Inverse Magnetron Injection Gun for 170GHz Gyrotron

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Abstract—*A key part of the research on the gyrotron is the research and design of the electron gun. As the source of the gyrotron, the electron gun converts the electrical energy of the power source into the kinetic energy of the electronic movement, and provides a stable electron beam for the gyrotron. The quality of the electron beam will directly affect the performance of the entire gyrotron. The effect of tube energy conversion, which determines the overall performance of the gyrotron. According to the operating parameters of the 170GHz electron gun, an inverse magnetron injection gun (IMIG) is designed in this paper. Under the condition that the acceleration voltage of the electron beam is 75KV and the current of the electron beam is 45A, it is obtained that the center radius of the electron beam guide is about 7.6mm, and the lateral-vertical speed ratio is 1.3. The transverse velocity dispersion is 3.6% and the longitudinal velocity dispersion is 5.6%, which meets the requirements of beam-wave interaction.*

Keywords—gyrotron; electron gun; inverse magnetron injection gun

Introduction

The electron optical system of the gyrotron, the electron gun is an important part of it, and the quality of the electron beam it provides directly affects the efficiency and output power of the whole tube. At present, the electron optical systems of various gyrotrons mostly use a magnetron injection gun (MIG) [1]. So how to design a high-quality electron gun is a very important task. In the practical application of the electron gun, due to the limitation of the size of the temperature hole of the superconducting magnet, the radius of the cathode emitter cannot be increased all the time, so that the working current cannot be further increased. Therefore, the design of the inverse magnetron injection electron gun is particularly important. Inverse magnetron injection gun (IMIG) can make the overall structure more compact and reduce the size of the temperature hole of the superconducting magnetic field [2-4]. At the same time, the cathode center radius increases, and the problem of cathode emission current limitation is solved. By adjusting the anode voltage of the inverse magnetron injection gun, the transverse and longitudinal velocity ratio of the electron beam can be controlled, and its effect is the same as that of the conventional dual anode magnetron injection electron gun.

Simulation results

2D simulation: The following is the two-dimensional overall structure of the inverse magnetron injection gun, which includes the cathode, anode and body. The electron beam trajectory, velocity ratio, transverse velocity, and longitudinal velocity are shown in the figure. Figure 1 shows the two-dimensional overall structure of the electron gun and the trajectory of the electron beam. It can be seen from figure 1 that the electron beam does not have abnormalities such as bombardment on the parts of the electron gun and reversal, and has good circulation. It can be seen from figure 2, figure 3 and figure 4, the velocity ratio α is 1.3, the transverse velocity dispersion is 3.6%, and the longitudinal velocity dispersion is 5.6%, which meets the design requirements.

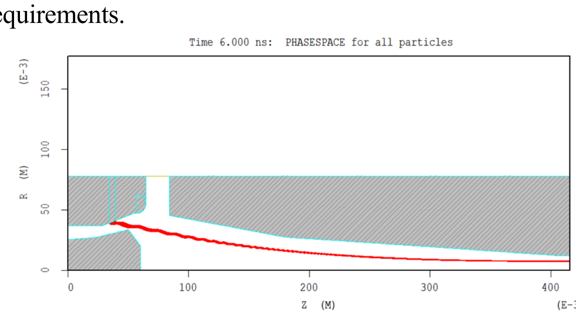

Fig.1. The trajectory of electrons

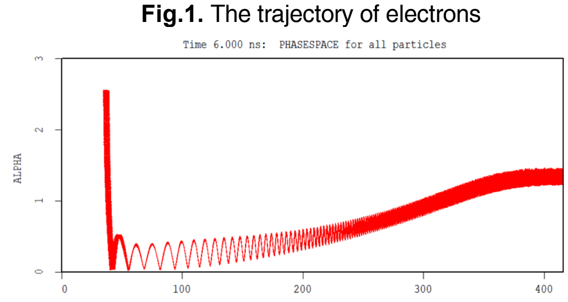

Fig.2. The velocity ratio along with axis

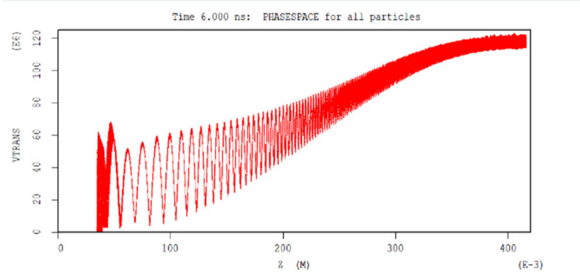

Fig.3. The transverse velocity distribution

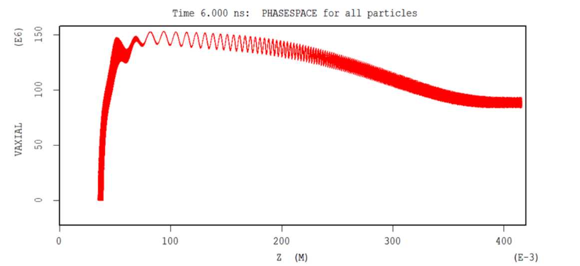

Fig.4. The longitudinal velocity distribution

3D simulation: We applied the relevant module of CST software to carry out 3D simulation of the IMIG. The motion trajectory of the electron beam in the three-dimensional space cannot be displayed in the two-dimensional simulation. As can be seen from Figure 5, this is the overall structure of the IMIG, including the cathode, anode and body. It's easy to see the ratio and size of them clearly.

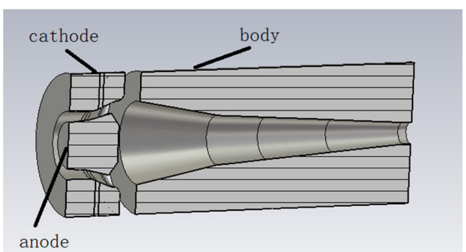

Fig.5. Three-dimensional structure

It can be seen from FIG.6 and FIG.7 that the distribution of the electron beams at the exit position of the electron gun is relatively uniform, and the thickness of the electron beams is thin. Except for the electron trajectory, there are no electron distributions in other regions, and the electron distribution is good. And the radius of the electronic guide guidance center is also consistent with the result calculated by MAGIC software.

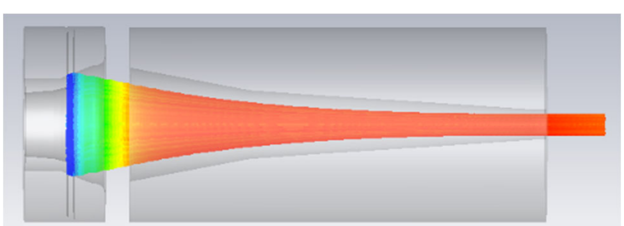

Fig.6. Three-dimensional electronic motion trajectory

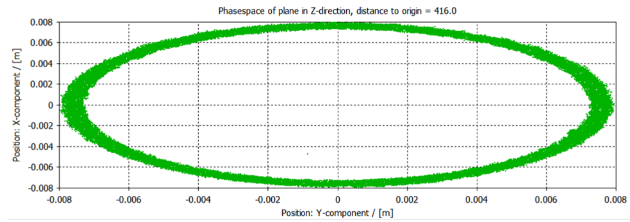

Fig.7. Electron distribution map at z=416mm

Through the analysis, simulation and optimization of the structure and other parameters of the electron gun, the optimized design parameters of the electron gun are shown in Table 1.

Table 1. Electron gun design parameters

Magnetic compression ratio f_m	25.7
Cathode tilt angle φ_c	21.5°
Magnetic field B0	6.6532T
Emission band width l_s	5 mm
Cathode voltage	0kV
Body voltage	75kV
Anode voltage	65kV
Beam current I_0	45 A

The electron beam generated by the electron gun has good performance, suitable speed ratio, small transverse velocity dispersion and longitudinal velocity dispersion, and meets the performance requirements of 170GHz gyrotron. Specific electron beam performance parameters are shown in Table 2.

Table 2. Electronic beam Performance Parameters

Velocity ratio α	1.3
Transverse velocity dispersion	3.6%
longitudinal velocity dispersion	5.6%
Guiding center radius r_{g0}	7.6mm

Conclusion

Based on the analysis of the IMIG above, a high-quality inverse magnetron injection gun is obtained, which velocity ratio can reach 1.3, the transverse velocity dispersion is 3.6%, the longitudinal velocity dispersion is 5.6%.

References

[1] B. Piosczyk. A coaxial magnetron injection gun (cmig) for a 2 mw, 170 ghz coaxial cavity gyrotron. , 27(8), 1041-1061

[2] S. Ruess, I. G. Pagonakis, T. Rzesnicki,etc. A design proposal for an optimized inverse Magnetron Injection Gun for the KIT 2 MW / 170 GHz modular coaxial cavity gyrotron[J].

[3] Arti, Kumar, Nitin, Singh, Udaybir,etc. Inverse Magnetron Injection Gun for Megawatt Power, Sub-THz Gyrotron[J]. IEEE Transactions on Plasma Science:1-7

[4] Ruess, Sebastian, Pagonakis, Ioannis Gr, Gantenbein, Gerd,etc. An Inverse Magnetron Injection Gun for the KIT 2-MW Coaxial-Cavity Gyrotron[J]. IEEE Transactions on Electron Devices:1-6