ELECTRON GUN OF THE ACCELERATOR TEST FACILITY FOR THE JLC

M. Akemoto, H. Akiyama, H. Hayano, H. Kobayashi, T. Naito, H. Matsumoto, Y. Otake and S. Takeda

KEK, National Laboratory for High Energy Physics
Oho 1-1, Tsukuba, Ibaraki 305, Japan

Abstract

For the electron source of the JLC (Japan Linear Collider), the electron guns with a low emittance and high current are required. In order to realize these requirements, the thermionic electron gun capable of operating at 240 kV has been designed and constructed for the Accelerator Test Facility. A conventional EIMAC Y-796 cathode-grid assembly is used as the electron source. This paper describes the design, specifications and results of test of the gun system.

Introduction

High-current, low-emittance and multi-bunch beam is required to attain high-luminosity of 10^{33} $cm^{-2}s^{-1}$ for the JLC (Japan Linear Collider)[1]. The parameters of the beam are summarized in Table 1 and the structure of the bunch is schematically shown in Fig. 1. The number of particles per bunch is 1.0 x 10^{10}. The number of bunches per bunch train is 10 with the bunch spacing of 1.4 nsec and the repetition rate of 200 Hz. The fluctuation of each bunch in a bunch train should be less than ± 2% to obtain the required luminosity. The rms normalized emittance should be also less than 10^{-3} rad·m for the acceptance of damping ring[2]. Increasing the cathode voltage of the gun, the beam emittance is decreased as well as the longitudinal space-charge forces in the pre-buncher. Therefore, the higher voltage is preferable to obtain low emittance high current beam. A 240 kV gun has been designed and constructed for an electron source of the Accelerator Test Facility.

Table 1 Beam parameter of the JLC

Number of particles per bunch	1.0 x 10^{10}
Number of bunches per rf pulse	10
Repetition rate of rf pulse	200
Bunch spacing	1.4 nsec
Flatness	< ± 2 %

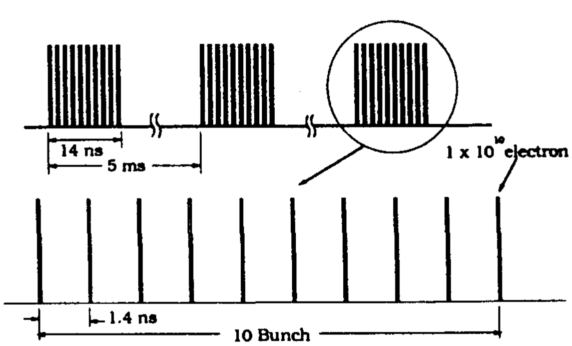

Fig. 1. Beam structure of the JLC

Electron Gun Design

The simulation of the beam trajectory was performed to design the electron gun with an applied voltage of 240 kV by using the electron trajectory program made by W. B. Herrmannsfeldt. The shape of the anode and cathode electrode are optimized in order to obtain a laminar flow and small beam size. The beam trajectory for the optimized geometry is shown in Fig. 2.

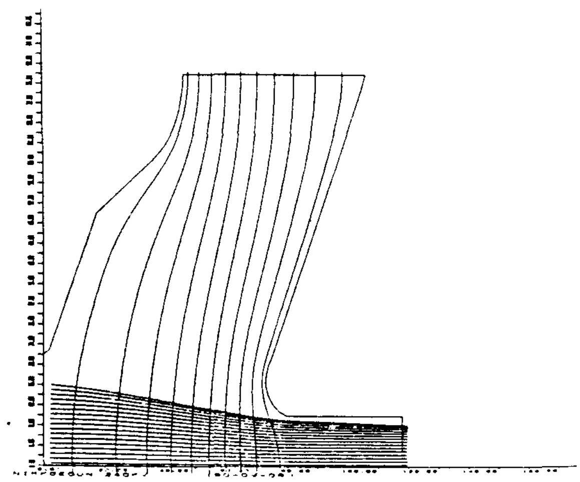

Fig. 2. Simulation of beam trajectory at 240 kV and beam current of 10 A

As shown in Fig. 3, EIMAC Y-796 cathode-grid assembly is utilized for the gun cathode. The electron gun consists of a cathode stem, HV insulator, vacuum chamber with anode and magnetic lenses. The diameter of the insulator is determined from the size of the flanges and the ICF253 flanges are used for the present gun. The length of the insulator is 360 mm, which is determined to avoid the HV breakdown in atmosphere along the outer surface of the insulator. The key issue of the gun design is the alignment of the cathode, anode, magnetic lenses, magnetic shield. Alignment of the axis both the cathode and anode is realized by precise machining of the flanges of the insulator. The axis of the cathode and anode can be aligned in 100 μm. The anode and magnetic lenses are fixed on the same SUS316L block which is also machined precisely to align the axis in 50 μm accuracy mechanically. The electron gun is installed on the support system where the linac components are set up. The support system is a 9 m long and 0.7 m wide L-block made of SUS316L. The flatness of the block surface is 36 μm/9 m. The components can automatically be aligned within 50 μm by setting on the support and alignment system. As the results. The electron gun, magnetic lenses and magnetic shield can be aligned within 100 μm

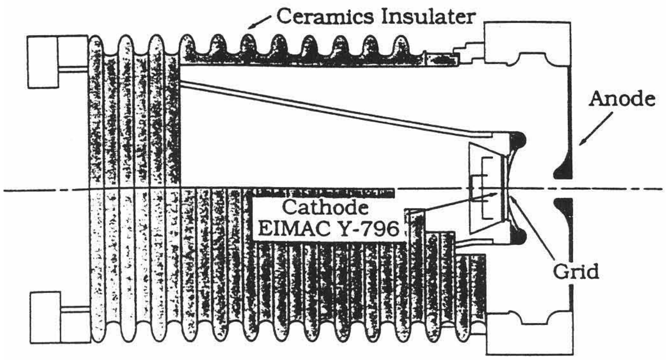

Fig. 3. ATF Electron gun assembly

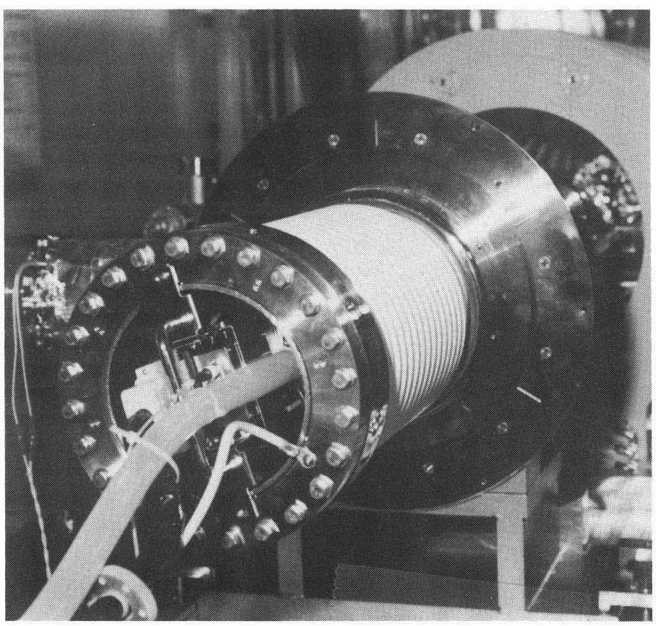

Fig. 4. A photograph of the gun

Gun modulator

The gun modulator consists of a 240 kV pulse modulator, a HV station with grid pulser and a control system. The high voltage pulse is generated by the HV modulator of a line-type with a 16 section pulse forming network and a de-Qing circuit stabilizes the output pulse. A high power dummy load is installed in a pulse transformer to decrease the impedance and to eliminate the sag of the output voltage. The gun pulsers are installed in the HV station set up near the electron gun. The gun pulser is designed to generate the following three modes: (1) long pulse mode (0.8 - 3 µsec), (2) semi-long pulse mode(10 - 100 nsec) and (3) short pulse mode (5 nsec). These modes can be switched easily by the computer control system as described below.

Table 2. Specifications of the HV modulator

Peak power output	24 MW
Average power output	8.4 kW
Output pulse voltage	240 kV
Output pulse current	100 A
Output impedance	2.4 kΩ
Load impedance	2.4 kΩ
Transformer ratio	1:15
Pulse width	7 µsec
Pulse flat top	3 µsec
Rise time	2 µsec
Repetition	50 pps
Pulse height deviation from flatness	<± 0.3 %
Pulse amplitude drift	
Short term	<0.2 %
Long term	<0.5 %

Control system for modulator and grid pulser

The schematic diagram of the control system is shown in Fig. 5. The local controllers are installed in both the modulator and HV station and they are connected with the main control console. These two local controllers provide the manual control of modulator and grid pulser individually. At the main control console, both the modulator and grid pulser can manually be controlled The controllers provide the controls and data acquisitions by programmable sequence controllers (PSC) with a CPU, DI, DO, ADC, DAC etc. The PSCs of the HV modulator and HV station are connected to the main control console with optical-fiber cables. The PSC of the main control console is also connected to the ATF control system[3] consisting of CAMAC and two microVAXs which are connected to the KEK network. The timing of the trigger pulses for the gun pulser and HV modulator can be controlled by VAX station through the CAMAC module.

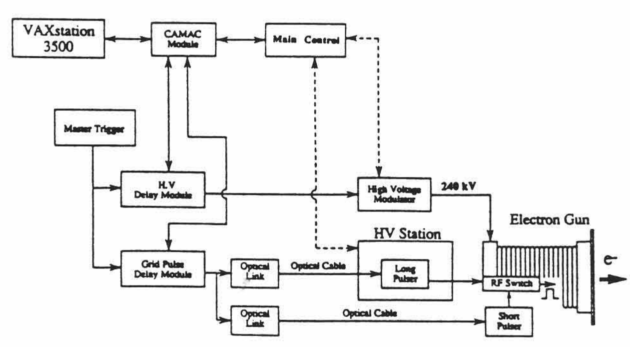

Fig. 5. Gun control system

Performances

The activation of the cathode after assembling whole system is made by a computer controlled automatic processing system under the condition that the vacuum pressure is kept less than $6x10^{-7}$ Torr.

The maximum voltage of 220 kV can be applied without using SF_6 tank outside the ceramic insulator at 5 pps. At the maximum voltage of 240 kV, the HV breakdown is generated inside the gun.

The beam current is observed with a wall current monitor and a core monitor. The beam profile is observed by a screen monitor made of a Cr doped Al_2O_3 plate and sets at 2 m downstream of the gun. The photograph as shown in Fig. 6 is the beam profile obtained at the accelerating voltage of 205 kV without using any steering magnet. As shown in Fig. 6, the dark part is the shadow of the support of the grid mesh and the pattern of the grid is clearly projected on the screen. This shows that the alignment of the gun has been made successfully.

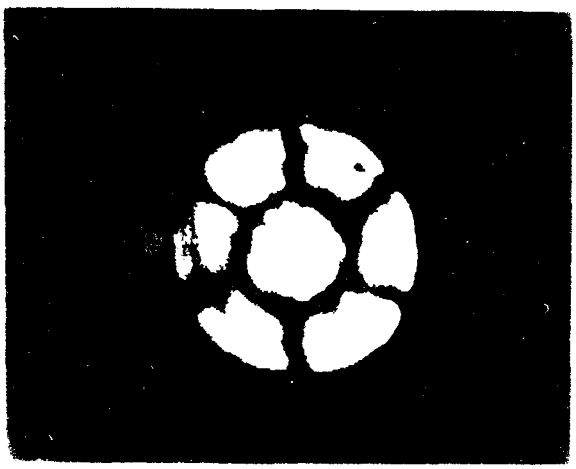

Fig. 6. Photograph of the beam profile at 2 m downstream of the gun.

Figure 7 shows the current waveform of the long pulse beam at the high voltage of 200 kV, the peak current of 2 A and beam width of 3 μsec.

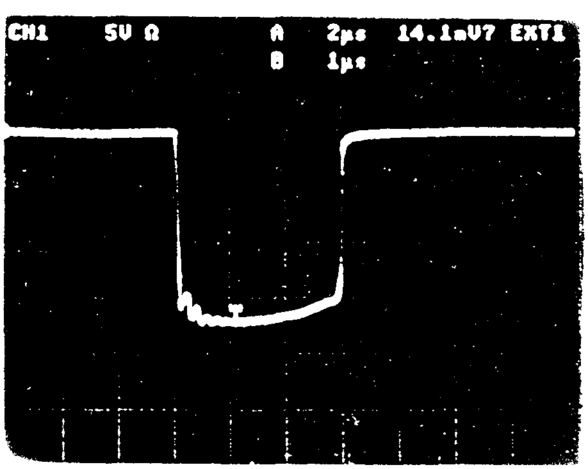

Fig. 7. Output waveform of the long pulse mode.

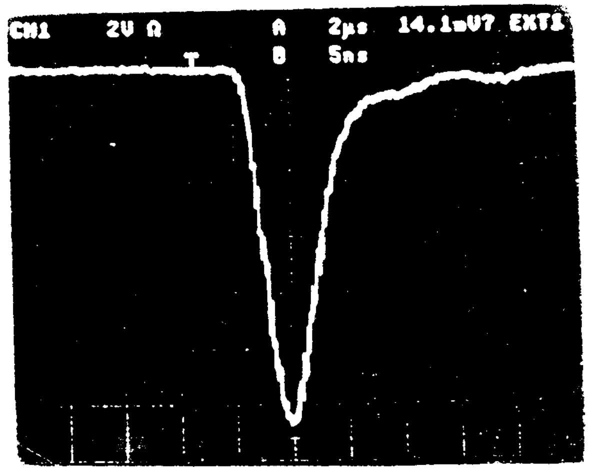

Fig. 8. Output waveform of the short pulse mode.

Figure 8 shows the current waveform of the short pulse mode at high voltage of 200 kV, the peak current of 4.8 A and the beam width of 5 nsec.

Summary

The construction of the electron gun has been completed and operated successfully[4]. The high voltage of 220 kV is applied without any serious problem. We expect to apply 240 kV without using SF_6 tank. The beam can be guided to the accelerating structures without using steering magnets since the accurate alignment system are effective. The whole system can be controlled easily with the computer control system through the network.

References

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2. J. Urakawa et al., "Preliminary Designs of 1.54 GeV Damping Ring and Bunch Compressor," contribution paper to this conference.

3. H. Hayano et al., "Control system of ATF," contribution paper to this conference.

4. H. Matsumoto et al., "Experimental Study of the S-band High Gradient Electron Linac," contribution paper to this conference.