DESIGN STUDIES ON NSC KIPT ELECTRON GUN SYSTEM

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Abstract

In NSC KIPT, a neutron source based on a subcritical assembly driven by a 100MeV/100kW electron linear accelerator is under design and development. The linear accelerator needs a new high current electron gun. In this paper, physical design, mechanical fabrication and beam test of this new electron gun are described. The emission current is designed to be higher than 2A for the pulse width of 3us with repetition rate of 50 Hz. The gun will operate with a DC high voltage power supply which can provide up to 150 kV high voltages. Computer simulations and optimizations have been carried out in the design stage, including the gun geometry and beam transport line. The test results of high voltage conditioning and beam test are presented. The operation status of the electron gun system is also included. The basic test results show that the design, manufacture and operation of the new electron system are basically successful.

INTRODUCTION

In NSC KIPT, a neutron source based on a subcritical assembly driven by a 100MeV/100kW electron linear accelerator is under design and development [1]. The linear accelerator needs a new high current electron gun. The electron gun is a conventional thermionic triode electron gun equipped with Y824 (EIMAC) cathode grid assembly [2]. It 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 etc. The gun should be able to operate in long pulse mode to generate the low emittance beam. The main parameters of the electron gun are shown in Table1.

Table1: Electron gun Parameters

Items	Units	Specifications
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

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GUN DESIGN CONSIDERATION

Gun body

A planar triode electron gun, the EIMAC Y824 with 150 kV GLASSMAN high-voltage deck, is used with a fast pulser cathode driver. The acceleration voltage is 120 kV, the maximum extraction current is 2A (normal operation is about 0.85A) with minimum pulse width of less than 3.0μs. The gun pulser system contains a driving circuit. A 3.0μs 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.1.

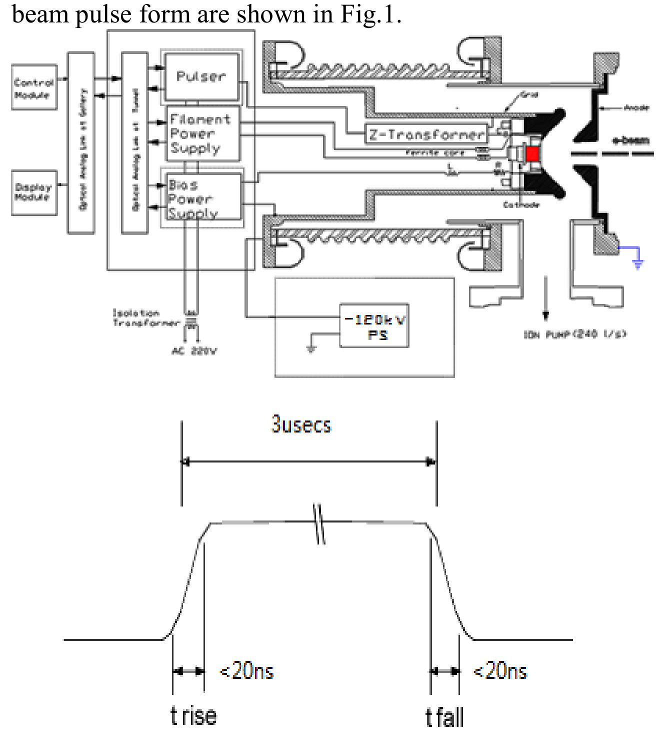

Figure 1: The gun structure (top) and the gun beam pulse form (bottom).

Beam optic simulation

In order to achieve the design goal, it is necessary to use an electron gun with good performance and high emission current. EGUN program is used to optimize the shapes and dimensions of the focusing electrode and anode [3].

The beam simulation result is shown in Fig.2. The simulation results show that if beam current is about 2A at high voltage 120 kV for example, then the beam emittance is about 5.7π·mm·mrad, which can easily satisfy the requirements of Accelerator with normal operation current of 0.85A.

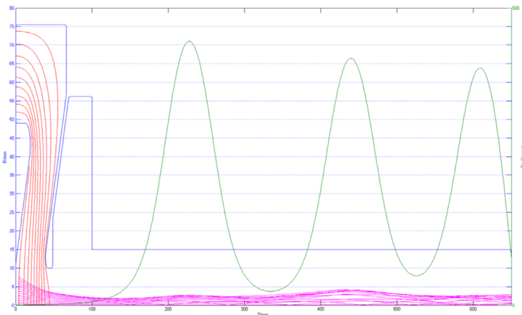

Figure 2: Beam optics with 2.0A/120kV in the gun.

Beam transport and elements

Two magnetic lenses and two sets of steering coils are adopted in our 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 bunching system. With such instruments, we can tune the beam flexibly and reliably. After compromising with some installation problems, the element distribution is shown in Fig.3.

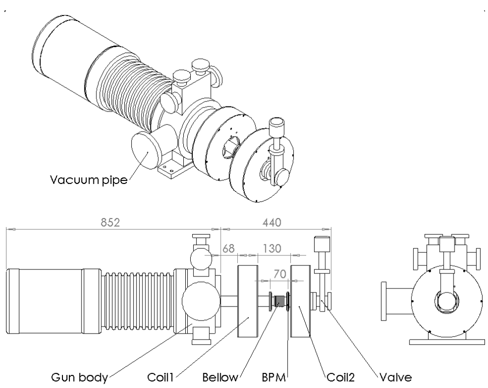

Figure 3: Element distributions between gun and bunching system.

GUN CONDITIONING AND TEST

After the arrival of the electron gun body from the machine shop, the new electron gun is tested on the test bench. These include building the experimental platform, to install the electron gun, to make the internal vacuum of the gun, the cathode grid assembly activation experiment, and finally the electron gun high voltage conditioning and beam test.

Installation

After installing the electron gun body, the cathode grid assembly is installed, vacuum leak detector shows the background no leakage and the vacuum inside the gun to meet the test requirements. Fig.4 shows the gun body on the test stand and cathode grid assembly installation.

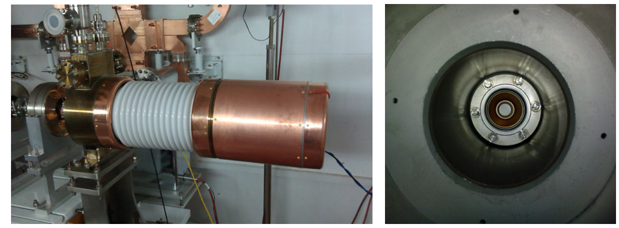

Figure 4: Gun test stand (left) and cathode grid assembly installation (right).

High voltage conditioning

Before electron gun beam test, the gun body needs to be high voltage conditioned between cathode and anode through the multiple low energy discharge between the electrodes. Conditioning process removes contaminants on the insulating ceramic and the electrode surface, eliminate burrs and micro-protrusion of the surface of the electrode, and improve the breakdown voltage of the electrodes. Fig.5 shows the sketch map of the high voltage conditioning for electron gun. Resistance effect is limited discharge energy gun arcing of in order to protect the gun and its power supply. The maximum voltage is about 135 kV on electron gun given by H.V power supply.

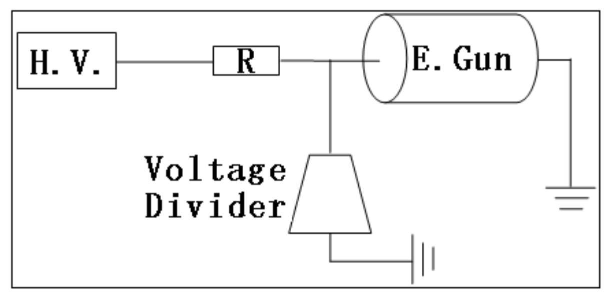

Figure 5: High voltage conditioning sketch map.

Cathode activation

Activation is achieved by converting the Barium Oxide in the tungsten matrix into free Barium on the surface of the cathode. The rate of activation is a function of tube cleanliness, cathode poisoning, time and temperature. In our system, the maximum power for filament is about 8.1V/6.3A (keeping 5 min.); the operating power is about 6.4V/5.5A. The activation time is up to the vacuum system and keeping the pressure at $1\text{x}10^{-6}$ Torr or better.

Beam test

One Faraday cup is mounted after the anode of the electron gun, and an oscilloscope is connected to it. With a 40dB attenuation, the Faraday cup signal is directly given by the oscilloscope. Faraday cup has an impedance of 50 Ohm, the oscilloscope's input impedance is also 50 Ohm, and we have the following approximate relationship: beam current equals the oscilloscope voltage readings plus 100/50, i.e beam current equals the oscilloscope voltage readings plus 2.

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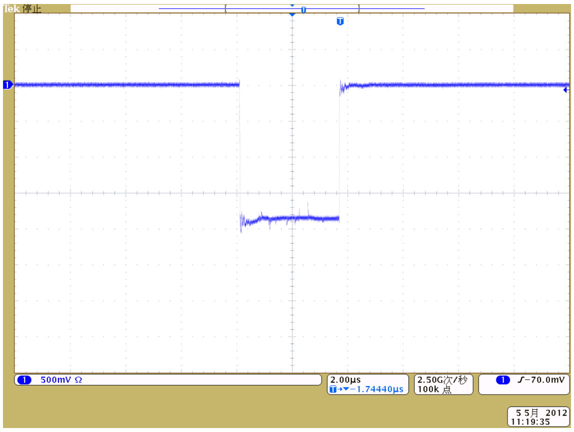

Figure 6: Gun current signal from oscilloscope.

3.5 A electron beam was successfully obtained when we applied 120kV high voltage at repetition rate 1~10Hz, the flat top width of the pulsed power supply output is about 3.5us as shown in Fig.6.

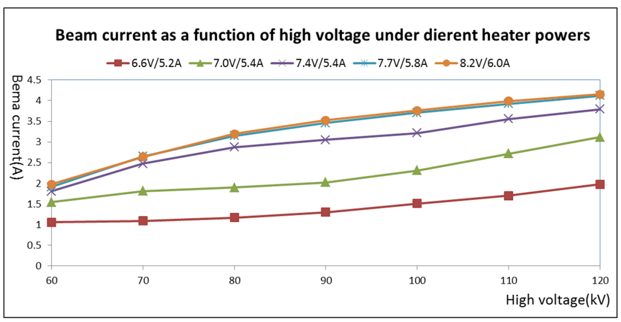

Figure 7: Beam current vs. high voltage.

Typical gun characteristics are shown in Fig. 7, which shows the gun current as a function of gun high voltage under different heater power; and in Fig.8, which shows the gun current as a function of grid bias voltage. In Fig. 7, grid bias voltage is set fixed value, -100V; and the pulser output is also fixed, about 200V. In Fig. 8, filament power is fixed o about 5.8A, and the anode high voltage relative to anode is 120kV.

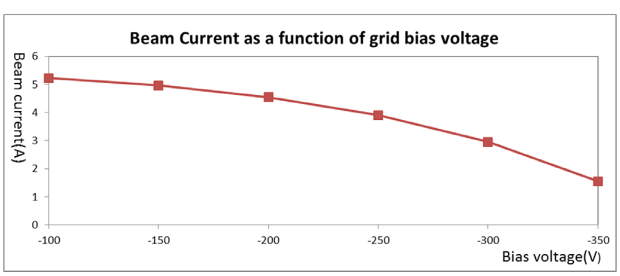

Figure 8: Beam current vs. grid bias voltage.

SUMMARY

The new electron gun system for NSC KIPT Linac is now operated under 120kV high voltage with repetition rate of 1~50Hz. The maximum beam current is about 3.5A at the gun exit. The beam pulse length is about 3.5us, which is enough for Linac operation. At this moment, the basic test results show that the design, manufacture and operation of the new electron system are basically successful.

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