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ELECTRON GUN FOR 100 MeV / 100 kW LINEAR ACCELERATOR OF ELECTRONS AS THE DRIVER OF NUCLEAR SUBCRITICAL ASSEMBLY NEUTRONS SOURSE

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Abstract

100 MeV / 100 kW linear electron accelerator of The NSC KIPT "Neutron Source" nuclear subcritical assembly uses the 120 kV triode electron gun as the primary source of electrons. The gun was designed, manufactured and tested at IHEP, Beijing, China. At present, the gun was installed and are under testing. The maximum pulse current of the gun is equal to 2 A. In design operation, the pulse current of the gun should be equal to 0.55 A. The report describes the design of the 120 kV triode electron gun, the results of testing and test operation.

INTRODUCTION

100 MeV/100 kW electron linear accelerator that is a driver of the ADS NSC KIPT Neutron Source was design and manufactured in IHEP, Beijing, China and assembled in NSC KIPT, Kharkov, Ukraine during 2010-2014 [1] .

In 2015 and 2016 the accelerator technological systems commissioning and beam commissioning were started in Spring 2017 the design value of pulse electron beam current was obtained in the end of the accelerator horizontal part. During the last year the main task of the accelerator commissioning was to optimize the technological system parameters and improve the accelerator performance in accordance with basic design parameters listed in Tab. 1 [2].

Table 1: Main KIPT Linac Parameters

Parameter	Value
RF frequency	2856 MHz
Beam energy	100 MeV
Pulse beam current	0-0.6 A
Average beam power	0.005 – 100 kW
Energy spread (1)	2 %
Emittance (1)	$5x10^{-7}$ m-rad
Beam pulse length	2.7 µs
RF pulse duration	3 µs
Pulse repetition rate	2 - 625 Hz
Gun voltage	~120 kV

The electron gun is a triode-type gun, which consists of an anode, cathode, and grid. The electron gun system consists of an electron gun body, a high voltage power supply, a high voltage deck, a pulser and a control unit. The gun should be able to operate in long beam pulse mode to generate the electron beam. The electron gun includes the following systems:

- electron gun cathode manufactured by EIMAC Y824;
- high-voltage power supply unit of the electron gun manufactured by GLASSMAN LT150N10;
- high-voltage station of GloryMV Electronics Limited, China;
- control system of the electron gun;
- Switching power supply of the electrode gun control grid developed at IHEP Institute of High Energy Physics, Beijing, China;
- electron gun protection and interlock system;
- vacuum system of the electron gun.

The main parameters of the electron gun are shown in Tab. 2.

Table 2: Main Electron Gun Parameters

Items	Value
Type	Triode
Beam Current （max） A	2
Anode Voltage kV	~120
Filament Voltage V	6.4
Filament Current A	5.5
Grid Bias V	50~ 500
Bunch length µs	3.0
Repetition Rate (max) Hz	625

GUN BODY

A planar triode electron gun, the EIMAC Y824 shown in Fig 1 with 150 kV (maximum) GLASSMAN high-voltage deck, is used with a fast pulser cathode driver. The acceleration voltage is 120 kV, the maximum extraction current is 2 A (normal operation is about 0.6 A) with minimum pulse width of less than 3.0 µs. The gun pulser system contains a driving circuit. A 3.0 µs FWHM pulser is used to drive the cathode for long pulse operation. The gun structure and the gun beam pulse form are shown in Fig. 2, 3.

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Figure 1: The EIMAC Y824 Cathode grid assembly.

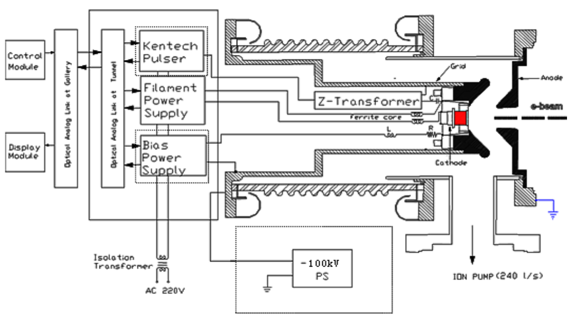

Figure 2: The gun structure.

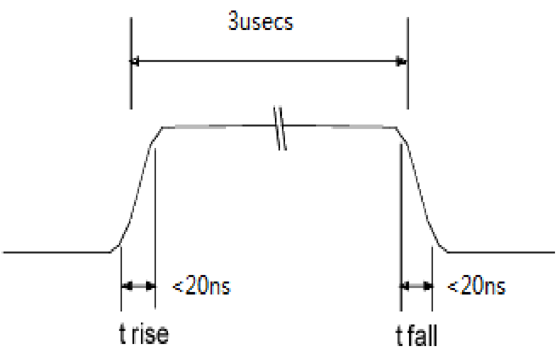

Figure 3: The gun beam pulse form.

BEAM TRANSPORT AND ELEMENTS

Two magnetic lenses and two sets of steering coils are adopted in the design to focus and adjust the beam between the gun and the bunching system. A few beam instrumentation elements, such as beam position monitors and beam profile monitor, are placed between the gun and the prebuncher. With such instruments, one can tune the beam flexibly and reliably. By some compromise between simulation and real mechanical layout, the element distribution is shown in Figure 4.

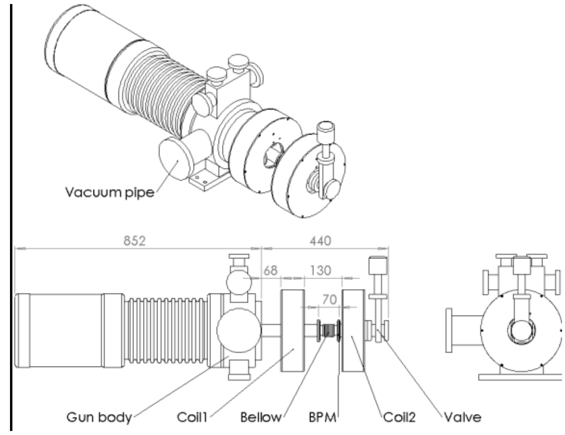

Figure 4: The process of survey target coordinate determinations.

THE ELECTRON GUN TESTING

When testing the gun at IHEP (Beijing, China), an electron beam current of 3.5 A was obtained at a voltage of -120 kV at the cathode of the gun and a pulse repetition rate of 1÷10 Hz. The pulse duration was 3.5 μs

Typical dependences of the gun current on the value of the voltage on the cathode (current-voltage characteristics) obtained during testing are shown in Fig. 5. The data were obtained with a fixed bias voltage on a grid of -100 V and an amplitude of a control pulse of 200 V.

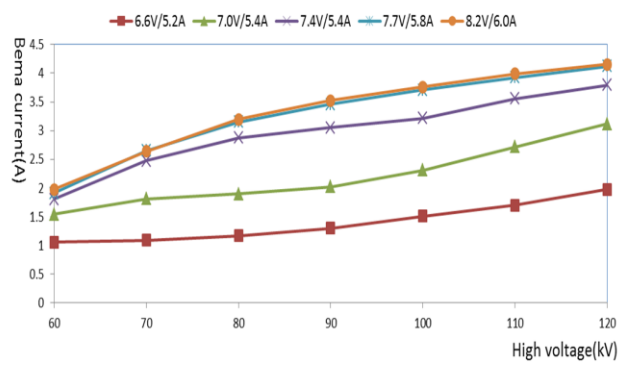

Figure 5: Current of the electron beam of the gun as a function of the voltage at the cathode for several values of the cathode heating current.

Figure 6 shows the dependence of the gun beam current on the bias voltage on the grid at a voltage and cathode filament current of about 7.4 V and 5.8 A respectively, the voltage at the cathode is -120 kV, the amplitude of the control pulse is 200 V.

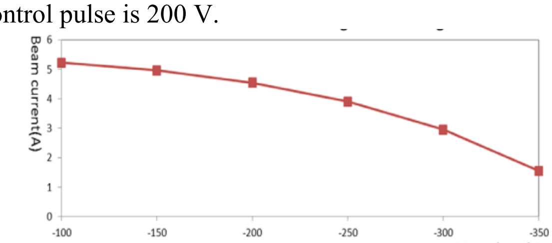

Figure 6: The current of the gun beam as a function of the bias voltage on the grid.

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ELECTRON GUN PERFORMANCE

During beam commissioning the gun showed the stable performance in pulse current range of 0.5 – 1 A (green line in Fig. 7) .

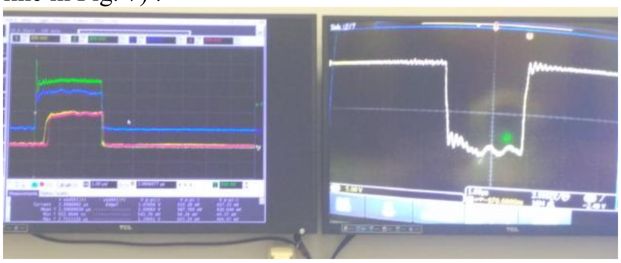

Figure 7: The electron beam current along accelerator (left photo, green line is FCT 1 pulse, blue line FCT 2, yellow is FCT 4, purple is FCT 5) and at the Faraday cup at the Neutron generating target (right photo).

In the same time, for observing of the beam IHEP and KIPT staff used a profile monitor detectors (PR) (see Fig. 8)

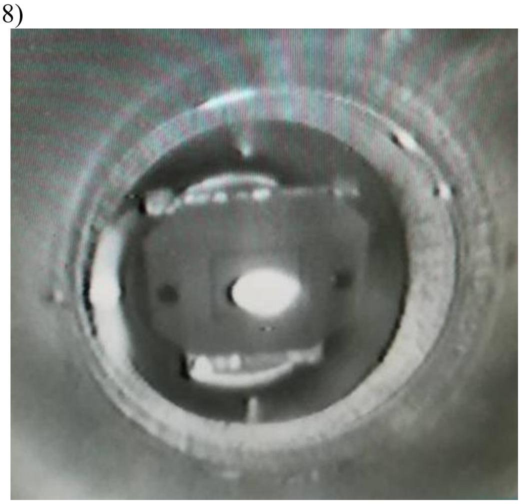

Figure 8: Signal from the PR monitor.

During the NSC KIPT Neutron Source commissioning, facility tests, neutron flux measurement system calibration and official State accepting tests and to avoid unnecessary equipment irradiation it is necessary to operate electron gun at low pulse beam current (10-100 μA). To test the performance of the gun in low current mode the gun current-voltage characteristic was measured. Figure 9 shows the anode electron gun current measured with FCT1 beam current monitor in dependence on gun grid pulser voltage. 50 V bias voltage was installed during the measurements. The pulser grid voltage can be controlled in the range of 0-200 V. As one can see from the figure the minimal electron gun at 0 V grid pulser voltage is about 225 mA. To have possibility to decrease beam current to zero it is necessary to have possibility to put negative voltage to the grid pulser [3]. According to the foregoing parameters, the pulser was modified and tested. The test results are shown on Figure 10.

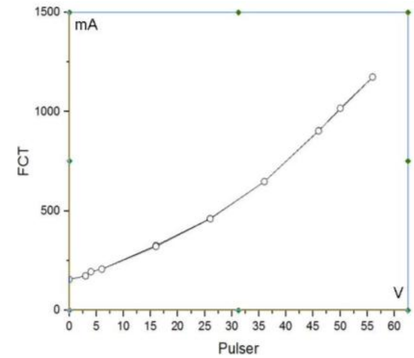

Figure 9: Triode electron gun current vs grid pulser voltage. Bias voltage is 50 V.

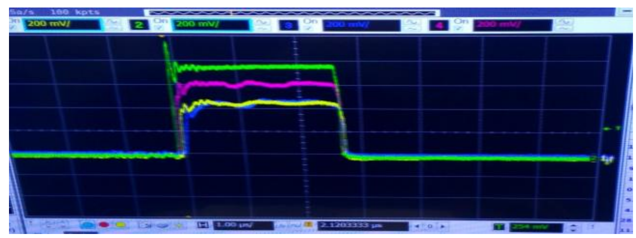

Figure 10: Result of testing of the gun after the replacement of the pulser.

CONCLUSION

Now the gun has passed all the tests shows a stable performance and provides design parameters necessary for regular and stable operation 100 MeV / 100 kW Linear Accelerator of Electrons as the Driver of Nuclear Subcritical Assembly Neutrons Source

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