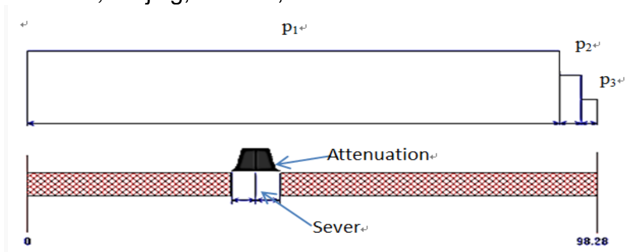

Fig.1 Interaction circuit model of W-band 30W CW TWT

Sever length was 8.8mm and BeO attenuators were inserted into sever section and attenuation coefficient was set as 2dB/mm. Output power and gain under 12-mW input power with frequency were shown in Figure 2, which showed that the maximum output power was 55.6 W at 95 GHz under 12-mW input power.

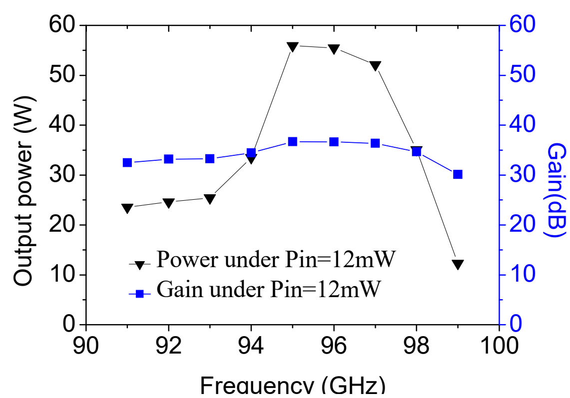

Fig.2 Output power and gain under 12-mW input power

In order to facilitate connection with standard waveguide, box window was designed as standard WR-10 waveguide. While rectangular cross-section of folded waveguide slow wave structure was determined by design goals. So there must be matching problem of the transition connection between input/output ports of folded waveguide slow wave structure and box window. Therefore, transition waveguide needs to be designed carefully to realize the impedance matching between them. A double linear gradual waveguide was selected as transition waveguide of W-band 30W TWT. The length of linear gradual section l has a great influence on transmission characteristics. HFSS software was used to simulate sapphire box window with double linear gradual transition waveguide. The joint model and calculation results were shown in Figure 3. It can be seen from the figure that increased l can makes VSWR in operation band smaller and smoother and this effect becomes more obvious with the increase of frequency. However, when reliability of TWT structure and difficulty of processing technology are considered, transition waveguide length must be limited. After comprehensive optimization, length of linear gradual section l of transition waveguide was taken as l = 33mm.

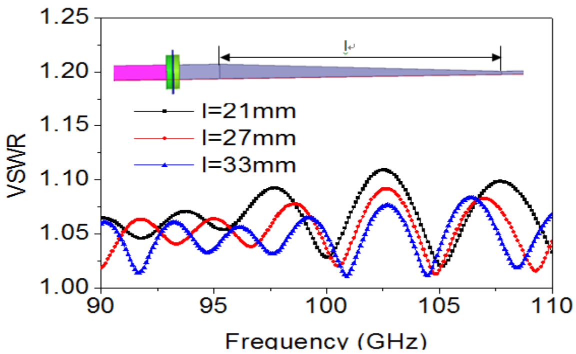

Fig.3 Joint model of sapphire box window and transition waveguide and its calculation results

III. PERFORMANCE OF THE TWT

According to design scheme, W-band 30W CW TWT was fabricated. The TWT consisted of electron gun, magnetic shield structure, folded waveguide slow wave structure, input/output window, transition waveguide and depressed collector. The weight of TWT was 1.5kg and dimensions were 350mm × 45mm × 55mm.

The developed W-band 30W CW TWT was tested and electrical parameters of TWT were listed in Table 1.Hot measurement setup was shown in Figure 4. The test showed that beam transmission was over 98.5% at dc and better than 97% at the highest peak RF power. Saturated output power and gain comparisons between measurement and simulation by MTSS were showed in Figure 5. It could be seen that measured saturated output power were greater than 31W with saturated gain more than 26.7dB within frequency range of 90-99GHz. The maximum output power was 58.1W and the maximum saturated gain was 37.7dB at center frequency point of 94GHz. The trend of measured output power and saturation gain curve was consistent with that of the simulation calculation curve except that measured values were lower than the simulated values. The possible reasons for above differences could be summed up in the fact that losses caused by assembly error, welding deformation and mismatch between folded waveguide slow wave structure and input/output transition waveguide have been ignored in the simulation.

Table 1 Electrical parameters of W-band 30W CW TWT

Cathode voltage to ground(kV)	-15
Beam current(mA)	80
Anode Voltage to cathode (kV)	11.3
Filament voltage(V)	5.8
Filament current(A)	0.78
Collector Voltage to cathode (kV)	8

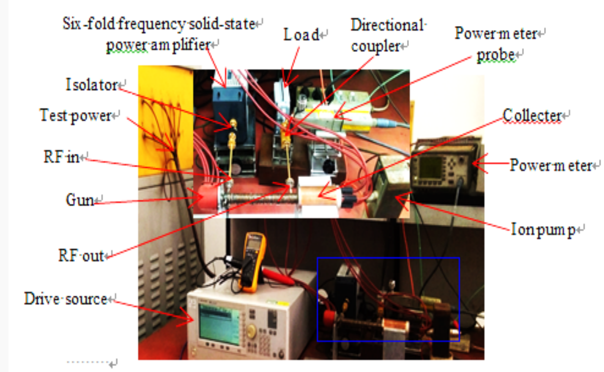

Fig.4 Setup of the hot measurement system

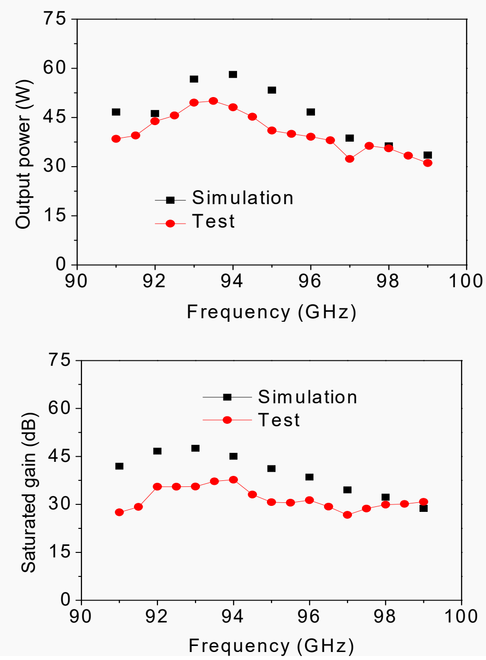

Fig.5 Saturated output power (top) and saturated gain(bottom)comparisons between measured results and simulated results

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