THE ELECTRON GUN FOR THE PNC HIGH POWER CW LINAC

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Abstract

An electron gun extracting high average current beam has been designed for the high power CW electron linac at PNC [1]. As the average current of the gun is high, a mesh grid is not able to be used for control grid because of heating up or melting of grid. We employed an electron gun with two aperture grids to control beam current and diameter. The geometry was designed by using computer simulation code EGUN [2]. In addition, a new gun structure has been proposed to be able to have plural beam ports and view ports to investigate beam characteristic and cathode surface condition. This gun geometry was simulated by using 3D electrostatic field solver of computer simulation code MAFIA [3].

Introduction

A peak electron beam current of 400mA with beam energy 200keV is required from the chopper and the buncher system design. However its average current is very high(20mA), a mesh grid is not able to be used for current control because of heating up or melting of grid. Furthermore, the beam current have to be variable up to 400mA to match with downstream modules, especially the accelerator guides equipped with a TWRR(Travelling Wave Resonant Ring). Main specification of the electron gun is shown in Table 1.

Table 1
Main specification of the electron gun

Energy	200keV
Beam Current(Peak)	100μA ~ 400 mA
Max. Average Beam Current	80 mA
Norm. Emittance	<10 π mm mrad
Pulse Length	100μs ~ 4 ms
Pulse Repetition	50 Hz
Duty Factor	20 %

If single aperture grid is used to control the emission from the cathode, beam diameter at the exits of anode is changed greatly by "lens effect" of the single aperture grid and by the difference of the space charge force in the beam. We employed the electron gun with two aperture grids to control beam current and beam diameter. The dimension of the electrodes, electron trajectory, the size of beam radius, and gun emittance were simulated by EGUN.

Generally, after a gun was installed in a beam line of a linac, it is difficult to measure the beam emittance and the profile immediately and to observe the change of the cathode surface condition directly. We have proposed a new gun system to be possible to measure the gun performance including cathode condition with installing in the beam line(see Fig.5). The gun structure is not coaxial as usual. A gun stem to insulate a working voltage of 200kV is mounted in the vertical direction to the axis of a beam line. A cathode head, made up of cathode assembly and control grids, mounted on the nose of the gun stem, is possible to rotate axially along the gun stem without vacuum break. Therefore, the gun chamber is able to have plural beam ports and view ports. If the cathode head rotate, we can select one of plural beam lines launching the electron beam at will, and observe the condition of cathode surface to fix the cathode head toward one of view ports. Preliminarily, possibility of this gun geometry was simulated by using 3D electrostatic field solver of MAFIA.

Basic Design

Grid Effect

In usual, a mesh grid is used to control the emission from a cathode. Typically, its material is tungsten wire with 20μm in diameter, the mesh spacing is about 200μm. A mesh grid is possible to attach at the position of about 200μm close to cathode surface. So it is enough that control voltage applied to the mesh grid is about 100V, furthermore it is expected that the characteristics of rise and decay time is very fast. In our case, the mesh grid cannot be used because of heating up or melting of the grid. One of the methods to control current without using the mesh grid is by an aperture grid. Fig.1 shows a diagram of electron trajectory near the cathode and the grid in the case of using a single aperture grid. The aperture grid acts as a convergent or divergent lens by potential applied to cathode, grid and anode. As long as a single aperture grid is used for the control of the peak current of beam within the very wide range of 100μA to 400mA, beam diameter and emittance keep constant at the anode by "lens effect" of the grid. In the worst case, part of the beam strikes the anode plate.

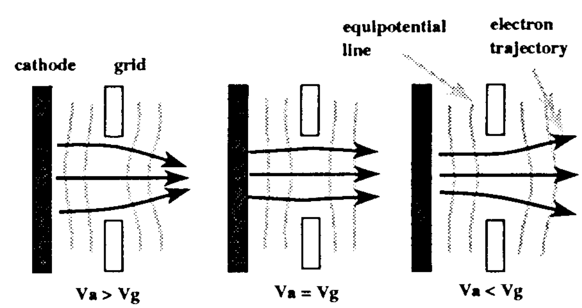

Fig. 1 The diagram of electron trajectory near a single aperture grid. The trajectory differs with electric field(shape of equipotential line) near the grid. Va : voltage between anode and cathode. Vg : voltage between grid and cathode.

Double Aperture Grid

In order to control the beam current and to maintain beam diameter not to strike anode plate, double aperture grid system was employed. The cathode-to-anode voltage must be set to 200kV because of bunching section requirement. The 1st aperture grid has the function to control the beam current. The potential of the 2nd aperture grid is changed to the potential applied to the 1st grid, so that these two grids play a role as an electrostatic convergent lens for the beam not to attack the anode plate. The 1st grid must be attached at the distance about cathode diameter from the cathode surface to cut off the beam. So the voltage between cathode and the 1st grid is much higher than a mesh grid case. The control voltage applied to the grid increases as the distance between cathode and grid becomes longer, and the characteristics of rise and decay time get worse. To avoid getting the control voltage higher, the distance between the cathode and the anode must be kept long apart.

EGUN Calculation

If the radius of the used cathode is 2mm, it is considered that the distance between the cathode and the 1st grid is 4mm. It is estimated that the realistic voltage applied there is a maximum of 5kV. Therefore, supposed to locate the 1st grid at equipotential line, the cathode-to-anode distance has to be set at about 200mm, because the cathode-to-anode voltage is 200kV. The voltage applied to the 2nd grid is decided a maximum of 20kV to act for the beam as convergent lens. One of the realistic geometry obtained in careful consideration is shown in Fig.2. EGUN calculation is executed for this geometry.

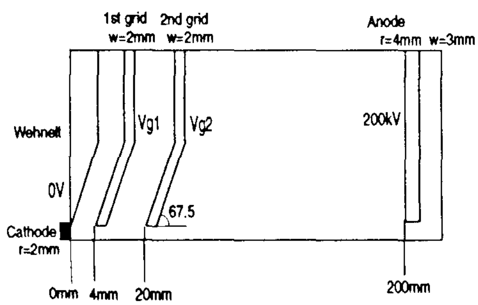

Fig.2 The geometry of the electron gun with double grids.

In the results of EGUN simulation, pairs of two parameters, the potential of the 1st grid and the 2nd grid, to satisfy the condition in which normalized emittance of beam is 10πmm.mrad or less without striking the anode were found. Fig.3 shows current versus 1st grid potential(left), emittance versus beam current(right) of EGUN results. The lowest value of the emittance in their respective beam currents is shown in Table 2. The cathode emission current density is set at 2.2A/cm² in consideration of cathode life time. The gun current only depends on the 1st grid potential. If the proper 2nd grid potential is selected, the beam doesn't strike the anode and beam emittance is low in the range of beam current from about 10μA to 400mA. Fig.4 shows typical beam trajectory and phase space plot at downstream of the anode in the Table 2 data. To transport a beam to the buncher section, proper magnetic lens system with low aberration is needed. It is controlled to match the strength of its magnetic field with beam intensity. It is necessary to analyze beam trajectory from the gun to the magnetic lens system before chopper system.

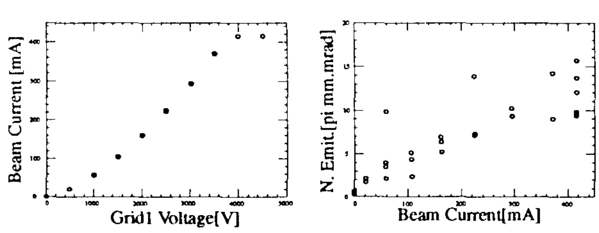

Fig.3 Plots of EGUN results. Left : Beam Current vs. Grid1 Voltage. Right : Normalized Emittance vs. Beam Current.

Table 2
The best emittance data of EGUN results in their respective beam currents

Vg1(V)	Vg2(V)	I(mA)	N.Emit (π mm.mrad)
.0	5000.0	.01677	.26498
500.0	10000.0	21.14845	1.77437
1000.0	15000.0	58.57972	2.23742
1500.0	20000.0	106.05710	2.41703
2000.0	20000.0	162.35013	5.29174
2500.0	20000.0	224.59380	7.32864
3000.0	20000.0	294.71383	9.32757
3500.0	20000.0	370.89229	9.07220
4000.0	20000.0	415.65449	9.40195
4500.0	20000.0	415.62314	9.59617
5000.0	20000.0	415.59114	9.86896

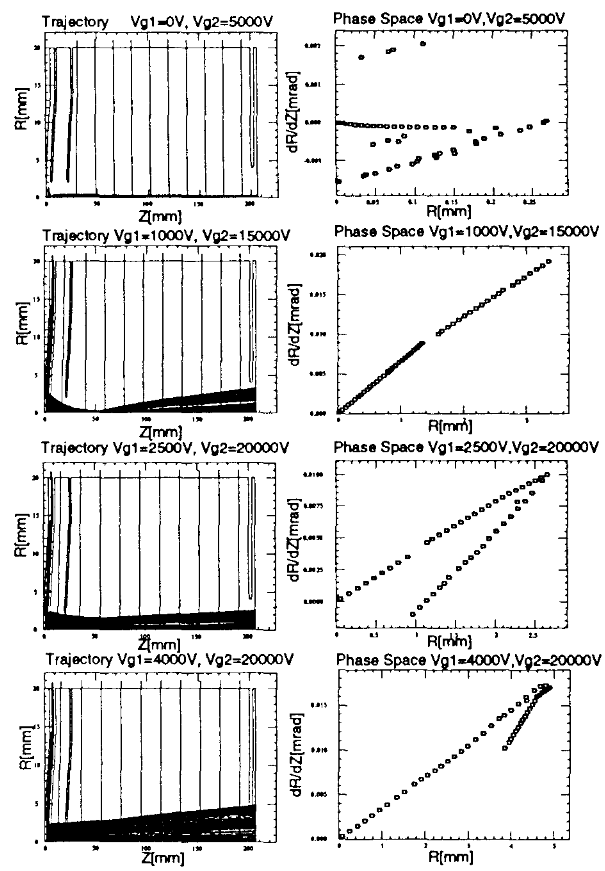

Fig.4 Plots of EGUN results for each conditions. Left : Beam Trajectories. Right : Phase Space Plots.

Manufacturing Design

The design drawing of a new gun system to be able to measure the gun performance with installed to the beam line is shown in Fig.5. A gun stem including the cathode head is possible to rotate axially along the gun stem without vacuum break, so that the gun chamber is able to have plural beam ports and view ports. It has four beam line ports and four dummy ports of ICF253 to use for cathode investigation, maintenance, and so on. In future, one of ports will be to pass through laser light for photo cathode study. The bottom port is for vacuum system, mounted an ion pump with pumping speed in 270 l/s. A supplementary ion pump with pumping speed in 8 l/s is attached for the bearing system in vacuum to rotate the gun stem. The bearing system is thought out to guarantee high-accuracy positioning of the gun stem. The ceramic adapters to feed through a working voltage of 200kV is divided two parts of about 400mm long ceramic. To avoid electric insulation break a pass connected by a very high resistance are made at both ends of the ceramic adapter. This length of the ceramic adapter is considered enough to insulate a voltage of 200kV-DC. This gun geometry was simulated by using 3D electrostatic field solver of MAFIA.

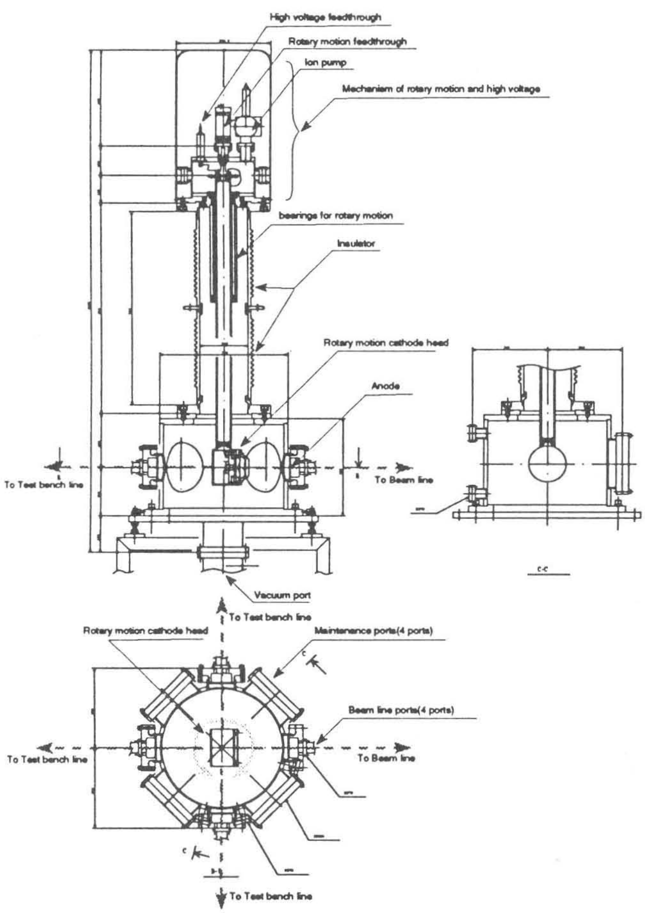

Fig.5 The design scheme of a new gun system to be possible to measure the gun performance including cathode condition with installing in beam line of the linac.

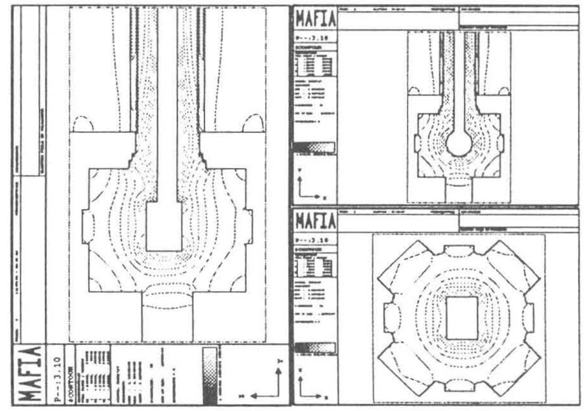

Fig.6 Equipotential contour plot of MAFIA results. Left : a cross section cutting by y-z plate. Upper right : a cross section cutting by x-y plate. Lower right : a cross section cutting by x-z plate.

Fig. 6 shows equipotential contour plots of MAFIA results on a cross section cut by each plates. In these simulations, mesh size is not small enough to get fine information near boundary for a reason of mesh number limit in MAFIA. But qualitatively the shape of electric field near the axis of beam line is obtained preliminarily. A possibility is found that this structure of the gun chamber makes electric field between cathode and anode symmetrical axially near the beam axis.

Summary

An electron gun employed double grid system has been designed for the high power CW electron linac at PNC. It was found from the results of EGUN calculation that if proper potential is applied to the 1st and the 2nd grid, this gun geometry is possible to launch peak current of beam from about 10 μA to 400mA with normalized emittance of 10πmm.mrad or less. Furthermore, a new gun structure was proposed to be able to have plural beam lines and view ports to investigate beam characteristic and cathode surface condition without vacuum break.

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