A Multi-Beam Terahertz Coaxial Cavity Reflex Klystron

Hongyang Guo, Zhanliang Wang, Huarong Gong, Zhigang Lu, Zhaoyun Duan and Yubin Gong*
National Key Laboratory of Science and Technology on Vacuum Electronics
University of Electronic Science and Technology of China, Chengdu, Sichuan, China, 610054
*E-mail: ybgong@uestc.edu.cn

Jinjun Feng
Vacuum Electronics National Laboratory
Beijing Vacuum Electronics Research Institute
Beijing, China, 100016

Abstract: *A multi-beam (6 beams) terahertz reflex klystron based on a coaxial cavity is presented. 6 beams instead of 1 beam are used to increase the total direct current and output power. When the beam voltage is 2000V, the single beam current is 5.7mA and the reflection voltage is 2235V, the electromagnetic field of* TM_{110} *mode with frequency of 316.54GHz is excited and the output power and electron efficiency are 832mW and 1.2%, respectively.*

Keywords: Reflex Klystron; Coaxial Cavity; Beam-Wave Interaction

Introduction

Reflex klystron is a klystron oscillator that enables electron beam to achieve velocity modulation at the interaction gaps of re-entrant resonant cavity, drift and bunch in the reflection zone between cavity and reflection electrode, and finally returns to the gaps to convert kinetic energy to electromagnetic (EM) energy and so on [1]. Reflex klystron is usually assembled as a microwave generator with advantages of small size, short beam channels, and low voltage, etc. The coaxial resonator has a larger size compared with cylindrical ones when resonating at the same frequency, which can store more EM energy and be easy to be fabricated. Compared with single-beam reflex klystron, the single beam current density of multi-beam klystron decreases while the total current density could be maintained at a high level, which can reduce the design difficulties for both the electron gun and the focusing system while increases the output power [2]. Based on above analysis, a multi-beam terahertz coaxial reflex klystron is presented and designed.

STRUCTURE OF THE MULTI-BEAM COAXIAL CAVITY REFLEX KLYSTRON

As depicted in Fig.1, the reflex klystron in this paper is equipped with 12 drift tubes, of which 6 drift tubes have electrons flowing through them. The six empty drift tubes between two adjacent beam channels can widen the frequency intervals between different modes and suppress the mode competition [3]. The intermediate waveguide between coupling hole and R2.8 standard waveguide is utilized to reduce the reflection of output signal. Some structure parameters of the reflex klystron are listed in Table 1.

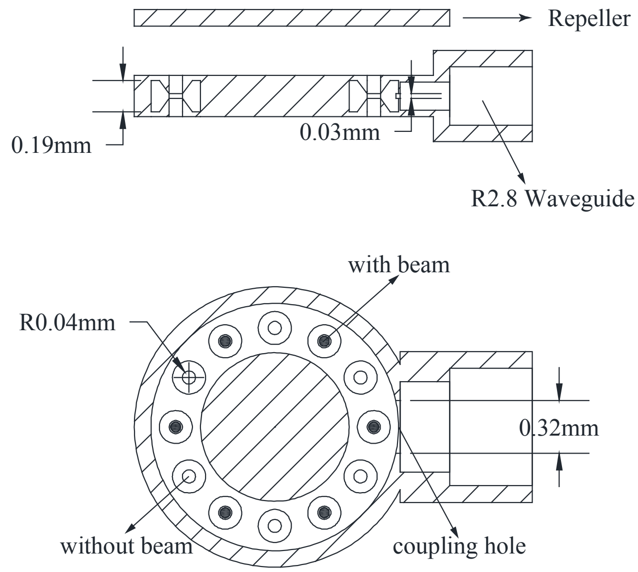

Figure 1. Structural diagram of the reflex klystron with front section view(up) and top section view(down).

Table 1. Structure parameters of the coaxial cavity

Parameter	Symbol	Value/mm
beam channel radius	rebc	0.04
inner radius of the cavity	a	0.45
outer radius of the cavity	b	0.75
height of the cavity	d	0.19
distance of interaction gaps	h	0.03
cavity-repeller distance	drc	0.3

SIMULATION RESULTS

In the reflex klystron, the single beam current is set as 5.7mA with current density of 200A/cm^2. The beam voltage is 2000V and the coupling coefficient of interaction gaps is slightly lower than that of the ideal gaps with 0.77. When the reflection voltage is 2235V, as depicted in Fig. 2 and Fig. 3, the output power and average power loss of electron are 832mw and 1.1W, respectively. The power loss of the electron beam is output through the waveguide and stored in the cavity separately. The electron efficiency of this reflex klystron is 1.2%. According to the bunching theory of reflex klystron, oscillation reaches maximum when the beam drift time in the reflection zone satisfies t=(n+3/4) T, where n is a natural number and T is period of the EM field between the gaps [1]. As shown in Fig. 4, the EM field of TM_{110} mode with frequency of 316.54GHz is activated, the pure frequency spectrum means that no other modes are excited to compete with it. The drift time of electrons in the reflection zone can be calculated as 12.75T using the Newton's law of motion, which means the electrons return to the gaps at an optimum phase to be decreased by the EM field between them.

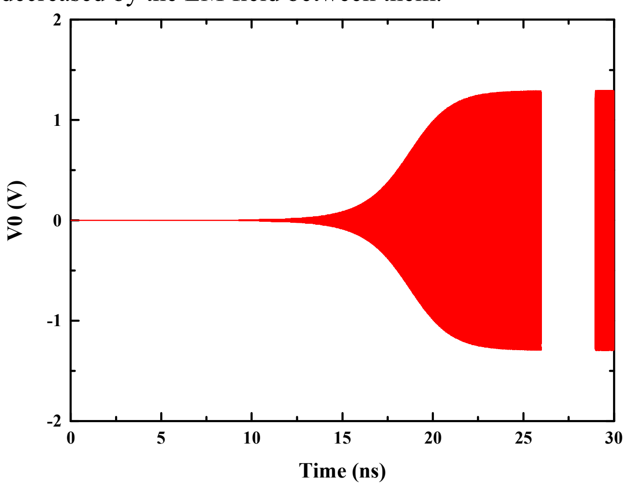

Figure 2. Output signal voltage vs time of the reflex klystron

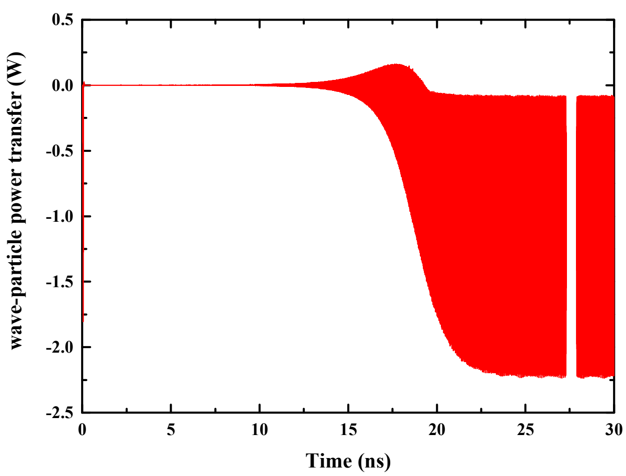

Figure 3. Wave-particle power transfer vs time of the reflex klystron

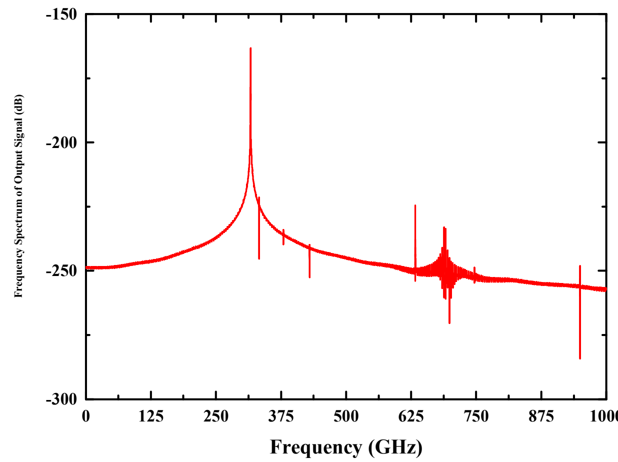

Figure 4. The Fourier Transform of output signal vs Frequency of the reflex klystron

Conclusion

A 6-beam terahertz coaxial cavity reflex klystron is presented in this paper. A coaxial re-entrant cavity instead of cylindrical one is designed to enlarge the size of resonator to reduce the machining difficulties and increase the power capacity of cavity. Multi-beam is used to increase the total DC current and output power. When the beam voltage is 2000V, single beam current is 5.7mA, reflection voltage is 2235V, the TM_{110} mode with frequency of 316.54GHz is activated and there are no other parasitic modes are excited. The output power and electron efficiency are 832mW and 1.2%, respectively.

Acknowledgements

This work is supported by national natural science foundation of China (Grant No. 61921002 and 61531010)

References

1. E. L. Ginzton, A. E. Harrison, "Reflex-Klystron Oscillators," PROCEDINGS OF THE IRE, vol. 34, no. 3, pp. 97-113, March 1946.
2. A. Gilmour, "Klystrons, traveling wave tubes, magnetrons, crossed-field amplifiers, and gyrotrons," Norwood: Artech House. 2011.
3. Y. Ding, B. Shen, J. Cao, et al, "Research Progress on X-Band Multibeam Klystron," IEEE TRANSACTIONS ON ELECTRON DEVICES, vol. 56 no. 5, pp. 870-876, April 2009.

978-1-5386-8288-3/20/$31.00 ©2020 IEEE