DEVELOPMENT OF THE ELECTRON GUN FOR THE JNC HIGH POWER LINAC

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Abstract

An electron gun for a high-power electron linac in the Japan nuclear cycle development institute (JNC) has been developed and tested. In this electron gun, two types of grid control systems (mesh grid type and double aperture grid type) were tested for their ability to deliver high average current beams. In this paper, we discuss the problems associated with each type of gun system.

1 INTRODUCTION

JNC has developed a high power electron linac producing energy of 10MeV and a maximum beam current of 20mA, on average, for various applications including the transmutation of fission products. This linac is driven by a long macro pulse width (max.4ms), and its duty factor is attained at 20%. In December 1999, an average beam current of 5mA was accelerated up to 7MeV with a pulse width of 1.5ms and repetition rate of 35pps [1]. However we have not yet attained the linac's maximum performance due to various problems that remain to be addressed. The primary obstacles are the aggravation of the vacuum and the creation of heat due to beam leakage. In order to solve these problems and raise beam quality, reconstruction of the linac is currently underway. The electron gun could perform a beam test only up the power level generated only by the linac's partial potential.

We investigated two types of grid to control the electron beam from the cathode [2]. One is a conventional mesh grid that can control the beam by low voltage and has good characteristics for time pulse shape. We actually succeeded in generating an electron beam of milliampere average current in the mesh grid electron gun. In the mesh grid case, a part of the beam cut off by the mesh grid causes heating of the mesh, while grid emission is also significant problem for the high duty linac. Another problem lies in an aperture grid that doesn't cut the beam off from the cathode surface. In the case of the aperture grid, we employed an electron gun with two aperture grids to control beam current and diameter. We call it the double aperture grid system. In this experiment, although rated voltage could not be applied because of local electric discharge on the cathode head, it succeeded in fundamental beam generation.

2 GUN AND HV POWER SUPPLY

Table 1 shows the main design parameters of the electron gun which had been adopted for this linac. The macro pulse width is a maximum of 4ms. We adopted a DC power supply (Cockcroft-Walton high voltage generator) to supply high voltage to the electron gun. The gun schematics are shown in Figure 1.

As the gun chamber is not geometrically symmetrical in regard to the beam line, we found that some cover electrodes should be set in such a way so as not to be affected by the asymmetry of the electric field between the cathode and the anode. Therefore, the gun-heads have the electrode with the wehnelt like a flange. The gun stem including the cathode head can rotate axially along the gun stem without allowing a vacuum break, so that the gun chamber is able to have plural beam ports and view ports. This DC power supply has a capacitance large enough to restrain voltage drop caused by beam loading. The capacitance of the power supply stored the energy of 24kJ at 200kV[3].

Table 1: Design parameters of the electron gun

Max. Beam Energy	200 keV
Beam Current (Peak)	400 mA
Max. Average Beam Current	80 mA
Pulse Width	0.01 ~ 4 ms
Repetition Rate	50 pps
Duty Factor	20 %

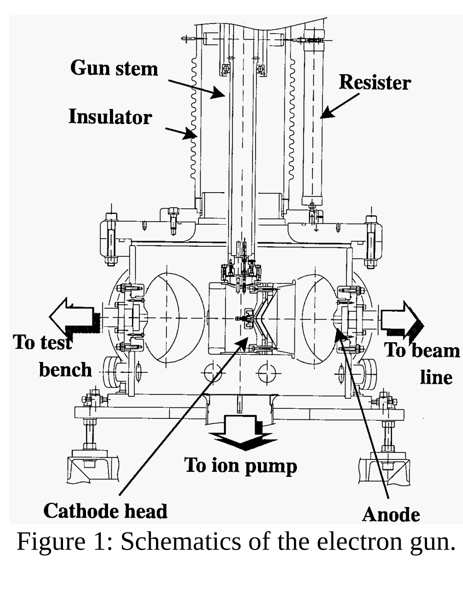

Figure 1: Schematics of the electron gun.

3 MESH GRID GUN

We can use both types of grid in the one gun chamber. One of them is the mesh grid gun in which the EIMAC Y646E is used as a cathode assembly. The grid pulse power supply is selected for the system involving a FET (Field Effect Transistor) as a power switching device. The maximum pulse and bias voltage is 400V, 200V, respectively. Figure 2 shows the electrical layout of the pulsed power supply for the mesh grid. At the beginning, although the voltage applied to the electron gun was DC200kV, we operated at 180kV due to the instability caused by electric discharges. A current value demanded in the linac is 300mA. In order to optimise the voltage applied to the mesh grid and the heater current for the cathode, the beam current from the electron gun was measured for various conditions. The results are shown in Figure 3.

When the heater current exceeded 1.6A, grid emission increased extremely and could be observed clearly by the profile monitor. Therefore, the heater current of less than 1.55A was chosen. We observed x-rays caused by the beam leakage in order to find the most stable condition. The most effective grid voltage to get the peak 300mA with low leak current was 150V(bias : 100V). According to this condition, the mesh grid electron gun succeeded in generating an average current of 5mA(macro pulse width 1.5ms, repetition rate 35pps). However, when it raises current further, damage and grid emission of the mesh grid will become significant problems.

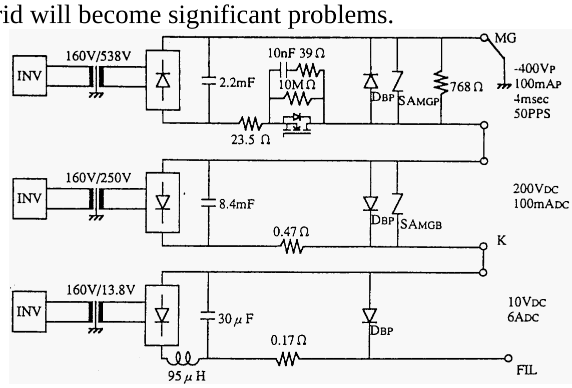

Figure 2: Electrical layout of the pulsed power supply for the mesh type grid.

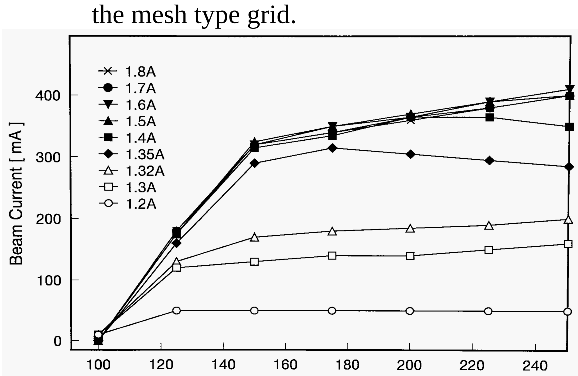

Figure 3: The beam current as a function of the grid pulse voltage with HV180kV for each cathode heater current.

4 DOUBLE APERTURE GRID GUN

To solve the problem involving the mesh grids, we have been developing an electron gun which employs a double aperture grid (Fig. 4). The merit of this configuration is that it does not interrupt the beam from cathode, so that damage to the grid can be avoided. An advantage lies in the ability to control the large current beam. However, the grid pulse voltage has to become higher, thus the beam from cathode must be shielded from the 200kV DC voltage between the cathode and the anode. If the grid voltage is changed, the lens effect of aperture may arise, and causes great changes in the diameter of a beam. In order to solve this problem, the use of a double aperture grid can more effectively protect the shield while the size of a beam can also be operated with current control. We simulated the system's geometries and the beam trajectories by using EGUN[4]. The results showed that the necessary conditions are G1 at 5kV, and G2 at 20kV at the maximum. The system of the power supplies also uses circuits employing plural FETs (Q_{G1P}, Q_{G2P1}-Q_{G2P4} are 12 series of FET circuit), as shown in Figure 5.

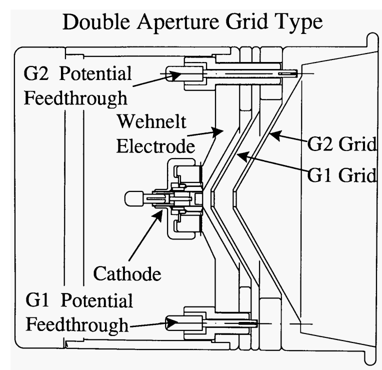

Figure 4: Schematic of the double aperture grid gun.

We measured the pulse shapes of the anode beam current on the oscilloscope by using a CT monitor, as shown in Figure 6. In the experiments, the voltage of the DC power supply was set to 145kV in order to avoid discharges on the insulators isolating the two grids and the cathode. In this condition, the maximum beam current is about 160mA, which is in agreement with the results of analysis using EGUN. Although the beam currents of conditions (a) and (b) (Fig. 6) are about 160mA, the falling of pulse shapes is different. This is the reason why a part of the beam hits the aperture grid according to the conditions of two grids' potentials, and why the time constant of the gun head circuit changes. When the beam hits the grid, the falling of the pulse is faster. We simulated the beam trajectories near the two aperture grids by using EGUN under conditions as shown in Figure 7 (a) and (b). We found that the structure of the double aperture grid head must be improved so as to avoid the discharges and so as not to make the beam hit to the grids.

5 SUMMARY

We developed a high-power electron gun with two types of grid control system. In the mesh grid system, it attained a 3ms pulse width with 300mA, HV180kV, and 35pps. However, the potential of damage to and emission from the mesh grid are a source of concern. On the other hand, the double aperture grid system was also launch using a high average current. The fundamental operation of the system was proved possible. However we found that the structure's improvement was necessary in order to avoid discharges and for the beam not to hit the grids.

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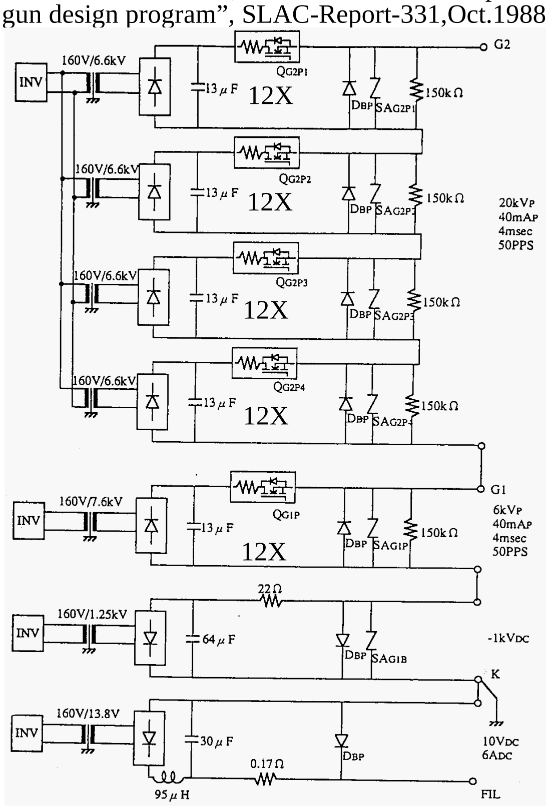

Figure 5: Electrical layout of the pulsed power supply for the double aperture grid gun.

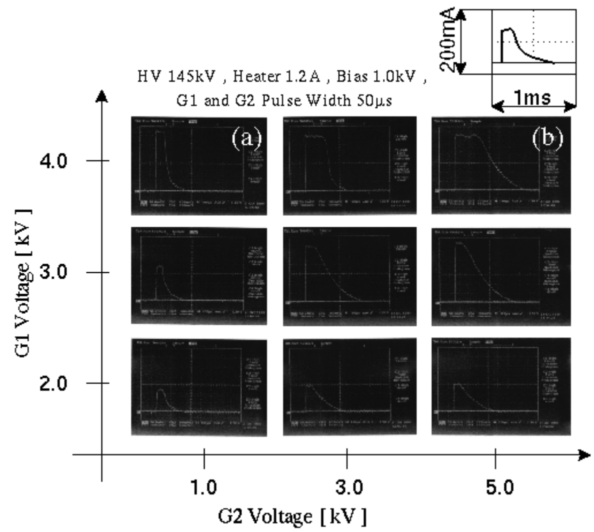

Figure 6: The beam current shapes as imaged on the oscilloscope for the double aperture grid gun.

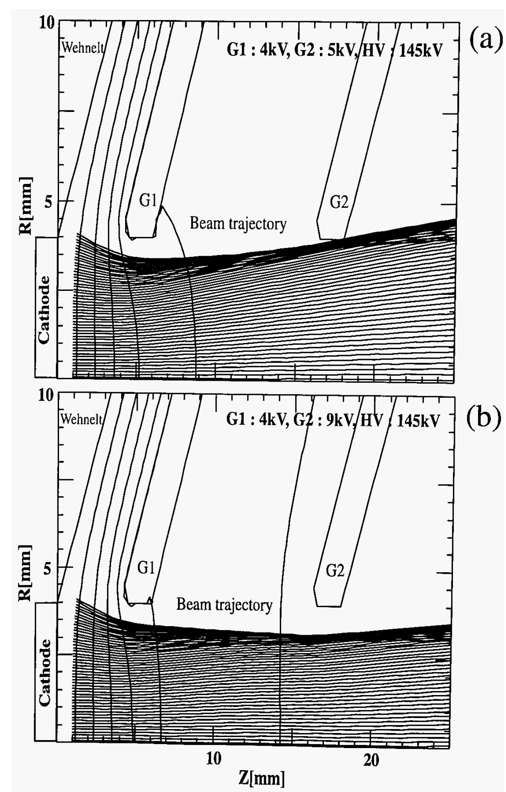

Figure 7: The beam trajectories near the two aperture grids (G1,G2) as analyzed by EGUN.