Stability Improvement of Electron Gun for Millimeter Wave TWTs by Immersed Flow Focusing System

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Abstract: *This paper introduces a high-stability electron optical system for millimeter wave traveling wave tubes. Firstly, a circular electronic injection Pierce electron gun is designed. The electron channel radius is 0.2mm, the current is 90mA. Then the immersed flow method was used to design a ppm focusing system with a magnetic field period of 7.3 mm and a peak value of 4900 Gauss. The stability of the immersed flow electron gun is compared with the gun under a conventional ppm magnetic field in consideration of thermal deformation and assembly errors.*

Keywords: Immersed flow; electron gun; focusing system; electron beam.

Introduction

The traveling wave tube (TWT) has a series of advantages such as wide bandwidth, large output power, high efficiency. So it is a widely used microwave vacuum electron device [1]. As the “heart” of the TWT, the electron gun plays a key role in the traveling wave tubes [2]. Over 100GHz, the performances of the whole device are extremely sensitive to the accuracy assembly of the electron gun and the thermal-deformation of the cathode. So designing a high-stability electron gun is essential.

As shown in Figure 1, on the basis of Brillouin focus, an additional magnetic block is added in front of the first magnetic pole piece to allow the magnetic field lines to pass through the cathode and be coincident with electron emission trajectory. With this immersed flow focusing system, under the ideal conditions, the electrons emitted from the cathode have their electron trajectories completely coincident with the magnetic lines of force. When the electron trajectory crosses the magnetic line due to errors such as thermal deformation and processing assembly, the lines of magnetic force cause these electrons to rotate around the magnetic lines of force, which act to "bound" these electrons that deviate from the "established orbit", thereby improving the stability of the electron beam.

In the previous researches, the immersed flow focusing system was sometimes used in the design of electron guns, but there was no clear study on stability improvement. We verified by software simulation that the immersed flow can improve the transmission stability of the electron beam.

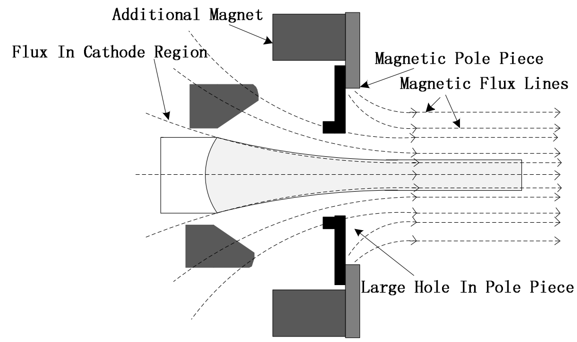

Figure 1. Immersed flow focusing system.

Electron gun design

As shown in Figure 2, a double-anode convergent electron gun is proposed here. The simulation results of CST PARTICLE TRACKING show the area compression ratio is about 100, with current of 90 mA and waist radius of 0.1 mm.

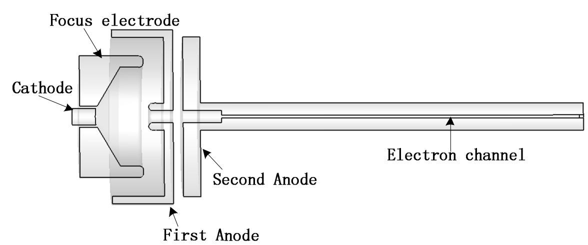

Figure 2. Electron gun structure.

Design of immersed flow focusing system

It is calculated that the Brillouin magnetic field required for the focus of the electron beam is 2200 Gauss. The effective value of the periodic magnetic field is $1/\sqrt{2}$ times the peak value of the magnetic field [3], and we often take 1.5-2 times of the Brillouin magnetic field as the effective magnetic field in the design. So the CST EMS was used to obtain a periodic magnetic field with a period of 7.3 mm, a peak magnetic field of about 4900 Gauss, and a magnetic field of 20 Gauss on the cathode surface.

The structure of the magnetic focusing system is shown in Figure 3. The additional magnetic block is used to form the immersed flow magnetic field penetrating the cathode surface. The magnetic field distribution near the cathode is shown in Figure 4. It can be seen that the magnetic field lines are close to the electron emission trajectory at the cathode.

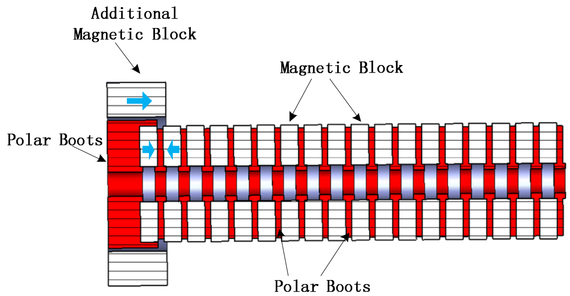

Figure 3. Immersed flow magnetic focusing system.

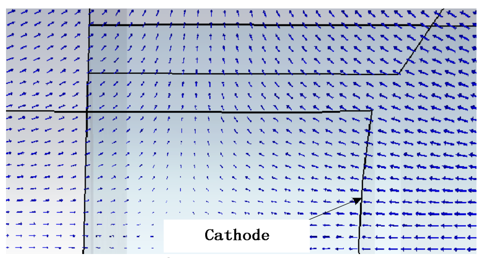

Figure 4. Magnetic field distribution near the cathode.

Study on Stability Improvement

Considering the actual assembly errors and thermal deformation, we explored the effect of changes in cathode position on the electron beam: cathode axial displacement, cathode radial displacement, and cathode rotation at a certain angle. At the same time the position of the focus electrode is kept unchanged. Immersed flow and non-immersed flow focusing system are adopted here. The two sets of magnetic fields are identical except for the gun area, with the same peak and period. The two sets use the same electron gun, and the two sets of electron guns are optimized to the best, the scalloping size is almost the same. The changes of beam transmission are compared based on the two different focusing system.

The Figure 5 is the variations of beam transmission factor when the cathode moves axially, It can be seen from the figure that for the non-immersed electron gun, the beam transmission drops sharply when the axial displacement of the cathode exceeds the range of -30um to +10um, which could be caused by the thermal effect of the cathode and assembly error. the beam transmission is almost 100% in the range of -50um to +50 um for the immersed electron gun.

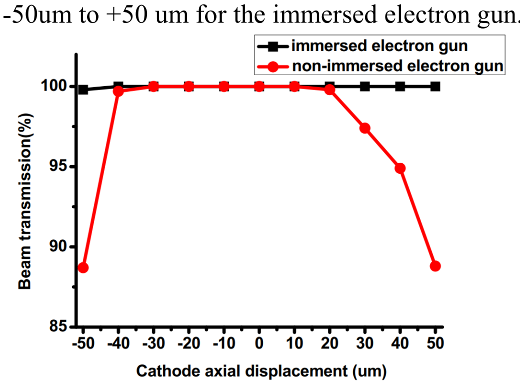

Figure 5. Changes in beam transmission when the cathode moves axially.

The figure 6 and 7 is the changes in beam transmission when the cathode moves radially and rotates at a certain angle. It can be seen that in both cases, the immersed electron gun has a higher beam transmission than the non-immersed electron gun.

In summary, the immersed electron gun could have excellent stability because it is insensitive to the assembly errors and thermal deformation of the cathode.

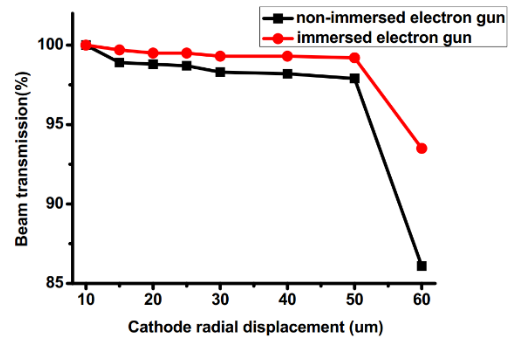

Figure 6. Changes in beam transmission when the cathode moves radially.

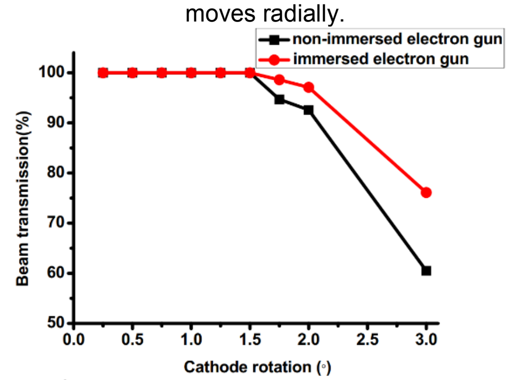

Figure 7. Changes in beam transmission when the cathode rotates at a certain angle.

Conclusion

In this paper, a millimeter wave electron gun and its immersed flow ppm focusing system are designed. Comparing to the traditional design, the immersed flow focusing has better stability.

Acknowledgments

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References

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