AN ELECTRON GUN FOR THE LNLS PRE-INJECTOR

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Abstract

We present results obtained with an 80 KeV, 1 A peak current electrostatic electron gun developed at the Brazilian Synchrotron Light Laboratory (LNLS). A test bench for gun characterization including gun emittance measurement is also described.

1 Introduction

An 80 KeV electron gun has been developed at LNLS to be used as an injector for the LNLS 50 MeV LINAC [1]. The gun is a gridded triode and produces 100 ns pulses of up to 1.7 A peak current at a maximum repetion rate of 33 Hz. The cathode grid assembly was purchased from EIMAC. This is a dispenser cathode (Y845) with 0.5 cm^2 emitting surface. The ceramic-metal welding was done with the Moli-Manganes process, using filler euthetic alloy (72% Ag, 28% Cu) and kovar rings in a reducing atmosphere oven at the Institute of Advanced Studies of São José dos Campos. The ceramic insulator tube is made of Alumina 96%. The working pressure is 3.010^{-8}mbar.

2 Gun Optics

Beam optics simulation was done with the SLACGUN computer code written by W.B. Herrmansfeldt [2] and modified by M. Sedlacek. The gun was calculated as a diode, the current being limited to 1 A. Electrode shapes were optimized to get the smallest possible emittance. Figure 2 shows electron trajectories for a 80 keV, 100 mA (0.0044 μPerV) beam. The calculated r.m.s. emittance is 0.99 πmm.mrad. Beam r.m.s. radius and divergence at gun exit are 1.83 mm and -6.8 mrad respectively.

3 Test Bench

A test bench was built in order to measure the gun output current and the r.m.s. optical parameters (emittance, radius and divergence) of the electron beam. Figure 1 shows a schematic diagram of the test stand.

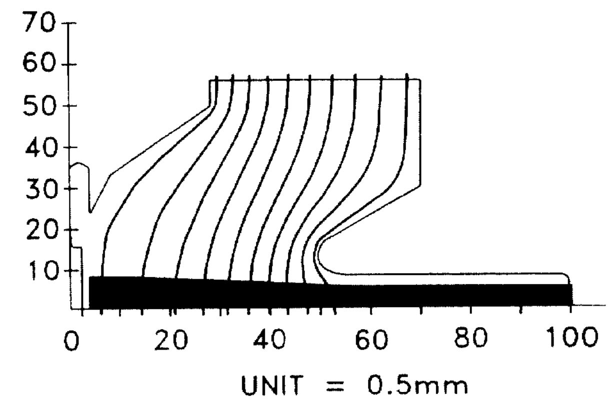

Figure 2: Electron Trajectories inside the gun. Energy is 80 keV and beam current is 100 mA.

Beam current is measured with a toroidal ferrite current transformer and beam profile plots are obtained with an Alumina plate at the end of the transport line. The light emitted by the fluorescent plate upon electron impact is then viewed with a television camera. The video signal produced by the camera is fed into the Y channel of an oscilloscope, while the X channel is fed with the synchronism (either horizontal or vertical) signal. We can thus obtain reasonably well defined profiles. Another current transformer is installed to measure the current emitted by the cathode. About 20% of the total emitted current is drained by the grid.

4 Optical Characterization Procedure

The optical characterization method is based on a similar experimental set-up proposed by B. Aune et al[3]. Two iron-shielded magnetic lenses are used to focus and transport the beam to the fluorescent plate. The first lens (L1) is set to get the maximum transmitted current at the current transformer (M1). The second lens (L2) is then used to vary the size of the spot at the profile monitor.

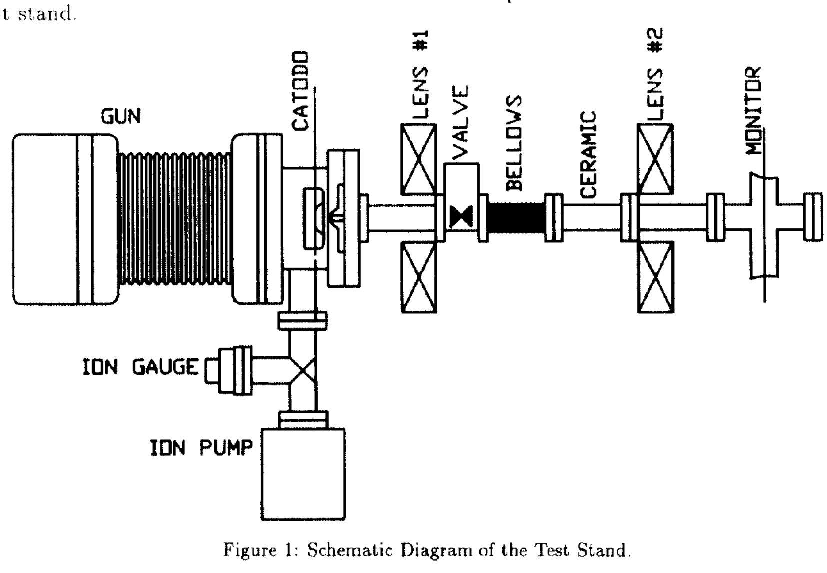

Figure 1: Schematic Diagram of the Test Stand.

Beam sizes are recorded for various settings of L2. A computer code that solves the r.m.s. envelope equation for cylindrically symmetric beams is then used to find the three phase-space ellipse parameters at the exit of the gun that fit the experimental data. An important feature of the method is that it explicitly takes space charge into account.

The r.m.s. envelope equation derived by Lee[4] describes the evolution of the r.m.s. radius of a cylindrical beam in a solenoidal transport channel. The main approximations made by Lee are:

- Cylindrical symmetry.
- Paraxial trajectories.
- Self-similar expansion. The shape of the current density profile is fixed as the r.m.s. radius changes.

For a shielded cathode, the envelope equation takes the form (MKS units):

$$R'' + \frac{U}{R} + \left(\frac{\omega_c}{2\beta c}\right)^2 R - \frac{\epsilon_0^2}{R^3} = 0 \qquad (1)$$

$$U = -\frac{e\mu_0 I}{4\pi\gamma^3\beta^3 mc} \qquad (2)$$

I is the beam current, $\beta = \frac{v}{c}$, $\gamma = (1-\beta^2)^{-1/2}$, m is the electron's rest mass and $\omega_c = \frac{eB(z)}{\gamma m}$ is the cyclotron frequency at the point z where the axial magnetic field is B(z). The axial magnetic field of L1 and L2 was calculated with the Poisson code [5] and measured with a Hall probe. Typical measured field profiles are shown in figure 3.

The initial conditions R_0, R'_0 necessary to integrate equation (1) are related to the beam ellipse parameters by

$$R_0 = \sqrt{\epsilon_0\beta_0}; \qquad R'_0 = -\frac{\alpha_0\epsilon_0}{R_0} \qquad (3)$$

Fitting of the three optical parameters (ϵ_0, α_0, β_0) to the experimental data was done with the MINUIT package [6] by minimization with respect to these parameters of the function:

$$\chi^2 = \sum_1^N \frac{\{R_{exp} - R_{calc}(\epsilon_0, \beta_0, \alpha_0)\}^2}{R_{calc}(\epsilon_0, \beta_0, \alpha_0)} \qquad (4)$$

where N is the number of L_2 settings, R_{exp} is the measured beam radius, R_{cal} = calculated beam radius.

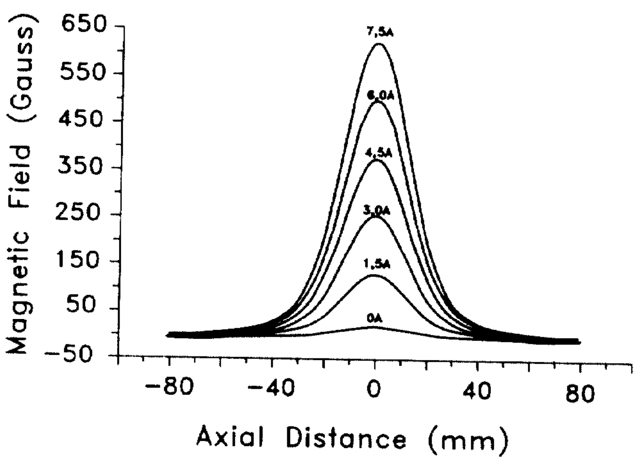

Figure 3: Measured Field profiles for varius currents in the magnetic lens.

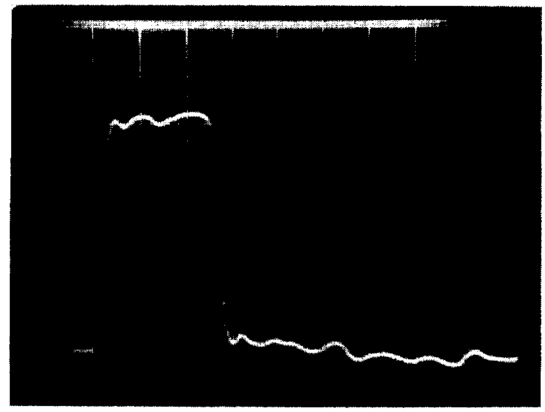

Figure 4: Beam current pulse. Vertical scale = 350 mA/div and horizontal scale = 50 ns/div.

5 Results

Gun output current exceeded our expectations, the maximum being close to 1.7 A. All optical measurements however, were done with up to 100 mA beam current since the emittance term in equation 1 is negligible at currents of the order of 1.0 A. Figure 4 shows a photograph of the beam current pulse.

In figure 5 we show one of the experimental date sets for 50 mA. The solid curve was obtained by numerically solving the envelope equation using the values of emittance, radius and divergence at the exit of the gun that were found by minimizing expression 4. The fitted and theoretical values for R_0, R'_0 and ϵ_0 are presented in table 1.

	R_0 (mm)	R'_0 (mrad)	ϵ_0 ($\pi 10^{-6}$m rad)
I_e= 50 mA			
Experimental	2.0 ± 0.1	-4.0 ± 3.0	15.0 ± 1.0
Theoretical	1.80	-7.5	0.992
I_e=100 mA			
Experimental	2.0 ± 0.4	3.0 ± 6.0	15.0 ± 2.0
Theoretical	1.83	-6.8	0.989

Table 1: Theoretical and experimental results.

The measured radius and divergence agree fairly well with those calculated by the SLACGUN code. The emittance value, however, is about an order of magnitude higher. This can be understood by writing the emittance as the sum of three terms:

$$\epsilon^2 = \epsilon_a^2 + \epsilon_T^2 + \epsilon_g^2 \qquad (5)$$

where ϵ_a is the gun aberration term (i.e., the one calculated by SLACGUN), $\epsilon_T = \pi r_c \sqrt{\frac{kT}{m_0 c^2}} \frac{1}{\beta\gamma}$ is the thermal contribution and ϵ_g is the grid contribution.

Since $\epsilon_T \approx$ 1 mm.mrad, we conclude that the grid aberration is the effect that determines the final emittance of the gun.

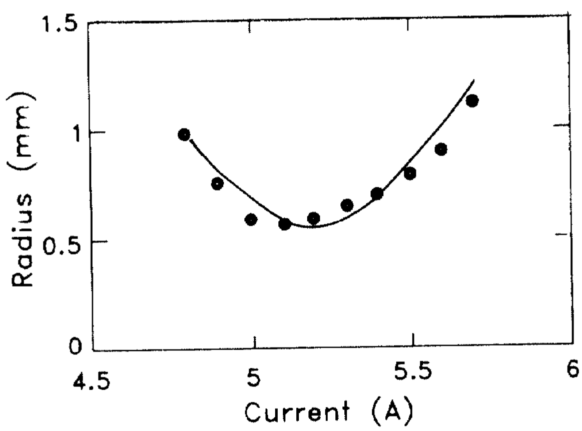

Figure 5: Measured and calculated beam radius against current in lens L2 for a fixed value of current in lens L1.

References

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[4] E.P.Lee e R.K.Cooper, 'General Envelope Equation for Cylindrically Symmetric Charged-Particle Beams', Particle Accelerators Vol. 7, 83 (1976).

[5] User's Guide for the POISSON/SUPERFISH Group of Codes, Los Alamos Accelerator Code Group, LA-UR-87-115. Reference Manual for the POISSON/SUPERFISH Group of Codes, Los Alamos Accelerator Code Group, LA-UR-87-126.

[6] CERN Computer Center, 'Program Library MINUIT', CERN/DD Internal Report 75/20.