Design and Analysis of a Y-band Extended Interaction Oscillator with a Pseudospark-Sourced Electron Beam

Zhang Zhang[1]*, Yong Yin[1], Liangjie Bi[1], Zhiwei Chang[1], Changpeng Xu[1] and Lin Meng[1]
[1]University of Electronic Science and Technology of China, *Chengdu, Sichuan610000, China*
* Contact: sunshinezz6688@163.com

Abstract—**In this paper, a pseudospark(PS) discharge system instead of traditional electron gun is designed for the pencil beam Y-band extended interaction oscillator (EIO). The characteristics of EIO circuit and the PS discharging voltage of the electron beam are studied to optimize the performance of the Y-band EIO. The CST simulation results show that the averaged output power over 24 W with a main frequency of ~286 GHz can be achieved by using a 30.75 kV PS discharge voltage. The advantage of the newly proposed device is that high current density electron beam pulse is transported in the positive-ion focusing channel without a guiding magnetic field. Meanwhile, high impedance(R/Q) and high gain per unit length is another characteristic of the device.**

Index Terms—**Extended interaction oscillator (EIO), pseudospark-sourced electron beam, vacuum electronics.**

INTRODUCTION

At present, terahertz (0.1-20 THz) sources are a currently active research area and are important for applications to high data rate communications, biological spectroscopy, molecular spectroscopy and biomedical diagnostics etc [1-4]. EIO is a novel type of vacuum electronic high power terahertz sources. It has the advantages of high interaction impedance and high gain per unit length. For the development of Terahertz EIO, the high frequency characteristics and the parameters of EIO circuit are researched. Meanwhile, PS discharge is one of gas discharge, which operates in the hollow cathode, axially symmetric parallel electrodes and planar anode configuration [5], [6]. It can produce high current density, narrow beam diameter and axially symmetric electron beam pulse. The recent research about pseudospark-sourced electron beam show that several thousand Amperes electron beam pulses produced by PS source can be transported distances up to 20cm in 3mm diameter beam tunnel without a guiding magnetic field [7]. Using the pseudospark-sourced electron beam instead of traditional electron gun can become a novel way to generate terahertz wave.

In this article, we present research result that demonstrate the successful design and optimize of Y-band EIO based on a pseudospark-sourced electron beam for a 30.75 kV 0.5A beam with a 0.2mm diameter beam tunnel, which has produced over 24 W of peak output power at Y-band with the help of 3-D particle-in-cell simulation.

CIRCUIT DESIGN

A Y-band EIO circuit is presented in this paper. The photograph of EIO circuit is shown in Fig.1. The material of the device shell is the copper to ensure a better heat dissipation environment for circuit. The circuit consists of identical nine slots and two symmetrical coupling cavities located up and down respectively. A 0.2mm diameter beam tunnel passes through the centre of the nine-slot slow wave structure. The power is exported to the WR-3 standard waveguide attached to upside coupling cavity through a coupling hole. The EIO operates in the 2π mode. Contour of the electric field distribution component Ez at Y-Z and X-Y cross-section and electric field strength along the Z direction is shown in Fig.2. Based on the structure parameters of EIO circuit, the dispersion curve of Y-band EIO is shown in Fig.3. This result show that the operation frequency is ~286 GHz and the dispersion curve of the EIO circuit is in synchronism with a 30.75 kV electron beam. Under the circumstance, we can guarantee a more effective interaction between the interaction circuit and the electron beam.

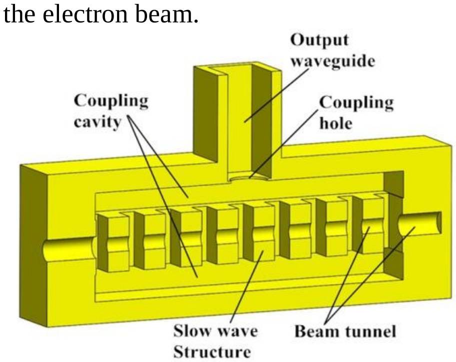

FIG.1. The photograph of EIO circuit.

With the help of simulations, the dimensions of EIO circuit are optimized, including coupling hole, slot, coupling cavity, and electron beam tunnel. The dc beam was designed for a voltage of 30.75 kV, an electron current of 0.5 A, and a guiding magnetic field of 0.5 Tesla is adopted. When the beam-wave synchronous condition was met, the oscillation of the circuit was established and power was exported stably after 17 ns. Fig.4 shows simulated output single and frequency spectrum. The averaged output power was about 24 W and the operation frequency was 286 GHz.

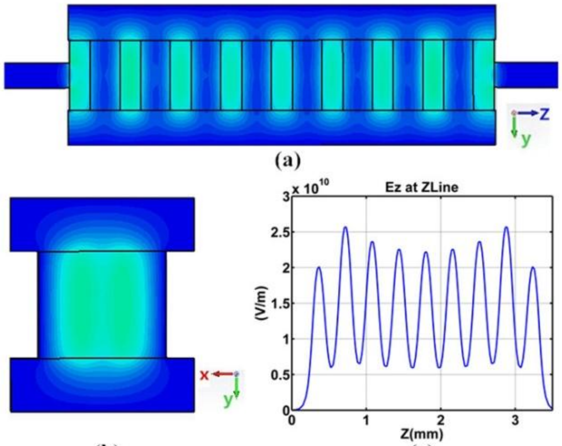

FIG.2. Contour of the electric field component Ez at (a)Y-Z and (b)X-Y cross-sections(from CST), and (c)the field strength along the Z direction.

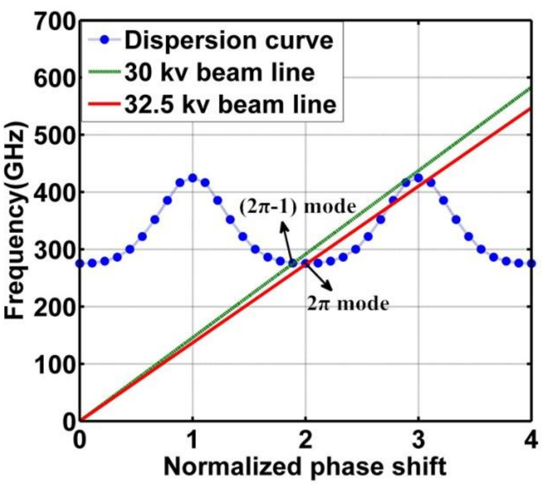

FIG.3. Dispersion curve of Y-band EIO circuit.

The operation voltage range and the oscillation startup time are important parameters of the EIO with pseudospark-sourced electron beam. Electron beam interacts with the standing wave of the EIO circuit. Fig.5 illustrates the relationship between the output power and the oscillation startup time versus different beam voltage at 0.5 A beam current. As shown in Fig.5, operation voltage ranges from 28.5 kV to 32 kV. The fast falling edges of the output power at 32 kV was due to the change of the operation mode. When beam voltage goes beyond operation voltage range, the electron velocity is too fast, which may motivate other mode of the cavity. The Q_o will decrease and Q_e will increase. The operating voltage region of the 2π mode in the EIO was 3.5 kV.

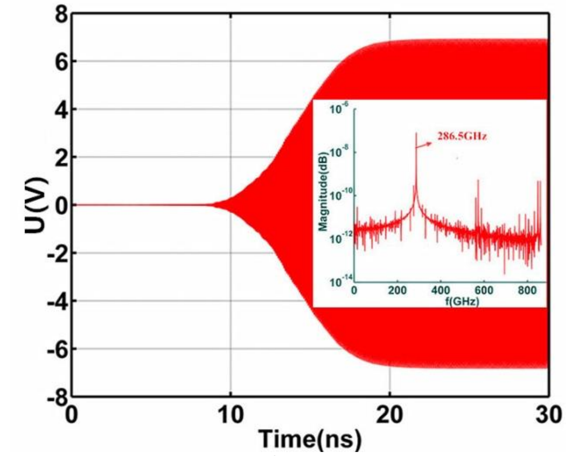

FIG.4. Simulated output single and frequency spectrum.

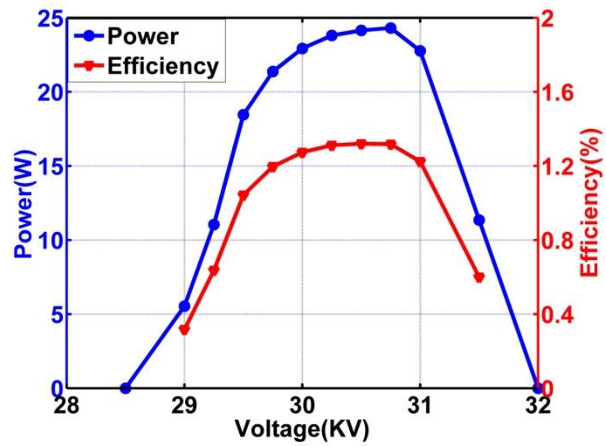

FIG.5. The averaged output power and efficiency versus voltage.

CONCLUSIONS

In this paper, a CST 3-D model of EIO circuit was established to study the correlation interaction properties of the cavity operating mode. Under the condition that the injected beam diameter is 0.2 mm, 30.75 kV beam voltage, 0.5 A beam current and the operating frequency is about 286 GHz, the averaged output power is achieved about 24 W. Meanwhile, using the pseudospark-sourced electron beam instead of a thermionic electron beam achieve a novel way to generate terahertz wave.

ACKNOWLEDGMENT

This work was supported by the National Natural Science Foundation of China under Grant 61201011 and the Fundamental Research Funds for the Central Universities under Grants ZYGX2015J037 and ZYGX2015J039.

REFERENCES

[1] J. B. Baxter, and G. W. Guglietta, “Terahertz spectroscopy,” *Anal. Chem.*, vol.83, pp. 4342-4368, May 2011.
[2] J. H. Booske, R. J. Dobbs, C. D. Joye, C. L. Kory, G. R. Neil, G. S. Park, J. Park, and R. J. Temkin, “Vacuum electronic high power terahertz sources,” *IEEE Trans. Terahertz Sci. Technol.*,vol.1, pp.54-74, Sep.2011.
[3] J. H. Booske, “Plasma physics and related challenges of millimeter-wave-to-terahertz and high power microwave generation,” *Phys. Plasmas*, vol.15, p.055502,2008.

[4] P. H. Siegel, "Terahertz technology," *IEEE Trans. Microwave Theory Tech.* , vol.50,pp. 910-928, Mar.2002.

[5] K. Frank and J. Christiansen, "The fundamentals of the pseudospark and its applications," *IEEE Trans. Plasma Sci.*, vol.17, pp.748-753, Oct.1989.

[6] S. Muhl and A. Perez, "The use of hollow cathodes in deposition processes: A critical review," *Thin Solid Films*, vol. 579, pp. 174-198, Mar. 2015.

[7] H. Yin, A. W. Cross, A. D. R. Phelps, D. Zhu, W. He, and K. Ronald, "Propagation and post-acceleration of a pseudospark-sourced electron beam," J. Appl. Phys., vol.91, pp. 5419-5422, Apr. 2002.