Electron gun for SSRF

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Abstract A 100 kV triode-electron-gun has been designed and manufactured for the Linac of Shanghai Synchrotron Radiation Facility (SSRF). In this paper the performance of the gun and some key components are described.

Keywords Thermionic gun, EGUN

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1 Introduction

A 300 MeV Linac is designed for the injector of the booster of Shanghai Synchrotron Radiation Facility (SSRF) and the proposed DUV FEL facility. In the first phase, a thermionic gun, which has been designed and manufactured during the R&D of SSRF, a pre-buncher and a buncher are used as the injector of the Linac. The whole electron gun system is described in the following text, covering the design, fabrication, assembling and the measurement of electron beam.

2 Electron gun

This gun is a conventional triode electron gun, i.e. classic Pierce gridded gun with a thermal cathode.[1,2] The gun structure is designed to fit the cathode grid assembly Y646B manufactured by EIMAC, which has a circular cathode area of 0.5 cm^2 equivalent to 8 mm in diameter and a grid cathode spacing of 0.15 mm. The gun structure is shown in Fig.1. Up to now instead of Y646B, we use the cathode grid assembly YH01, which has a circular cathode area of 0.75 cm^2 equivalent to 10 mm in diameter and a grid cathode spacing of 0.15 mm.

The main difference between the two cathode grid assemblies is that the former has a dispenser cathode, while the latter has an oxide cathode. In our case, the peak current is high and the repetition is low, so the oxide cathode is a good choice. After activation, keeping the filament voltage and current at the nominal values 6.3 V and 1.5 A, the peak pulsed current can reach to 4 A. Because we only need 1.2 A to 2 A, this cathode is sufficient.

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The shape of cathode and anode, the gap between cathode and anode and the gun focus were designed with the code EGUN.[3] The optimum of gun geometry was determined to obtain small emittance for 100 kV and 2 A. The normalized emittance is equal to 4 mm•mrad. The gap between cathode and anode is 28 mm and the anode hole is 8.8 mm in diameter. The waist of the beam is 2.5 mm in diameter. Fig.2 shows the calculated beam trajectories.

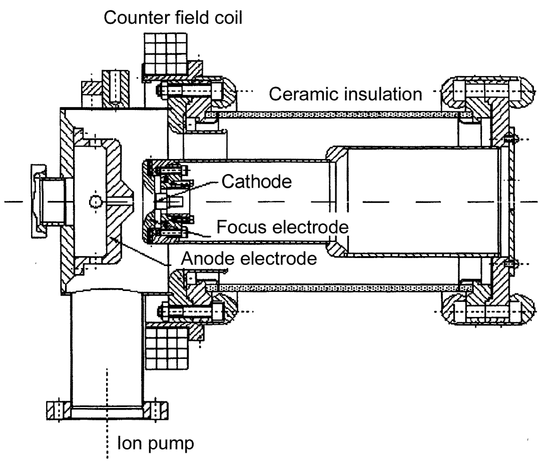

Fig.1 Structure of gun assembly.

The ceramic isolator is made of alumina oxide (purity 99%). Two Ti flanges are brazed onto both sides of the ceramic isolator. After mechanical processing, the alignment error of two flange centers is less than or equal to 10 μm. Two anti-corona rings are assembled onto the flanges to withstand up to 100 kVDC at least.

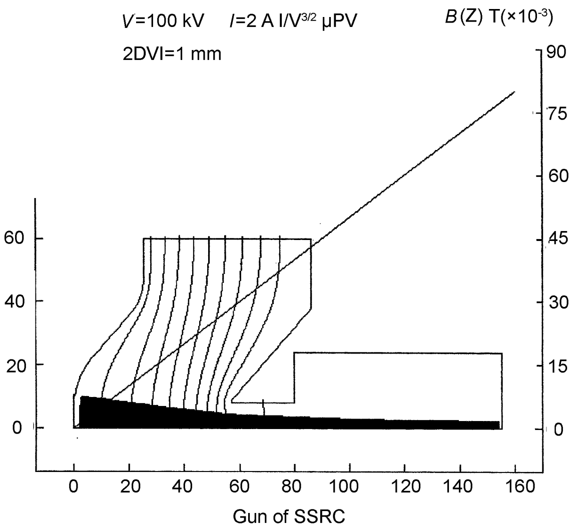

Fig.2 Computed electron beam trajectories.

A 50 L/s ion pump directly under the cathode-anode space exhausts the high voltage region of the gun. A vacuum gauge monitors pressure at the entrance of the ion pump. The pressure is about 4×10^{-6} Pa while the gun is running. At the exit of the gun, a gate valve manufactured by VAT is used to separate the vacuum of the gun from the vacuum of the downstream parts.

Before assembling, all the parts under vacuum were cleaned by the ultrasonic cleaning equipment. After assembling, the whole gun was baked at 150℃ for more than 16 hours. During the activation process of cathode, the vacuum pressure was kept under 10^{-3} Pa.

The high voltage conditioning was performed up to 110 kVDC with a grid cathode negative bias of 70 V to protect the cathode from damage.

A counter field coil is assembled in the cathode plane to cancel the background magnetic field of the Linac. The magnetic field inside the gun is zero at the cathode surface and increases with a gradient of 0.1 T/m.

3 Pusler system

To meet the requirement of two operating modes, two different pulser systems are used to generate the grid pulses, which drive the triode gun. The block diagram of the pusler system is shown in Fig.3.

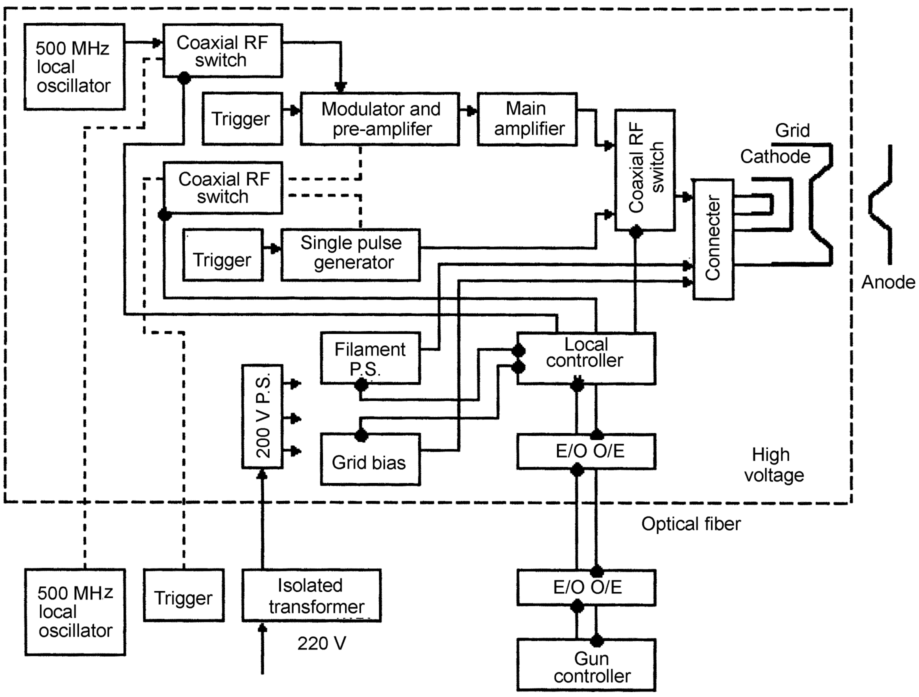

Fig.3 Block diagram of the pulser system.

In single bunch operating mode, a single bunch with a current of 2 A and a pulse width of 1 ns (FWHM) must be generated by the gun. Considering the attenuation and distortion in the transmission and connection, a single pulse with a voltage of 300 V on a 50 Ω load and a pulse width of 1ns (FWHM) is needed. An array of avalanche transistors with a very fast ECL trigger is used to generate a single pulse with a negative voltage of 300 V on a 50 Ω load. The single pulse's falling time and rising time is about 600 ps and 800 ps respectively, and its pulse width is less than 1ns (FWHM).

In multi-bunch operating mode, a bunch trains with an average current of 300 mA and a macro-pulse length of 300 ns (FWHM) must be generated by the gun. It's necessary to modulate the 500 MHz with the peak power of 500 W by a macro-pulse of 300 ns. A 500 MHz CW signal from the local oscillator is modulated with a trigged square wave signal by the PIN diode. Then, two broadband solid-state amplifiers are used to amplify the signal up to 500 W. The rising time of the macro-pulse is about 50 ns, while the falling time is about 30 ns. The pulse width can be adjusted from 100 ns to 1000 ns.

A special coaxial transmission line is used to supply the grid pulse, filament power and grid bias to the cathode grid assembly. A TEK TDS784A oscilloscope with 1 GHz bandwidth is used to measure the power attenuation through the transmission line. In the using of single pulse and multi-pulse modes, the attenuation is –2 dB and –3.7 dB respectively.

Two operating modes can be switched from one to the other by using the output coaxial RF switch. Another two more switches will begin to work when the gun is triggered by the synchronous signal from the main control system.

4 Control system

A remote control system running on a PC is connected to a local control system in the high voltage deck via an optical fiber. Switching operating mode and adjusting filament power and the grid bias can be realized from the control room easily.

5 Beam diagnostic system

A beam diagnostic system is designed to measure the beam parameters. A coaxial Faraday cup with a response of nanosecond is used to get the longitudinal structure of the beam. A profiler is used to observe the beam profile and together with a quadrupole magnet the transverse emittance can be measured.

6 Performance of electron gun

The beam signal is picked up by the coaxial Faraday cup and measured by an oscilloscope through a set of attenuators. A TEK TDS694C oscilloscope with a bandwidth of 3 GHz and a rising time of 200 ps is used. The total power attenuation between the Faraday cup and the oscilloscope is 50.5 dB.

The peak current of the single bunch is 2.0 A and the bunch length is 1.2 ns. The single bunch signal is shown in Fig.4. The small overcharge on the right side of the main pulse is related to the distributed inductance.

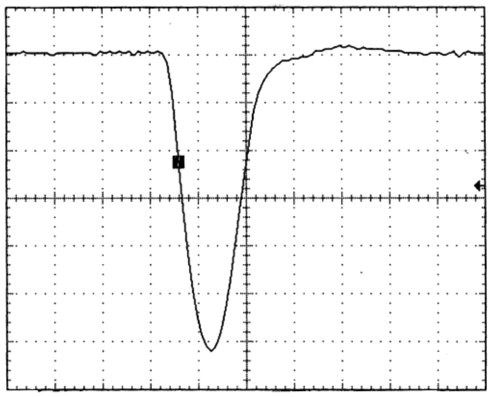

Fig.4 A single bunch (1.2 ns, 2 A).

The full multi-bunch signal recorded by the oscilloscope is shown in Fig.5. With a rising time of less than 50 ns and a fall time of less than 20 ns, the flat top fluctuation is less than 10%. The detail of the multi-bunch is shown in Fig.6. With peak current of 375 mA and the micro bunch length of 0.65 ns, the repetition frequency of the micro bunch is 500 MHz.

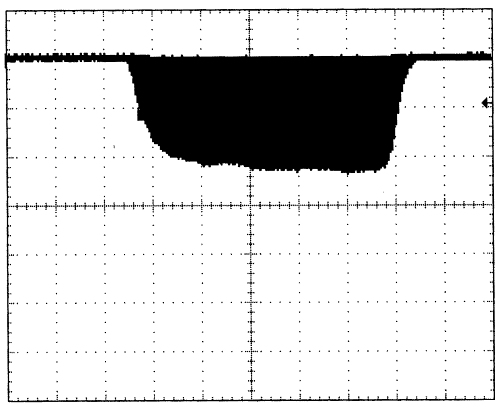

Fig.5 Envelope of the multi-bunch (200 ns, 0.375 A).

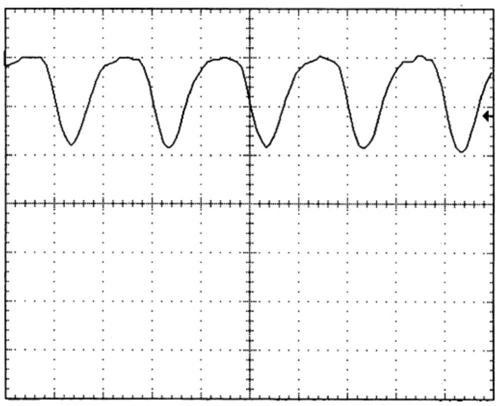

Fig.6 Micro bunches in multi-bunch (0.65 ns,1.5 A).

7 Conclusion

This electron gun can meet the requirement of SSRF basically. Further experiments and studies will be made on this electron gun to find the best operating parameters for SSRF operateion.

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