Design and Analysis of Electron Gun for C band 250 kW CW High Power Klystron

O S Lamba, Meenu Kaushik, L M Joshi, Prachi Bansal,
Suman Baloda, Pradeep, D. Kant, D Pal,
Microwave Tubes Area.
CSIR- Central Electronics Engineering Research Institute, Pilani (Rajasthan):333031
(Council of Scientific and Industrial Research, New Delhi)
Email: osl@ceeri.ernet.in

Abstract: **Klystron is vacuum electron device operating in microwave range of frequencies. It is used as power amplifier in a variety of systems including radars, particle accelerators and thermonuclear reactors. With the availability of reliable design codes, it is now possible to optimize the design and develop a tube with minimum iterations in fabrication. In the present case standard design codes like EGUN, CST Microwave Studio, AJDISK and MAGIC have been used to estimate and optimize different design parameters of klystron for desired tube performance. The paper presents the results of simulation and cold testing of 250 kW CW C-Band klystron with specifications as given in Table1 is under development at CEERI, Pilani. The proposed klystron to be used as a RF source for ITER program.**

Keywords-Electron gun; Klystron; Magnetic field

I. INTRODUCTION

The basic role of the electron gun in a microwave tube is to provide an electron beam of desired characteristics for the interaction with the RF fields. The shape, size, current density & energy, which characterizes beam, depend on the type of interaction mechanism used for energy exchange between the RF fields & the electron beam. The Pierce type electron gun has been designed with spherical cathode. The BFE-Cathode spacing is being optimized to get a cylindrical beam of 10 amps current with 60kV voltage without any voltage breakdown between these electrodes. The magnetic focusing circuit is designed such that a small fraction of the magnetic field needed for focusing links at the cathode with flux lines parallel to the electron trajectories. The initial estimation of the shape of the electrodes has been done using synthesis approach of Vaughan[4]. A computer program has been written which generates the basic dimensional information about the electrodes for a beam of desired characteristics at rated beam voltage and current. The other input parameters needed are beam waist radius and emission current density of cathode.

TABLE1 SPECIFICATIONS OF 5GHZ KLYSTRON

Parameters	Value
Operating frequency	5 GHz
Output power	250 kW CW
Beam voltage	60 kV
Beam current	10 A
No. of cavities	6
Efficiency	40% (min)
Gain	40dB (min)

II. RESULTS AND DISCUSSIONS

In electron guns it is desirable to compress the beam radially so that it fits into the aperture of the RF cavity structure being employed for microwave generation or for acceleration of the beam. The compression is achieved by shaping the electrodes in the gun to introduce a focusing transverse electric field near the cathode and by utilizing the focusing action of the magnetic fringe field. By choosing appropriate electrode angles, one can obtain a transverse focusing force at the beam edge that either exactly balances the space-charge force to keep the radius constant or exceeds the space charge to obtain a converging beam (for radial compression) in the gun region. The important parameters are the linkage of magnetic flux with the cathode, the field increase slope at the gun region and the ration of magnetic field in the drift region to the Brillouin value. The magnetic flux density at the beam drift region is 2.3 times of the Brillouin value which is 780 gauss in the present case. In the vicinity of output cavity, the magnetic flux density is raised to about three times of the Brillouin value in order to counteract the increased space charge forces in the heavily bunched beam. The solenoid magnet is designed by TRAK code and the output results of this code are validated in MAGIC2D code and the results are shown below.
Figure 1 is the electron beam profile without magnetic field in which beam is striking at the walls of the anode.

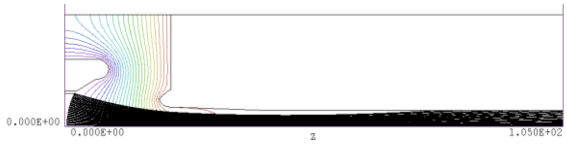

Figure 1. Beam profile without magnetic field in TRAK code

So, to focus the electron beam along the full length of the RF section, we have to design a solenoid which can generate enough magnetic field to make the beam laminar and focused. The coil and polepiece is designed using TRAK code and is shown in figure 2.

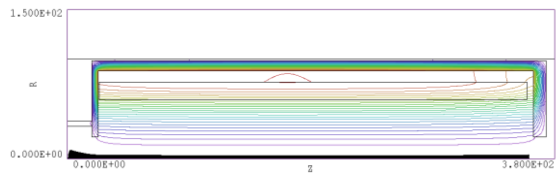

Figure 2. Design of magnet: Focused electron beam trajectory through polepiece and coil

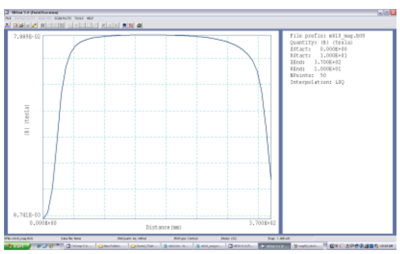

Figure 3. Plot showing magnetic field ~ 780 Gauss

Finally, the electron beam distribution in the electron gun after applying magnetic field of 780 Gauss using TRAK and MAGIC code is shown in figure 4 and figure 5 respectively. Here, the beam is now not striking to the walls of the anode, has laminarity and is fully focused throughout the anode without crossing among itself.

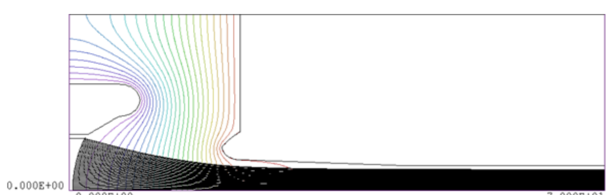

Figure 4. Focused Electron beam in electron gun

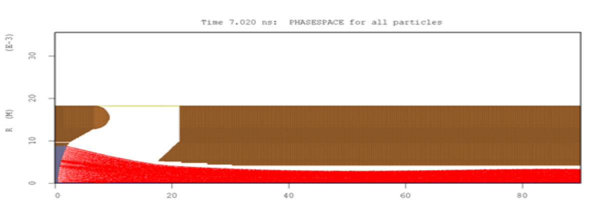

Figure 5. Electron beam distribution in MAGIC2D

The electron gun is designed for operating voltage 60kV. Simulated result of V-I characteristics is shown below.

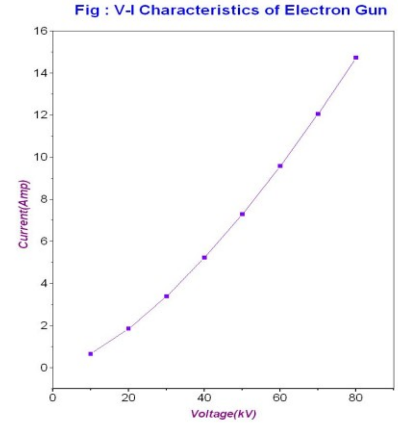

Figure 6. V-I characteristics of gun

TABLE2: DESIGN PARAMETERS OF ELECTRON GUN

Input Design parameters	**Value**
Beam voltage (kV)	60
Cathode disk radius (r_c)	8.9 mm
Cathode spherical radius	26 mm
Anode spherical radius	2.37 mm
Output parameters obtained	
Cathode anode axial spacing	19.55 mm
Beam current	10 A
Beam waist radius	3.0 mm
Beam Throw	48 mm
Beam Perveance	0.64 µP
B-field	780 Gauss
E-field (b/w cathode & anode)	8 kV/mm

CONCLUSION

In this paper the design of electron optics system is discussed for 250 kW C-band klystron. The electron gun geometry optimized through combined electrostatic and magneto static fields to obtain desired focused beam for beam wave interaction. The simulated design has been converted into engineering design and parts are being fabricated for development of experimental electron gun.

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