Design of Sheet Beam Electron Gun for a X-band Klystron

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Abstract: *This paper presents the design of a sheet beam electron gun intended for use in an X-band sheet beam klystron (SBK). The initial gun design parameters have been synthesized analytically. Starting with these design parameters, the gun has been simulated using three-dimensional electromagnetic software and optimized to get the desired parameters. The optimized gun parameters are revalidated using another three dimensional electromagnetic simulation software. The steps of optimization and simulated results are presented in this paper.*

Keywords: sheet beam devices; electron gun; sheet beam klystron; electron gun simulation;

Introduction:

The potential of the sheet beam devices to deliver high power RF over the conventional cylindrical beam ones is well reported in the literature[1]. The Central Electronics Engineering Research Institute (CSIR-CEERI) has recently initiated design and development of sheet beam devices in the microwave and mm-wave frequency ranges [2]. Under this initiative, design of a sheet beam electron gun has been carried out and is proposed to be used in a sheet beam klystron (SBK) working in the X-band frequency. Geometrical dimensions of the electron beam have been taken in accordance to the RF circuit of the SBK. The main gun design parameters have been summarized in Table 1.

Parameters	Values
Beam Voltage (kV)	100
Beam Current (A)	100
Beam Size (mm x mm)	80 x 4.5

Table 1. Main gun parameters used for synthesis.

The sheet beam electron gun consists of a rectangular cathode, a beam focusing electrode and an anode with axial hole allowing the beam to pass through. Using the input parameters of Table1, the initial gun synthesis has been carried out following Vaughan's approach for Pierce gun synthesis [3]. Since Vaughan's approach is applicable for electron guns with cylindrical geometry, the synthesized parameters serve the purpose of an informed initial guess. Using these initial parameters, the performance of the electron gun has been evaluated using the commercial three dimensional tracking code CST Particle Studio [4] and optimized to meet the desired design goals. In the second stage the optimized gun geometry has been simulated with another three-dimensional code OPERA [5] for validating the results.

Design results:

The initial geometry considered for the gun simulation is shown in Fig. 1. The dimensions of the rectangular cathode (with a cylindrical cut) have been taken such that its area is approximately equal to that of the cylindrical cathode used for gun synthesis, as well as consistent with the required beam size.

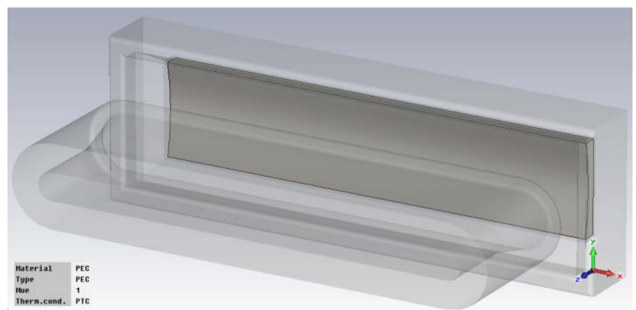

Figure 1. The cathode geometry used for the three dimensional gun simulation

The gun tracking simulations have been carried out with the particle studio solver of CST EM studio. In order to represent the minute geometrical details of the cathode, BFE and the anode, proper meshing has been provided for the simulation. The trajectory of the electrons from the simulation is shown in Fig. 2. Although in this case a beam current of 117 Amp has been obtained, the beam exhibits "dumbbell" type of distortion as shown in Fig. 3.

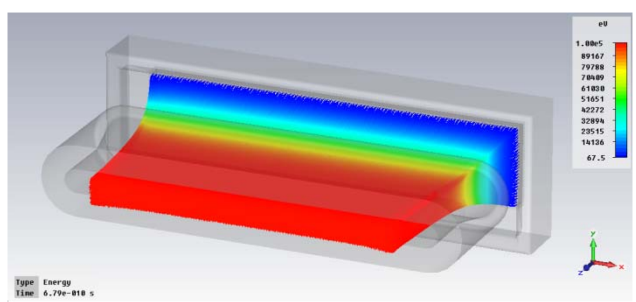

Figure 2. Beam trajectory for the sheet beam gun with rectangular cathode.

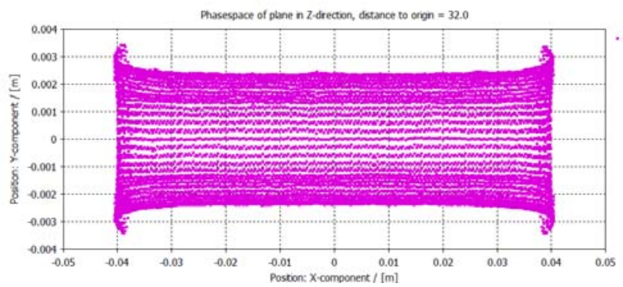

Figure 3. Phase space plot of the electrons at a transverse plane showing the "dumbbell" distortion.

To eliminate the problem of the beam-distortion, the shape of the cathode has been optimized and it has been found that the beam distortion can be minimized by considering an elliptical cathode geometry. Using the elliptical cathode (with cylindrical cut), 107.2 Amp of beam current has been obtained. The beam trajectories and the phase space plot of the electrons at beam waist (transverse plane) is shown in Figs.4 and 5 respectively.

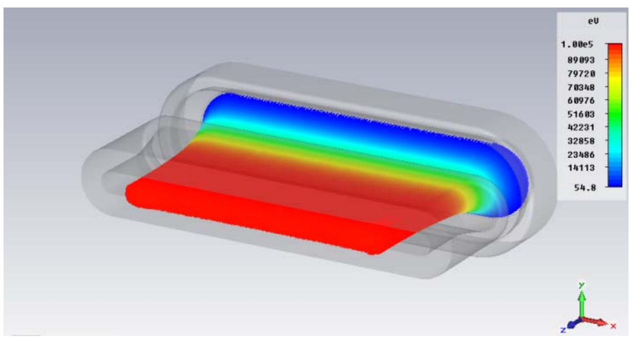

Figure 4. Beam trajectory for the sheet beam gun with elliptical cathode.

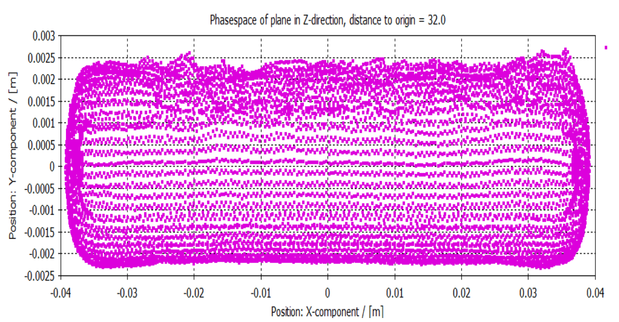

Figure 5. Phase space plot of the electrons at beam waist in case of the elliptical cathode.

In the next step, the electron gun with the optimized geometry has been simulated with the help of another commercially available tracking code, OPERA 3D. Cut view of the three dimensional gun along with the beam trajectory is shown in Fig. 6. The beam current obtained from OPERA 3D is 107.3 Amp.

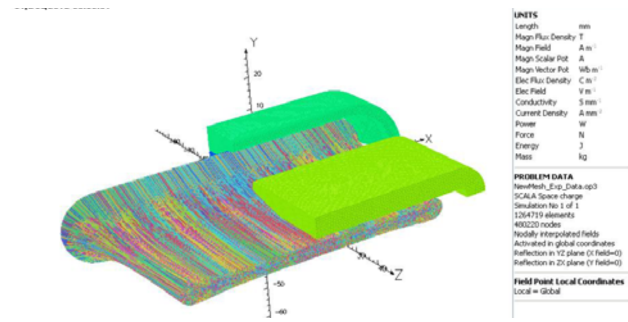

Figure 6. Electron beam trajectory obtained from the OPERA 3D.

The major beam parameters corresponding to the optimized gun obtained from the three dimensional tracking codes have been compared in Table 2. As it can be noticed, there is a good agreement between the results obtained from the two codes.

Parameters	CST Particle Studio	OPERA 3D
Beam Current (Amp)	107.2	107.3
Beam Waist (mm)	32	34
Beam Size (mm x mm)	78 x 4.5	80 x 4.5

Table 2. Comparison of the beam parameters.

Conclusion:

Design of a sheet beam electron gun has been carried out starting with the analytical approach. The gun geometry has been optimized using a commercial three dimensional tracking code to obtain desired gun parameters. The simulation results have been validated by comparing the simulation results from another three dimensional simulation tool. A good agreement has been achieved in the simulated results from the two codes.

References

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