

# DESIGN AND DEVELOPMENT OF A PIERCE ELECTRON GUN

D.Bhattacharjee, R.Tiwari, B.Nayak, A.R.Tillu, D. Jayaprakash, R. L. Mishra, K.C.Mittal,  
D.P.Chakravarthy, L.M.Gantayet  
BARC, APPD, EBC Kharghar, Navi Mumbai, India

## Abstract

An electron gun is designed and developed using the Pierce configuration for the focusing electrode. Simulations were carried out using CST Particle Studio. The Gun is a thermionic type electron gun with indirect heating of the LaB6 cathode. The gun is capable of delivering a beam current of 500 mA at 50 kV with a beam size of less than 3.5 mm. It was tested on the gun test bench. This paper presents the gun design, particle simulations study, testing of the gun on test bench and integration with the ECIL 9 MeV linac.

## INTRODUCTION

The 10 MeV Industrial RF Electron accelerator at EBC, Kharghar and the 9 MeV RF Electron accelerator ECIL, Hyderabad, use planar triode configuration electron guns with 8 mm and 6 mm cathode diameter beam emission areas respectively. The cathode for these guns is a LaB6 pellet of dimensions 10 mm dia. x 1 mm thk. It is known that a converging or collimating beam of smaller beam diameter at the linac input will improve the capture efficiency and hence the transmission of the beam. Also, for the 9 MeV ECIL Linac, which will be used for cargo scanning, the output beam should be of diameter  $\leq 2$  mm at the Tantalum target. To achieve this, a Pierce gun design approach was attempted.

## DESIGN ASPECTS

A design goal of beam current of 500 mA at 40 kV with a beam size less than 3.5 mm and using an 8 mm cathode was decided. To design the electron gun, simulations were conducted using the CST Particle Studio. It is a Diode Type thermionic Gun. It incorporates a Pierce geometry Grid, also known as Focusing electrode. Studies were conducted to obtain good beam quality, beam size and beam current by varying (a) Planar anode inner diameter, (b) Pierce angle of the Grid, (c) cathode-anode gap, (d) cathode-grid gap, (e) anode shapes.

The simulations resulted in the required 40 kV Diode electron gun with Pierce Focusing electrode (grid) of ID 23 mm and angle  $\sim 67.5^\circ$ , to give  $\sim 500$  mA of beam current and having a diameter of less than 4 mm at a distance of 100 mm from the cathode. The anode is also shaped with aperture of 10 mm. The cathode-grid distance is 9 mm and the anode-cathode distance is 25 mm. The gun is operated in the space charge region.

The cathode is a LaB6 Pellet of dia. 10 mm and thickness 1 mm. The Lab6 pellet is indirectly heated by a coil filament made out of Tungsten wire of dia 0.5 mm. A filament power of 270 W raises the temperature of the LaB6 pellet to about 1550 °K, to emit the required current of 500 mA. Filament heating power of maximum  $\sim 310$

watts can be supplied with the help of a 70 kV Isolation transformer.

LaB6 cathode is chosen because it has low thermionic work function 2.6 eV, high melting point 2715 °C, high current density, it can work in vacuum of the order of  $10^{-6}$  –  $10^{-5}$  mbar. LaB6 offers the capability of long life and orders of magnitude less sensitivity to air exposure than conventional dispenser cathodes.

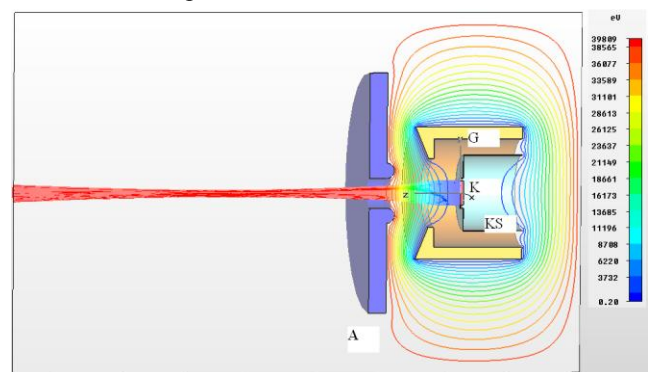


Fig 1: A CST simulation of the 40 kV, 510 mA Pierce Diode Gun. A is the anode, K the cathode, KS the cathode support and G the Pierce grid.

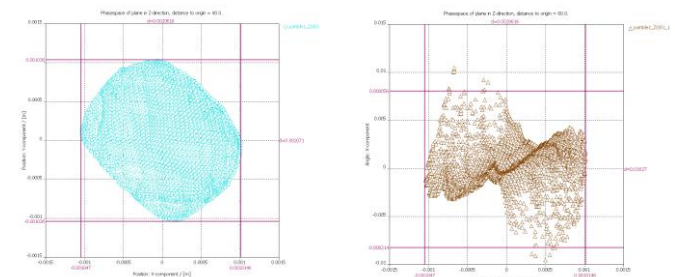


Fig.2: The beam size and xx' phase space at z = 80 mm from the cathode (49 mm from the anode).

## TESTING ON TEST BENCH

The Pierce focusing electrode (grid) and its support were fabricated to fit into the existing gun assembly. The gun was assembled; vacuum tested and put on test bench (fig.3). After the filament conditioning of the gun, the beam extraction experiments were conducted with cathode-grid shorted and the gun characteristics plotted (fig. 4 and fig. 5). For the 8mm cathode, at the filament power of 264 W and extraction voltage of 40 kV, a beam current of 500 mA was extracted (fig. 6), the vacuum being  $2 \times 10^{-5}$  mbar. The beam spot sizes were measured as puncture impressions (fig. 7) on four 12  $\mu$ m aluminum foils and an aluminum collector, kept at distances of 48 mm, 55 mm, 62 mm, 69 mm and 74 mm respectively from the anode. A beam size of  $\leq 3.5$  mm was obtained.

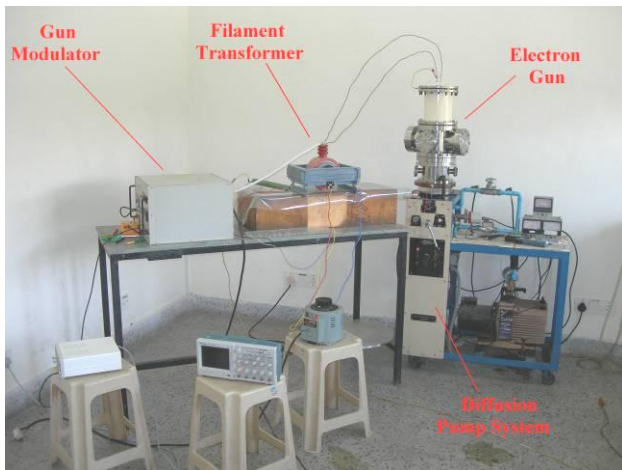


Fig. 3: Gun on Test bench.

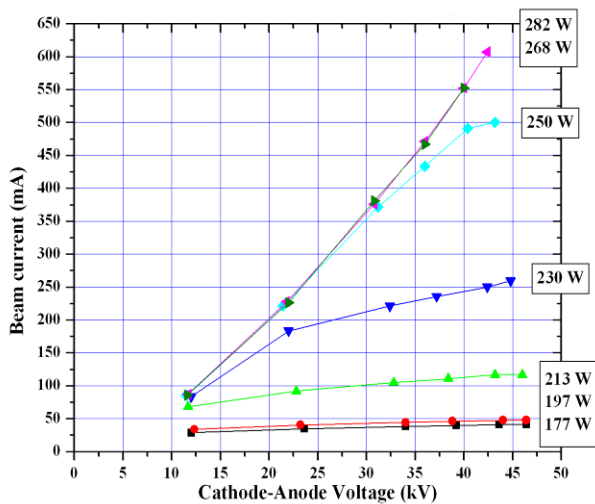


Fig. 4: Variation of beam current with extraction voltage, at different filament powers.

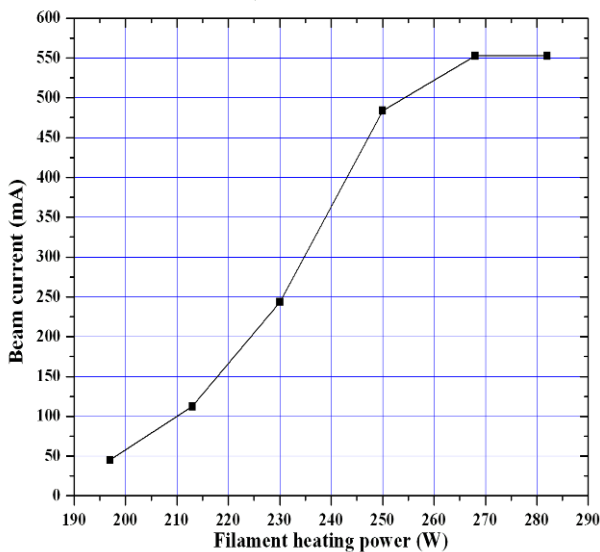


Fig. 5: Variation of beam current with filament power at fixed extraction voltage of 40 kV.

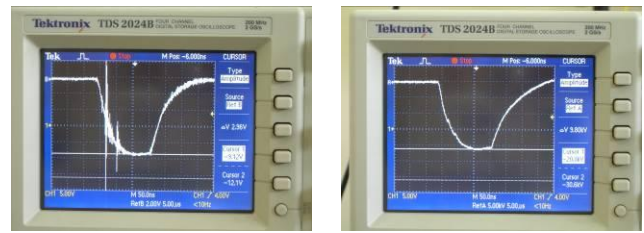


Fig 6: Left: Beam current waveform 542 mA and Right: HV waveform 41.6 kV.



Fig. 7: Beam spot sizes on Al foils and Al Disk.

With the 6 mm cathode, a beam current of 350 mA was achieved at 50 kV extraction voltage, 270 W filament power,  $2 \times 10^{-5}$  mbar vacuum and beam spot size  $\leq 3.5$  mm.

## EXPERIMENTS WITH ECIL LINAC

At ECIL, the planar configuration diode gun (cathode-grid shorted) gave an output current of 65 mA at for 65 kV gun voltage for 250 W filament power. Recently, the Pierce diode gun with 6 mm cathode was integrated with the linac. An output beam current of 105 mA was achieved at 65 kV for the same filament power.

### Grid Biasing Experiments

The grid biasing was done by using a resistive voltage divider. The Egun modulator output was taken across a series combination of a low value resistor  $R_1$  (1 k $\Omega$  to 3 k $\Omega$ ) and  $R_2$  (50 k $\Omega$ );  $R_1$  being connected to the HV terminal and  $R_2$  to the Gnd. For negative grid biasing, the HV terminal was connected to the grid, GND terminal to anode and the tapped voltage was connected to the cathode. For positive grid biasing, the HV terminal was connected to the cathode, GND terminal to anode and the tapped voltage was connected to the grid.

An output beam current of 146 mA was achieved with a positive grid bias of 3.8 kV and  $V_{KA} = 66.8$  kV. An output beam current of 58 mA was achieved with a negative grid bias of 3.8 kV and  $V_{KA} = 63$  kV.

## CONCLUSIONS

The Pierce gun geometry is designed, tested and operated successfully at ECIL Linac.

## REFERENCES

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