PERFORMANCE OF THE ELECTRON GUN FOR THE JNC HIGH POWER LINAC

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Abstract

An electron gun extracting high average current beam has been developed for the high power electron linac at the Japan nuclear cycle development institute (JNC). In this paper, we reported the design study and preliminary results of the basic characteristics of the electron gun.

Introduction

The average power of the electron linac being developed is 200kW at the maximum(average current : 20mA, beam energy : 10MeV). This linac is driven with long macro pulse width(max. 4ms), and its duty factor is attained at 20%. The injector section has RF chopper system where beam can pass through one-third of total RF phase in order to decrease dropout of beam in bunching process. Therefore the average current from the electron gun is required three times higher than after the chopper system. Table.1 shows the main design specification of the electron gun to adopt for this linac. The macro pulse width is 4ms at the maximum. We adopted DC power supply to apply high voltage for the electron gun. The gun is shown in Fig.1. The 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. We investigated two type grids to control the electron beam from the cathode. One is a conventional mesh grid that can control the beam by low voltage and has a good characteristics for time pulse shape. But in a mesh grid case, a part of the beam cut off by the mesh grid cause heating-up the mesh, and grid emission is also significant problem for the high duty linac. Another is an aperture grid that don't cut off the beam 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. Fig.2 shows both type cathode-head's structures that can be selected in the same gun chamber.

Table 1
Main specification of the electron gun

Max. Beam Energy	200 keV
Beam Current (Peak)	~ 400 mA
Max. Average Beam Current	80 mA
Pulse Length	10 μs ~ 4 ms
Pulse Repetition	50 pps
Duty Factor	20 %

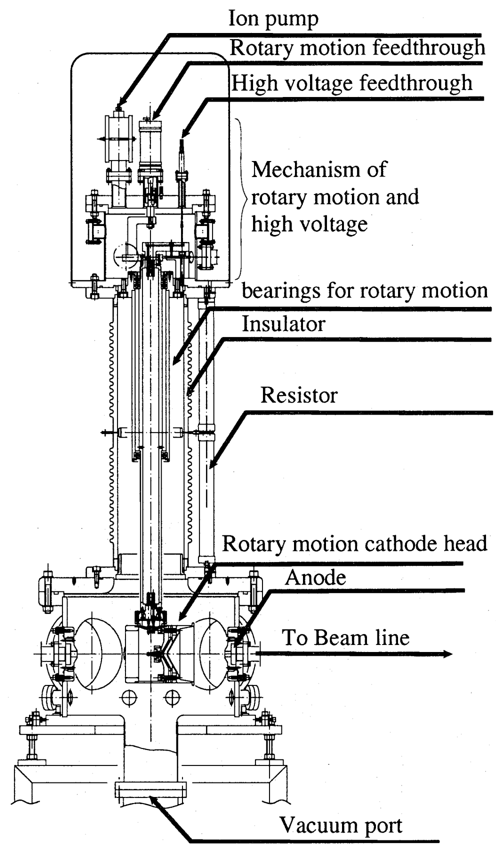

Fig.1 Schematics for the electron gun

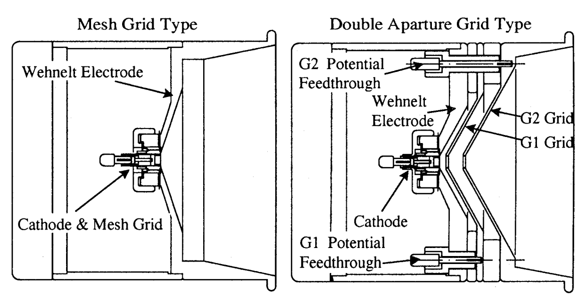

Fig.2 Two types of electron gun cathode heads

Gun High Voltage Aging

This gun is not axial symmetric geometry to the beam line and has big area electrodes provided high voltage, so it needs aging for a long time to apply stable DC 200kV between the cathode head and anodes. This DC power supply has large capacitance enough to restrain voltage drop by beam loading. If some discharge occurred during high voltage aging, metal surface of the gun chamber might suffer some big damage because the capacitance of the power supply stored the energy of 24kJ at 200kV. Fig.3 shows a discharge spot's pattern on the gun stem applied minus high voltage. We measured radiation dosage from the gun chamber to avoid big discharge, but some unavoidable big discharges was occurred intermittently. On the other hand, during the gun aging small continuous discharges were detected by the radiation monitor which is located at a view port of the chamber. We sighted that the continuous radiation increased with deterioration age. To reduce this continuous radiation we treated the main parts applied high voltage with the electrolysis polishing. The treatment decreased the frequency of discharge and dosage of continuous radiation. For example, Fig.4 shows a typical case of the increase the voltage where the first discharge occurs in a day. Now the gun is used with DC 180kV. It needs a few days to attain it. It means that it is increased about 10kV per a day in the voltage more than 160kV. The running time is about 8 hours in a day.

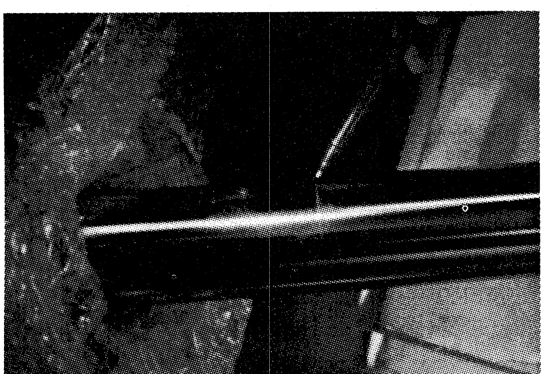

Fig.3 A typical discharge damage pattern on the gun stem.

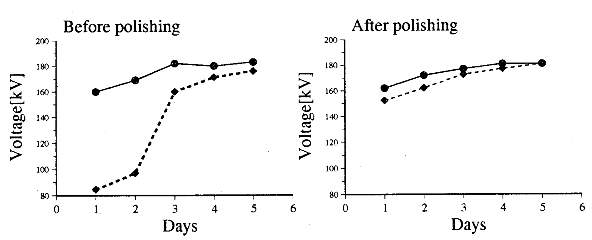

Fig.4 The improvement of the first discharge voltage in a day by the electrolysis polishing. Dashed lines mean the voltage when the first discharge occurred. Solid lines mean the maximum voltage applied without discharge.

Mesh Grid Type Gun

We can use the both type grids in the one gun chamber. One of them is the mesh grid gun in which the EIMAC Y646E as a cathode assembly is used. The grid pulse power supply is selected the system involving an FET(field effect transistor: Toshiba 2SK1120) as a power switching device in which the grid potential is set to DC HV level. The maximum pulse and bias voltage is 400V, 200V, respectively. As the gun chamber is not symmetric geometry to the beam line, we found that some cover electrode should be set not to effect by asymmetry of the electric field between the cathode and the anode caused by the gun chamber structure. Therefore gun-heads has the electrode with the wehnelt like a flange. In detail design study, the geometry of electrodes was simulated by EGUN and MAFIA. Fig. 5 shows one of EGUN results. It demonstrates the trajectory of electron beam at 160kV when current is 300mA. The effect of the guard electrodes on beam trajectory is to generate aberration between the cathode and the anode. It means that the focal length of each beamlets are not same, so the beam downstream the anode is not laminar flow as shown in Fig.6. Especially, outside beamlet of the beam may drop out in the downstream transport process. But we noted that the drop-out of some beamlets by the effect is not so much if the edge of the wehnelt is far away from the center of beam line.

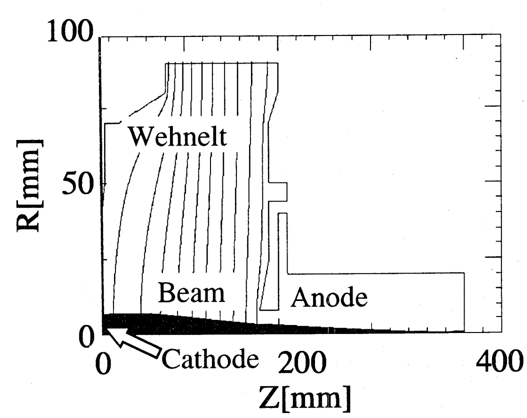

Fig.5 The example of beam trajectory simulated by EGUN. HV:160kV, Current:300mA.

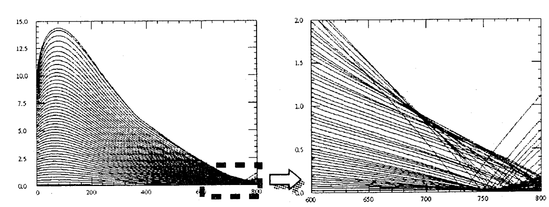

Fig.6 The effect of the wehnelt to the beam trajectory. The beam is not laminar flow.

In the experiments, the characteristics for the extracted currents from the anode of the mesh grid type gun were measured as shown in Fig.7. It shows the beam current measured by the CT monitor downstream the anode as a function of the grid pulse voltage with the bias 100V for each cathode heater current. In this figure, it is found beam current of some curves is declined in spite of increasing the grid pulse voltage. In this case, it was observed to go up the radiation dosage gradually from the gun chamber measured by the SSD radiation monitor. This means that parts of the beam were lost in the gun qualitatively. It is difficult to explain the phenomena by a quantitative analysis. But we guess that the potential applied on the each mesh of the net acts as divergent lens for the beamlet, therefore parts of the beam are dropped out on the anode and generates x-rays by the bremsstrahlung. If the potential of the grid is set the situation to adjust the equipotential line of the diode potential without the grid, the beam might keep the laminar flow. In the best condition for the grid potential, we attained the maximum power output beam(HV180kV, current 290mA, pulse width 2ms, repetition 7pps) within the limit of downstream section as shown in Fig.8.

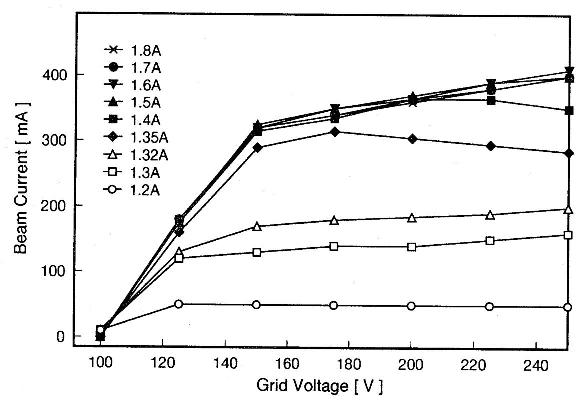

Fig.7 The beam current as a function of the grid pulse voltage with the bias 100V for each cathode heater current.

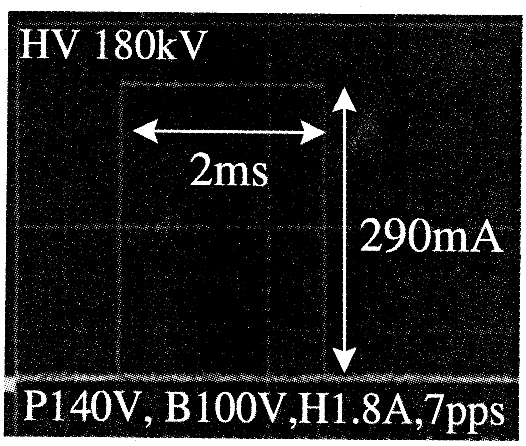

Fig.8 The picture of beam pulse shape measured by the CT current monitor.

Double Aperture Grid Type Gun

We developed the double aperture grid gun as another type because of launching high power current without disturbing the beam. The merit toselect two grids is to control the beam size and current, in additional to cut off the beam certainly when the pulse voltage on the grid is not applied. On the other hand, the pulse power supply used for this aperture grid is demanded a high driving voltage to extract and cut off the beam in comparison with the mesh grid. In the design study by simulations, we adopted a structure as shown in Fig.2 and simulated the beam trajectory about it by EGUN(Fig. 9). As the result, it is needed that G1 is 5kV, G2 is 20kV at the maximum. The system of the power supplies is also used circuits of plural FETs. In the experiments, we tried to operate the aperture grid gun, but discharges on the gun-head prevented to apply the high voltage. So we've not completed to develop the gun yet. We will improve and try again about it.

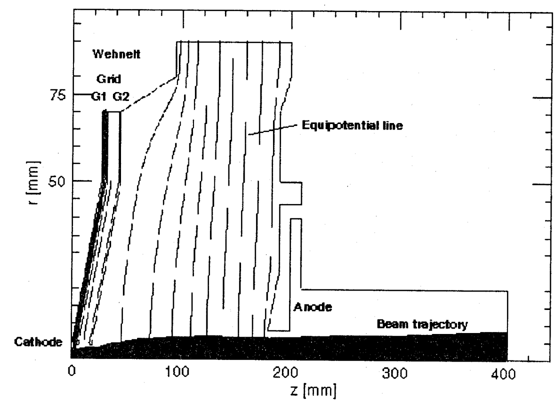

Fig.9 The result of EGUN simulation for the double aperture grid gun with 5kV on G1, 20kV on G2, HV 200kV. The beam current is about 400mA.

Summary

We developed the high-power electron gun with the plural beam ports and view ports. It is possible to act two type grid control system. In the mesh grid system, it attained 2ms in the pulse length with 290mA, HV180kV,7pps.

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References

[1] T. Emoto et al, LINAC'94.
[2] Y.Yamazaki, M.Nomura, LINAC'94.