Simulation of Non-Periodic Folded Waveguide Slow Wave Structure

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Abstract: *This paper proposed a novel slow wave structure (SWS) named non -periodic folded waveguide (NPFW) SWS. The novel NPFW has the ability to suppress the backward wave oscillation and can achieve a high-gain one-stage traveling wave tube (TWT). A W-band NPFW-TWT was built and simulated in this paper to verify the performance of the novel NPFW-SWS. The simulation results show that the maximal output power and gain are 105W and 27.6dB in the designed one-stage NPFW-TWT.*

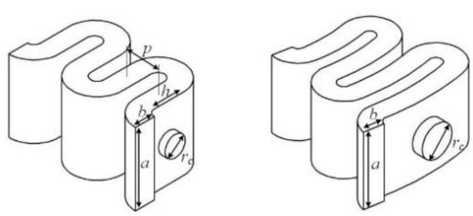
Keywords: traveling wave tube, back wave oscillation suppression, folded waveguide

Introduction

As a common microwave power amplifier, TWT has many advantages like high gain, broad bandwidth, low noise and so on. For most of the TWTs, they are truncated into two stage by the attenuator to achieve higher gain. The reason is that the higher gain requires a longer length of the SWS and it provide a higher gain to the backward wave at the same time. So many TWTs use attenuators to shorten the energy feedback loop and further to suppress the oscillation. However, the introduction of attenuators increases the difficulty of the fabrication of the TWT. In the purpose of developing a one-stage TWT with high gain, this paper proposed a novel NPFW-SWS.

Description of SWS

Folded Waveguide (FW) [1-2] is a conventional periodic SWS for millimeter wave and terahertz TWT. The proposed NPFW-SWS is similar to the traditional FW-SWS in geometry but not same. FW-SWS is a kind of periodic SWSs, while NPFW-SWS is non-periodic. The sketches of FW-SWS and NPFW-SWS are shown in Figure 1.



(a) (b)

Figure 1. Sketches of the FW-SWS and the NPFW-SWS

The difference between the NPFW-SWS and the traditional FW-SWS is their meander path. The traditional FW-SWS used the conventional S-shape periodic meander path, while the NPFW-SWS used a kind of non-periodic meander path. The non-periodic meander path used in the NPFW-SWS consists of a series of arcs. These arcs can be separated into two parts. The first part consists of a series of concentric arcs distributed in radial direction. The other part is some semicircular arcs for connecting the arcs in part 1 at staggered sides. The schematic diagram of the meander path of the NPFW-SWS is shown in Figure 2.

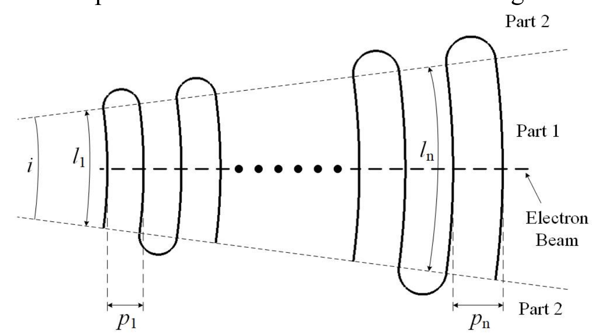


Figure 2. Schematic diagram of the meander path of the NPFW-SWS

The lengths of the arcs in part 1 are marked as l and l_n represents the length of the nth arc. The distances between adjacent beam crossings p are marked in the same way, as Figure 1 shows. The values of p are depended on the values of l, and their relation can be described as the equation of

$$p_n = (s_c - 1)\left(\frac{180}{i}\pi l_n - p_c\right) \quad (1)$$

Where, i is the angle of the arcs in part1, s_c is the rate of the change of l, p_c is a parameter for controlling p.

Simulation and results

To verify the performance of the novel NPFW-SWS, a simulation model of a W-band NPFW was built and simulated in this paper. The geometric parameter is listed in Table I.

TABLE I
GEOMETRIC PARAMETERS OF THE W-BAND NPFW-SWS

Symbol	Meaning of the symbol	Value
l_1	Length of the first l	0.715mm
s_c	Rate of the change of l	1.00188
p_c	Parameter to control p	162.7mm
a	Length of the broad side of the waveguide	1.7mm
b	Length of the narrow side of the waveguide	0.18mm
r_c	Radius of the electron beam tunnel	0.23mm
i	Angle of the arcs in part 1	1.5deg
N	Maximum of n	52

The simulation model of the designed W-band NPFW-SWS is shown in Figure 3.

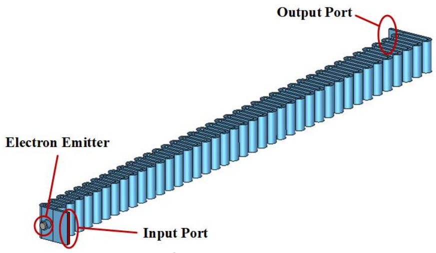


Figure 3. Model of the designed NPFW-TWT

The simulation results of transmission characteristics shown in Figure 4 indicates that the designed SWS is of good transmission.

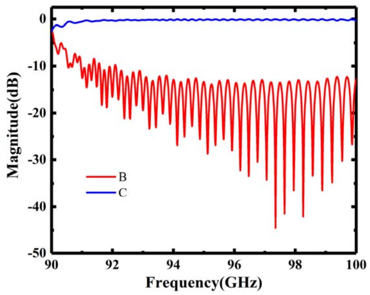


Figure 4. Transmission characteristics of the NPFW-SWS

Then, we simulated the designed NPFW-SWS by particle-in-cell (PIC) method. The operating voltage and current are set to 8.5kV and 160mA respectively, and the radius of electron beam is set to 0.17mm. When we input 180mW sine signals of different frequency, the output powers of the NPFW-TWT are shown in Figure 5. The corresponding gain and radio frequency (RF) efficiency are shown in Figure 6.

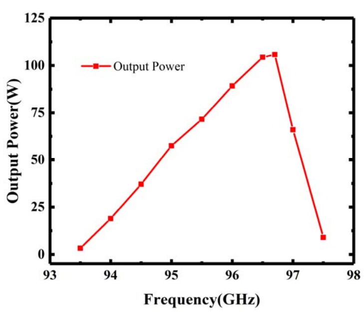


Figure 5. Diagram of output power versus frequency.

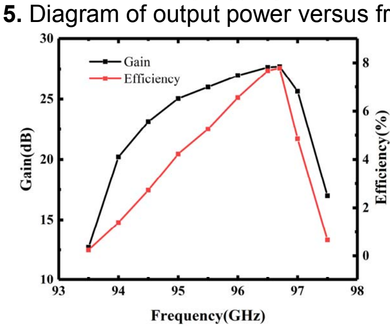


Figure 6. Diagram of gain and RF efficiency versus frequency

The maximal output power of the NPFW-TWT is over 100W at the frequency point of 96.7GHz. At the frequency range of 95-97GHz, the output power is over 57W and it illuminates that the 3-dB bandwidth of the NPFW-TWT is over 2GHz. Figure 7 is the input and output signals at the frequency point of 96.7GHz.

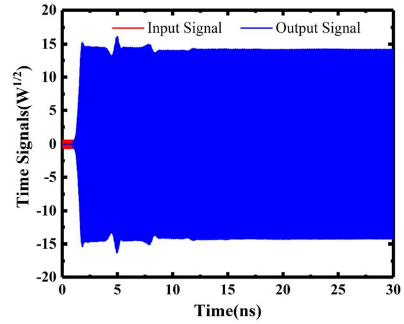


Figure 7. Input signal and output signal

As Figure 7 shown, the output signal is steady except the disturbance caused by the reflection and no oscillation observed in the duration time of 30ns. In addition, the frequency spectrum of the output signal, shown in Figure 8, also proved that.

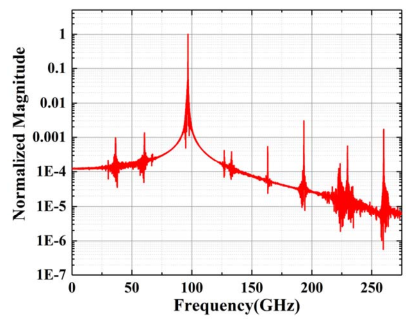


Figure 8. Normalized frequency spectrum of output signal

Conclusion

This paper proposed a novel high-gain oscillation-suppressed NPFW-SWS and designed a W-band one-stage NPFW-SWS. PIC simulation indicates that the maximal gain of the designed NPFW-TWT is over 27dB and the output signal is steady within the simulation duration time of 30ns. The simulation results can prove that the NPFW-SWS has the ability to suppress the backward wave oscillation.

Acknowledgements

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