Simulation and Design of 1THz Backward Wave Oscillator

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Abstract: A single grating rectangular waveguide is used as the slow-wave structures (SWS) of 0.978THz BWO. The dispersion characteristics of single grating structure are studied by Matlab simulation, and the structure parameters of grating are obtained. On this basis, three-dimensional electromagnetic simulation software Magic was used to build the structure model for simulation. Finally, under the condition of 1KV voltage and 100A/cm^2 banded electron injection input, the electromagnetic wave with output frequency of 0.978THz and power of 3.9mW can be obtained with an efficiency of 0.65%.

Keywords: BWO; single grating; dispersion characteristics; THz

Introduction

BWO is a representative vacuum electronic device[1]. In the past design, when the output frequency of a single grating structure is more than 500GHz, a voltage of more than 10kV[2] and a current density of more than 200A/cm^2 are required[3].In the actual processing process, the miniaturized structural devices cannot add excessive voltage, and the current density is too high to be realized [4].Zonal injection is characterized by its high coupling impedance and low voltage operation[5].Therefore, this design is based on the 1KV voltage, with the band electron injection with the current density of 100A/cm^2 that can be achieved under realistic conditions. The coupling impedance between zonal electron injection and high-frequency structure is increased by adding cover plate and adjusting the distance between cover plate and high-frequency structure, so as to realize electron clustering. Finally, appropriate output results are obtained by adjusting the number of cycles and the location of outlet.

Design and simulation of BWO

The dispersion characteristic curve and electron velocity of grating structure under specific voltage intensity are analyzed by Matlab, as shown in Figure.1. The high-frequency structure of single grating is designed under the condition of 1KV. When changing the grating depth, the greater the grating depth, the higher the coupling frequency. As shown in Figure.2, when the grating depth is 60um, the period length p is changed to obtain that the longer the single period length is, the higher the coupling frequency is. It can be concluded from figure 1 and figure 2 that there are two coupling points between electron injection and grating structure, and it is necessary to suppress the primary frequency point and improve the secondary frequency point in the calculation. According to the influence of the above grating structure size on the dispersion characteristic curve, characteristic impedance and quality factor, the grating structure size is obtained in accordance with the requirements of the current processing depth-width ratio. As shown in Figure 2, the period length p=34um, the grating height h=60um, and the slot length n=17um.

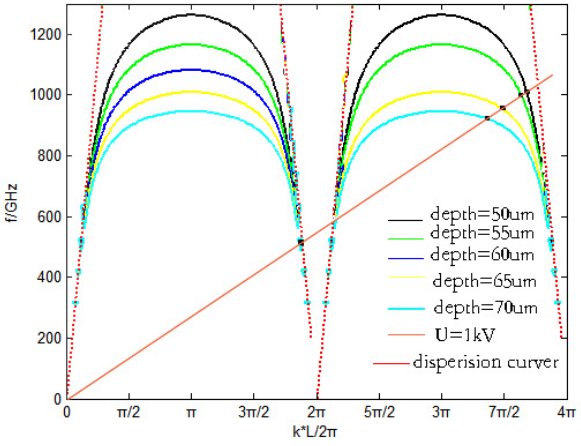

Figure 1. The coupling point of dispersion curve varies with depth

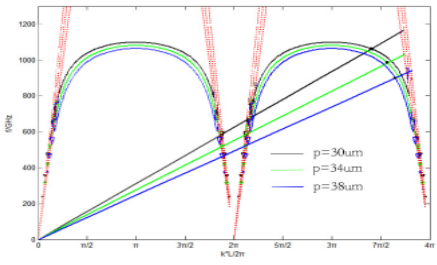

Figure 2. The coupling point of the dispersion curve varies with the length

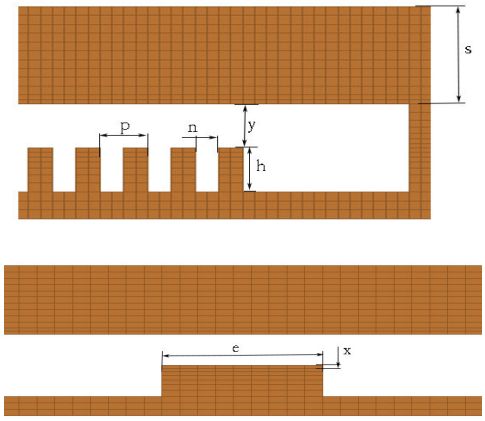

Figure 3. Slow-wave structure

After the model of the basic structure is established and the vibration is started, in order to obtain higher output efficiency and stable output frequency, the optimized ratio of each parameter is fully considered. Particle simulation software MAGIC is used for particle simulation optimization. On the one hand, the cover plate is added and the distance from the cover plate to the high-frequency structure is changed. On the other hand, by changing the number of periods of the grating, the optimal working voltage, starting current, output power, electron injection energy modulation, frequency point, working electric field mode and so on can be obtained. Finally, the optimized input and output structure parameters and operating parameters as well as simulation results are obtained.

When the distance y between the cover plate and the high-frequency structure surface is changed, it is found that the output is good when y is 24um and 60um, and the peak power can reach 8mW when y is 24um and 3.9mW when y is 60um.Considering the actual processing and assembly, it is easier to realize when the distance between cover plate and high-frequency structure is relatively large, so y=60um is selected for further optimization in this design. At the same time, a large number of simulation results show that the output is better at 99 cycles. The specific parameters are shown in table 1.

Table 1. structural parameters :unit(um)

p	n	h	y	s	e	x
34	17	60	120	180	180	6

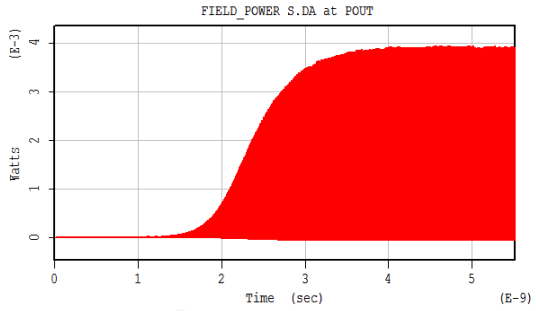

Figure 4. peak power

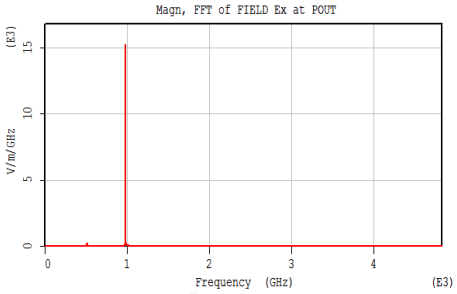

Figure 5. the output spectrum

In order to ensure the cluster effect and output efficiency, sets the thickness of strip electronic note to 6 um, when the current density of 100A/cm^2, through tests can achieve good clustering, the electronic injection can be more fully utilized, the output spectrum is shown in figure 4, 0.978 THz output frequency as shown in figure 5, it can be seen that the output frequency is very pure, peak power as shown in figure 5, effective peak power of 3.90 mW.

Conclusion

By means of Matlab software to establish the basic grating structure, the dispersion curves obtained considering the actual processing and assembling with the actual simulation calculation results, through the plate height and the adjustment of the number of cycles, ultimately through the input voltage of 1 kv and current density for 100 a/cm2 banded electronic note, with the cycle number for 97 single grating structure coupling output frequency is 0.96 THz, labor rate of 3.90 mW THz BWO.

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