Design of a Gridded Electron Gun for Traveling-Wave Tubes: an EGUN case study

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Abstract: *A design procedure of a 0.7µPerv electron gun, with grid and shadow grid, under space charge-limited flow to be used in traveling-wave-tube (TWT) is presented. The EGUN was used to determine the self-consistent electric fields for the electron beam and, as a result, it was obtained a current/perveance growth as the grid voltage increased and the cathode-to-anode spacing decreased. This behavior was observed when grid voltages and cathode-to-anode spacing were varied from 0-600 V and 0.8-1.2mm, respectively.*

Keywords: TWT; EGUN; electron gun; space-charge-limited flow.

Introduction

The proprietary design of TWTs is of high commercial value since it represents over 50% of all sales of microwave vacuum electronic devices [1] such as in satellite transmitters and in high-power radar systems. These applications require the use of grids, which ensure the beam flow control that can be pulsed whenever it is needed.

The electron gun is one of the critical components of a TWT, and computer simulations of the gun model are crucial for the success of the design, ensuring not only lower cost and reduced time but also the ability to develop highly complex geometries. Many codes have been developed in the last two decades, such as [2]-[4].

The EGUN, a seminal software program, was used to simulate the guns. The three major characteristics of EGUN are: user friendly; ability to work under space-charge-limited flow conditions; and solve electron trajectory equations using guns modeled even with grids and shadow grids. Deviation from EGUN results and the theoretical one of the standard Pierce diode for a sheet electron beam is about 1%.

In this work, in order to obtain a 0.7µPerv electron gun, with grid and shadow grid, under space-charge-limited flow, the gun's behavior was evaluated by changing the following parameters (Figure 1): cathode radius disc $\mathbf{r_k}$; electrode focus angle $\boldsymbol{\theta}$; cathode-to-anode distance **d**; grid-to-cathode distance $\mathbf{g_d}$; and grid voltages $\mathbf{V_{gd}}$.

The first part of this work presents the main characteristics of the gun model used in simulations. The second part describes the most relevant results obtained in the design of an electron gun working at 30 kV – 3.5A.

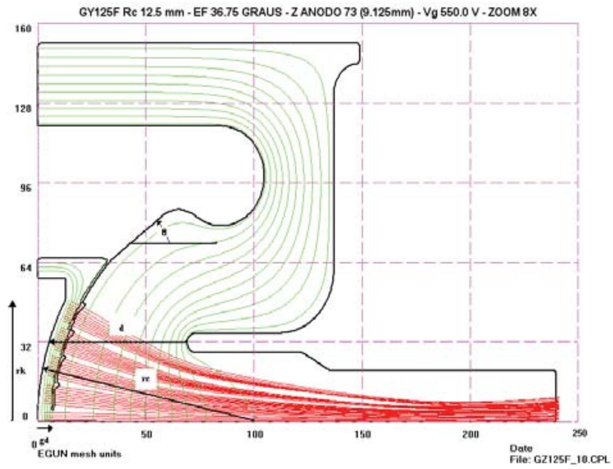

Figure 1. Gun parameters changed within EGUN to evaluate its response behavior: cathode radius disc $\mathbf{r_k}$; electrode focus angle $\boldsymbol{\theta}$; cathode-to-anode distance **d**; grid-to-cathode distance $\mathbf{g_d}$; and grid voltages.

The gun model

The simulations were conducted, and the gun's parameters varied as indicated in Table 1.

Table 1. Range of values used in EGUN simulations

Variable	Initial Value	Final Value	Step
$\mathbf{r_k}$(mm)	11.9	13.1	0.3
$\boldsymbol{\theta}$(degrees)	6.2	39.2	3
d(mm)	8.5	9.25	0.125
$\mathbf{g_d}$(mm)	0.9	1.1	0.1
$\mathbf{V_{gd}}$(Volts)	0	600	100

The anode voltage was set to 30kV in all simulations. In view of the EGUN's limitations, a scale factor of 8 was used since, when the mesh is created, there must be at least one mesh unit of separation between the different elements. As the EGUN is a two-dimensional (2D) code that supports either rectangular or cylindrical symmetry, the original grids were approximated as five concentric rings due to the axisymmetric model.

Results

Figure 2 presents the perveance behavior as a function of the grid voltage using the cathode-to-anode spacing as a parameter. Note that (i) perveance grows as the grid voltage increases; (ii) for the same grid voltage, the perveance grows as the cathode-to-anode distance decreases. It was also observed that for the same cathode-to-anode spacing and voltage, the grids closer to the anode provide higher gun perveance.

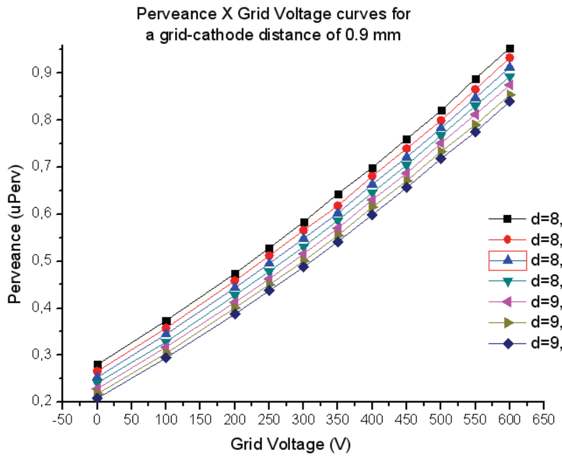

Figure 2. Behavior of perveance curves under different shadow-grid voltages and distance-to-cathode 0.9mm, with varying cathode-to-anode gap.

Without any grids, Figure 3 shows perveance decaying as a function of the cathode-to-anode spacing. It can be seen that perveance is increased for the same cathode to anode spacing by increasing the beam focus angle θ. On the other hand, it was observed that there is no significant variation in perveance, fixed a cathode-to-anode distance, when the cathode radius varies from 11.9mm to 13.1mm.

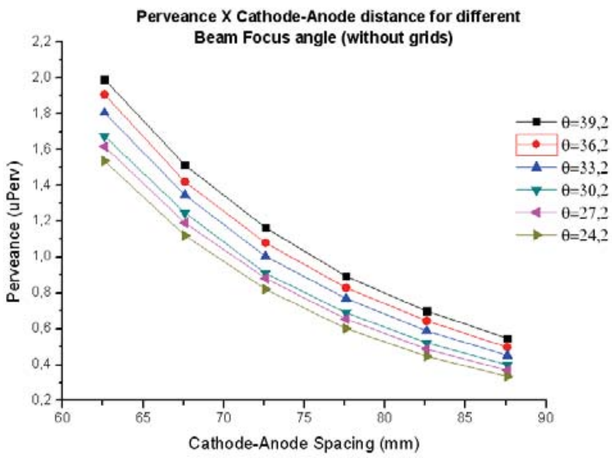

Figure 3 – Perveance versus Cathode-Anode distance curves obtained without the grid.

A relevant quantity in an electron gun design is its beam-waist. Since EGUN output gives only current density as a function of the radial coordinate using the axial coordinate as a parameter, and in order to determine the beam-waist, a three-dimensional (3D) viewer was developed. Figure 4 presents a typical output, highlighting the z beam-waist coordinate where the current density is at its maximum, with its value shown in a window.

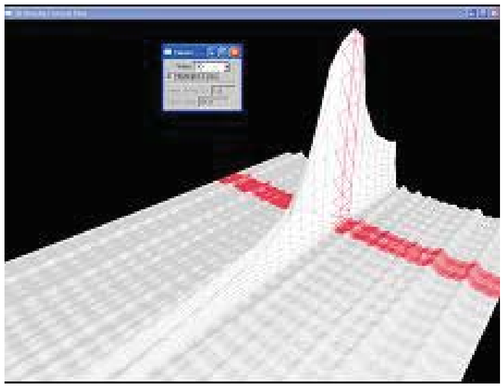

Figure 4 – Typical view of the 3D current density plot along the symmetry axis, highlighting the position where its value is highest

The gun design will be validated in a test workbench which is in its final stage of assembling. Basically, this workbench comprises the following items: an ultra-high vacuum chamber; an ionic vacuum pump; a solenoid to be used as a magnetic focusing system; optical windows to measure the cathode temperature; current and voltage monitors; a heater, cathode, grid and anode power suppliers.

Conclusions

In order to determine a 0.7μPerv electron gun working at 30 kV – 3.5A, with grid and shadow grid, under space-charge-limited flow, five physical geometric parameters of the gun was studied. Since it was possible to determine the current and perveance behavior as a function of each of the five geometric parameters, and the beam-waist with the 3D current-density viewer, a gun geometry model is provided.

References

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