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Effect on Beam Current on varying the parameters of BFE and Control Anode of a TWT Electron Gun

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This paper introduces the characteristics of the electron gun used in the traveling wave tube of 140w. The paper shows the variation in the parameters of beam focusing electrode and control anode the beam current of the electron gun also varies accordingly. The EGUN code was used to simulate the structure and properties of the electron gun, providing the reference size and debugging parameters for replacing the electron gun. Electron gun has been designed using EGUN for Ku-band 140W short length space Traveling Wave Tube (TWT). Pierce type electron gun with an electrically isolated beam forming electrode (BFE), a control anode and an ion barrier anode in addition to ground has been opted.

Keywords Traveling Wave Tube, Pierce Electron Gun, Thermionic M-type Dispenser Cathode

I. Introduction

The generation of high density electron beam for microwave tube, Pierce type electron gun using thermionic dispenser cathodes is invariably used as they are unique choice for such devices as shown in Fig1. Authors have designed a convergent type electron gun, using code EGUN, MAGFLD to deliver ~100mA beam current at 6.0kV beam voltage with beam waist radius (rw) 0.27mm.The electron gun assembly consists of M-type dispenser cathode with an electrically isolated BFE and ground accelerating anode. Initial estimation of gun geometry has been obtained for the desired beam parameter in terms of beam voltage, beam current, beam waist radius and cathode emission loading using synthesis approach and gun designed is finalized through simulation with optimized BFE shape, anode cathode axial distance and potentials with respect to cathode.

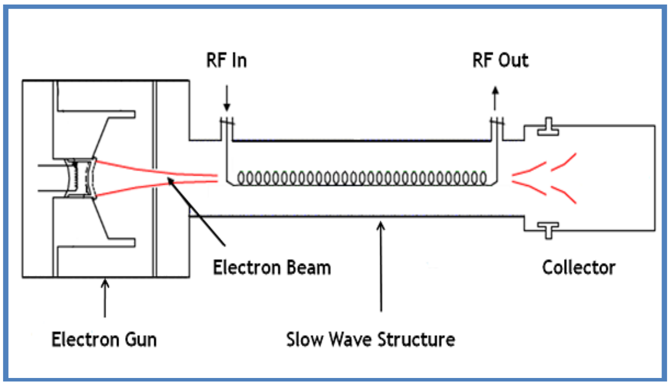

Fig.1 Schematic of an electron tube.

A confined flow beam focusing has been adapted and designed with solenoid magnet using code TRAK. This paper presents an approach for the design of electron gun and of focusing structure using simulation method by using commercially available software. There are many challenges to make an electron gun and beam focusing system at such a high frequency that have to be addressed. Electron gun with the features as been designed to achieve beam current ~ 100 mA at 6.0kV anode potential (A0), 5.9kV at ground anode (A1) with respect to cathode, and ~ .27mm beam waist radius as shown in Fig 2.

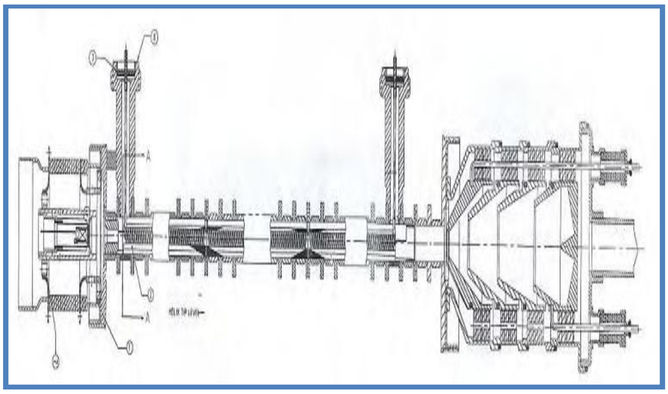

Fig.2 Schematic diagram of designed Ku-band 140W space TWT

The potential at control anode is 1.6kV with respect to cathode. Fig.3 shows the optimized electron gun simulation with the desired potentials, using EGUN code. Dependency of the beam current on the control anode voltage and control anode axial position with respect to cathode has been analysed. It has been observed that with the variation of on the control anode there is a variation in beam current (Fig.7) with the change in the axial position of the control anode, the current varies (Fig.8). The effect of BFE negative bias on beam current and on the beam waist radius has been studied. It has been observed that with the application of negative bias beam current has been reduced (Fig.9) and beam radius has been reduced by 40 micron on the application of

-10 V.

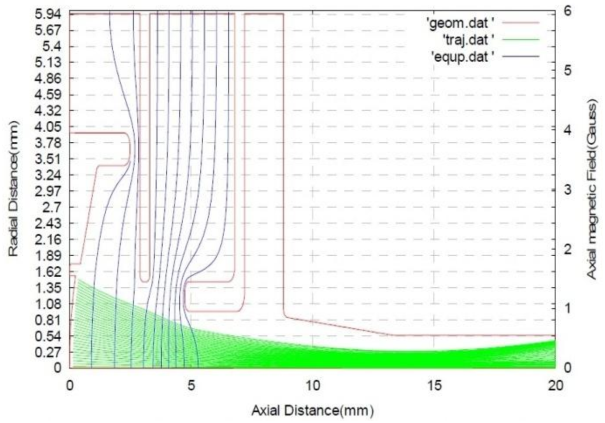

Fig.3: EGUN Simulated electron beam flow

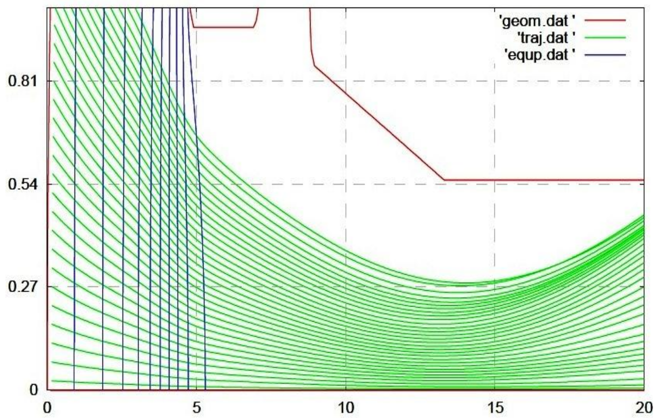

Fig.4: Enlarged view showing beam laminarity

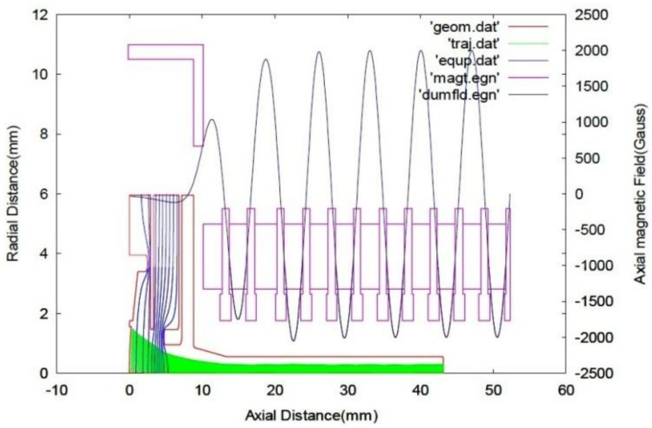

Fig.5 Beam flow under MAGFLD designed magnetic field profile

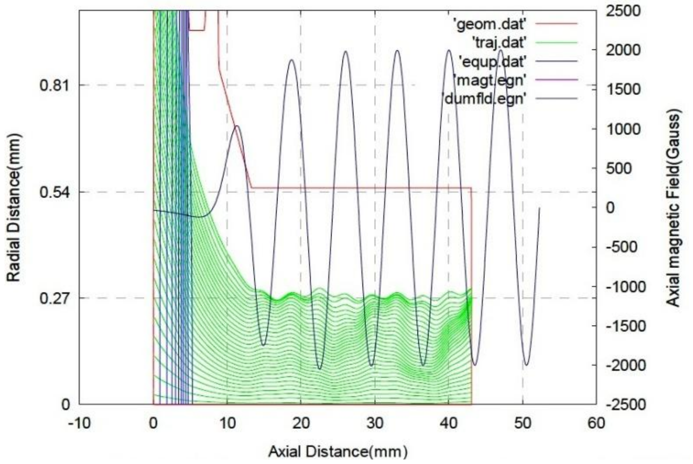

Fig.6: Enlarged view of beam flow under PPM

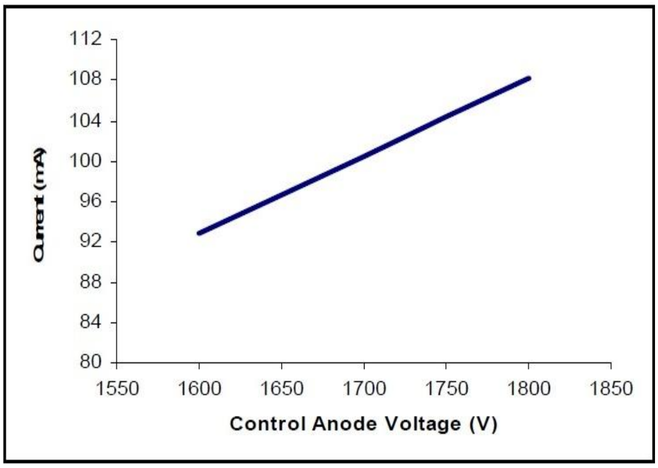

Fig.7: Dependency of beam current on control anode Potential

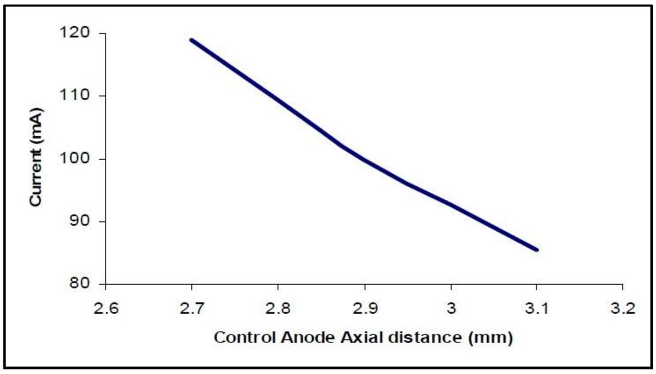

Fig. 8: Dependency of beam current on control anode axial distance

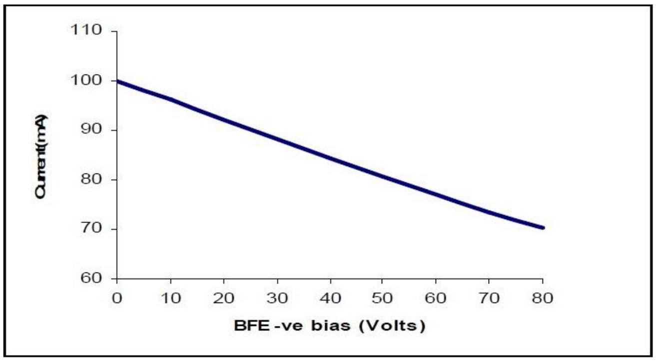

Fig. 9: Study of BFE negative bias w.r.t beam current

II. Design of Electron Gun

The electron gun has to provide the slow wave structure with a beam, which then interacts with the electromagnetic wave existing in the structure and finally is collected in the collector. In order to enable the interaction, the particles' velocity has to match the EM-wave's velocity on the circuit.

The necessary velocity determines the voltage to be applied. The electron gun has designed in a way that the emitted current is maximized. Initially electron gun has been synthesized for the desired beam parameter (Vo = 6.0kV and Io = 100mA & rw = 0.27mm) with the cathode of diameter (od=3.3mm, id=3.1mm and spherical radius 5.5mm). A rough estimate of gun geometrical parameter is obtained. Then gun geometry is completed by incorporating accelerating anode and BFE with proper shape and accordingly input file for gun simulation (e.g. .pol file of EGUN) is made and desired potential are applied at the different electrodes. For instant, in this case, cathode & BFE are kept at -6.0 kV and accelerating anode at zero potential. Inter electrode spacing and radial aperture dimension are optimized through simulation for the desired beam parameters along with laminsarity. It takes several iterations to arrive at the optimized design. Fig. 10 shows the the variation in the parameters of beam focusing electrode and control anode the beam current of the electron gun also varies accordingly. Fig 11 shows the EGUN simulated (optimized) electron gun when BFE axially shifted by =0.10 and current becomes 183.23 mA. Fig. 12 shows the expanded view, depicting beam laminarity and beam waist radius more clearly.

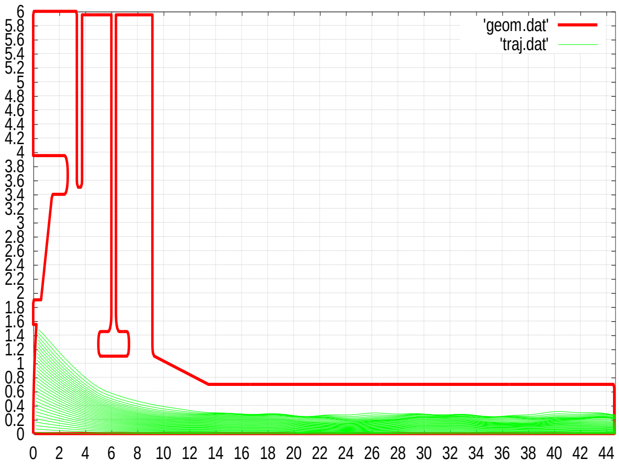

Fig.10: BFE axially shifted by +0.10 (a)CA radius increased by +1.5 & becomes 3.5, Current =92.994mA, Perveance=2.0009 *e-007 (b)CA Potential decreased from 1700 to 2000 and potential becomes 4.2 to 3.9 ,NEW Current =98.751mA, Perveance=2.1248 *e-007

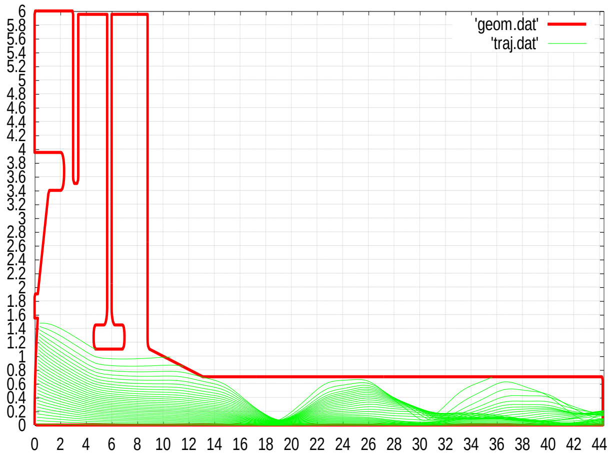

Fig 11: BFE axially shifted by +0.10, Current =183.23mA, Perveance=3.9426 *e-007 (a) CA radius increased by +1.5 & becomes 3.5, Current =92.994mA, Perveance=2.0009 *e-007 (b)CA Potential decreased from 1700 to 2000 and potential becomes 4.2 to 3.9

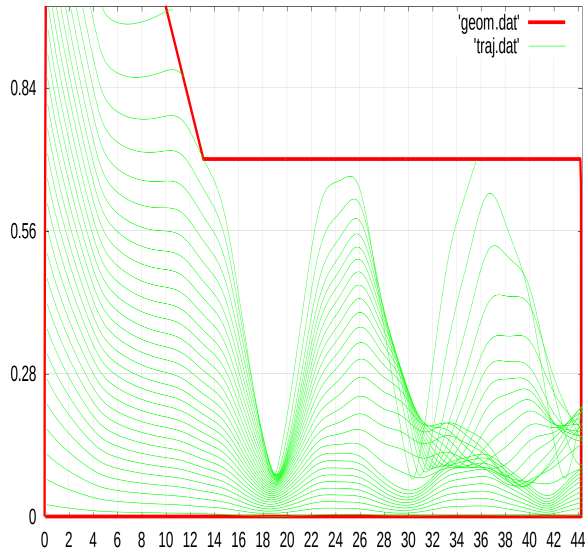

Fig.12: Enlarged view showing beam laminarity when BFE axially shifted by +0.10, Current =183.23mA, Perveance=3.9426 *e-007 (a) CA radius increased by +1.5 & becomes 3.5, Current =92.994mA, Perveance=2.0009 *e-007 (b)CA Potential decreased from 1700 to 2000 and potential becomes 4.2 to 3.9

III. DESIGN OF BEAM FOCUSING PPM SYSTEM

Beam focusing by means of Periodic Permanent

Magnet (PPM) has been accomplished using code MAGFLD. Samarium Cobalt Sm2C017 high energy magnetic material used to get the overall size and weight of magnets reduced and the required magnetic field can be obtained well below the saturated value. Fig. 5 shows the EGUN simulated electron gun with beam flow characteristic under the influence of code MAGFLD designed PPM axial field profile. Fig. 6 shows the expanded view of the PPM focused beam depicting beam laminarity is maintained and ripples are controlled well within 5% and the beam waist radius 0.27mm. The gun end adapter has been kept non magnetic in order to have required magnetic flux linked as per Busch's theorem at the cathode, for the confined flow focusing. Confined beam flow focusing is more rugged design and less sensitive to the variations of magnetic and beam parameters in comparison to brilliouin focusing. In the design of PPM focusing, the height of coupler magnet is kept -- 40% more than symmetric magnet to keep the comparable volume of the coupler magnet. The important magnetic field parameters are highlighted in Table 1. The detailed theoretical design and measured results would be presented.

Table.1: Magnetic field parameters

Sr. No.	Parameters	Value
1	Brillouin field (BB)	1112Gauss
2	B0 / (1.414 BB)	1.30
3	Plasma wavelength λp	20.6
4	Beam stiffness factor($\lambda p/L$)	~3.0
5	Magnetic flux at Cathode (Bc)	33.7G(analytical) 30G(simulation),

IV. ION BACK FLOW ANALYSIS

Ion back flow analysis has been carried out to ascertain the effectiveness of the ion barrier anode and it's estimate of ion barrier positive potential (w.r.t. Ai) to stop the ions of different energy levels. This shows that +100 volts (w.r.t Ag) on Ai is sufficient to stop the ions with 50eV energy.

V. SENSITIVITY ANALYSIS OF ELECTRON GUN

Sensitivity analysis of the electron gun has been carrier out using code TRAK in order to determine the dimensional tolerance of the different parameters in the gun. Through the study related to estimation of the dependence of beam parameters on different electrical and geometrical parameters, it has been observed that the axial location of the control anode and its potential are very sensitive. On an average around 2mA beam current changes per 20 micron shift in axial location of the control anode and around 6mA beam current changes per 50 volts change in control anode potential.

VI. HIGH VOLTAGE ANALYSIS OF ELECTRON

A complete gun assembly (compact size) has been designed with stack type high voltage seal assembly and suitable support structure for the different electrodes. Prior to the actual fabrication of the electron gun assembly it has been subjected to high voltage analysis using code ESTAT. It required a number of iterations to finalize the gun assembly and its support structure in order to yield the safe high voltage management.

VII. CONCLUSION

A Pierce type convergent electron gun assembly has been designed for Ka-Band helix TWT. For the initial design of the electron gun, the available M-type dispenser cathode has been taken. Long life considerations in the selection of cathode have been ignored. Electrostatic design of electron gun has been accomplished using code EGUN to obtain 100mA beam current at 6.0kV beam voltage. The control anode potential comes out to be 1.6kV. Ion back flow analysis has been carried out using code ESTAT to as certain effectiveness of ion barrier anode (A)) as an ion trap. Details sensitivity analysis has been carried out using code TRAK to determine the dimensional tolerance. Electron gun assembly has been completed using available cathode and small size ceramics. A safe gun geometry from high voltage point of view obtained.

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