Simulated Comparison of Two Anode Types of Coaxial Electron Gun for 170GHz Gyrotron

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Abstract: *The simulated comparison of two anode types of coaxial electron gun has been presented in this paper. The calculated results simulated by CST code indicate the electron gun could generate great quality electron beam both in two anode types. No reflected electron occurs and the laminar beam is obtained. The transverse velocity spread for single-anode gun and double-anode gun are 3.79% and 1.92% with the identical velocity ratio 1.3.*

Keywords: gyrotron; electron gun; MW-class; 170GHz

I. Introduction

Gyrotron is a significant high power source in millimeter and sub-millimeter bands. Besides, the output power usually reaches MW-class [1-3]. To ensure high output power, the interaction efficiency between beam and wave must meet the requirement. Therefore, the generation of high quality electron beam is a critical component. The electron is emitted from emitter strip of cathode and then interacts with static electric field and magnetic field. Eventually, the electron beam with appropriate velocity ratio and spread is obtained at the entrance of resonator. For coaxial electron gun, the proper radius ratio of inner conductor to outer conductor is capable of diluting mode spectrum, hence, reducing mode competition [4-5]. Moreover, the introduction of coaxial insert also bends the equipotential lines which makes a difference compared to conventional electron gun. The electron gun has two types with respect to anode numbers in general, namely, single-anode and double-anode gun. The double-anode gun has an extra electrode named modulating anode.

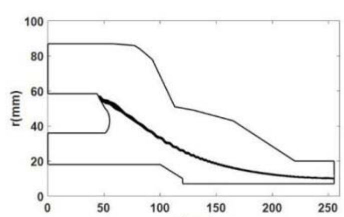
TABLE I. The nominal beam parameters for coaxial electron gun

Electron Beam voltage (V_0)	80kV
Electron Beam current (I_0)	70A
Magnetic field at cavity (B_0)	6.65T
Average guiding center radius (r_b)	10.1mm
Velocity ratio (α)	1.3
Transverse velocity spread ($\Delta\beta_{\perp}$)	<5%

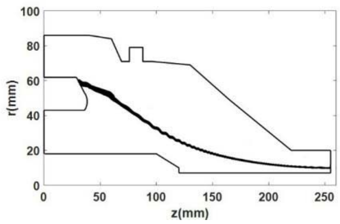
The modulating anode could adjust velocity ratio of electron conveniently. At the same time, the maximum electric field strength would satisfy the constraint condition of vacuum breakdown more easily due to lower modulating voltage. Nonetheless, the design of supplied power system for double-anode gun is more complex. Correspondingly, the geometry and supplied power system for single-anode are more simple. The flexibility of parametrical adjustment is less. The section II describes the comparison of these two types of electron gun in detail.

II. The simulation results

The nominal beam parameters for coaxial electron gun are listed in TABLE I. The choice of beam parameters rely on the demanded power output and the analysis of beam-wave interaction. The optimal electron trajectory for single-anode and double-anode gun are showed in Fig.1. Obviously, no reflected electron occurs and the great laminar property has been obtained. The distance between cathode and anode is larger for single-anode gun owe to the constant and high anode voltage. The peak electric field of single-anode gun is $6.8\,\mathrm{kV/mm}$ which is larger than double-anode gun's ($5.4\,\mathrm{kV/mm}$). In addition, the peak electric field is all located in cathode nose. In order to maintain the size of electron gun and acquire larger distance between cathode and anode, the radius of cathode is supposed to be reduced.



(a) single-anode



(b) double-anode

Fig.1. The optimal profile of electron trajectory

TABLE II. The comparison of different parameters between two anode types of electron gun

Parameter	Single-anode	Double-anode
Velocity ratio	1.3	1.3
Transverse velocity spread	3.79%	1.92%
Peak electric field	6.8kV/mm	5.4kV/mm
Electric field at emitter	4.4kV/mm	3.0kV/mm
Magnetic compression ratio	29.4	34.1
Pitch angle of cathode	49°	51°

And the distance between cathode and cavity is also reduced to keep the averaged guiding center radius at cavity constant. This behavior would make magnetic compression ratio of single-anode gun become lower compared to double-anode gun in the condition of identical magnetic field distribution. Because of the presence of modulating anode, the double-anode gun has one more degree of freedom to adjust velocity ratio and spread flexibly. Nevertheless, the adjustment of cathode and anode geometry is the main choice for single-anode gun. The comparison of different parameters between two anode types of electron gun are summarized in TALBE II. Furthermore, the influence of distance between cathode and coaxial insert is also investigated as showed in Fig.2. With the increase in distance between coaxial insert and cathode, the reducing tendency of velocity ratio is consistent to two anode types of gun. The transverse velocity spread has a small fluctuating range. It's obvious that the larger distance means lower electric field at emitter resulting in lower velocity ratio. On the other hand, this behavior also provides a reference to optimize the velocity ratio.

III. Conclusion

The optimal electron trajectory of two anode types of electron gun have been obtained which indicate great laminar property and no reflected electrons. The performance of double-anode gun seems to be greater than single-anode gun's with respect to lower transverse velocity spread and peak electric field. Of course, this is at the cost of relatively complex supplied power system. The introduction of coaxial insert also provides a new means to vary electric field distribution, adjust velocity ratio further. These simulated results provide guidance for practical manufacture of MW-class gyrotron to a certain extent.

Acknowledgements

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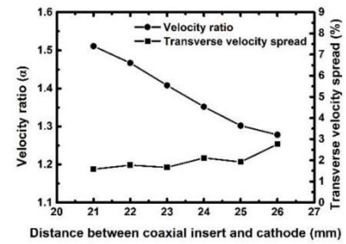
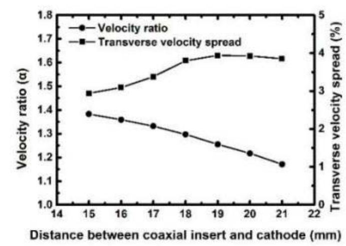


(a) double-anode



(b) single-anode

Fig.2. The influence of distance between coaxial insert and cathode

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