Experiment and Operation of BEPCⅡ Electron Gun System*

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Abstract The new electron gun system for the BEPCⅡ was tested on the test bench in July, 2004, and has been put into operation since Nov. 2004. This article describes the experiment results and operation status of this new system. The design current of the gun is 10A for the pulse length of 1ns single bunch or two bunches with repetition rate of 50Hz. The gun is operated with a pulsed high voltage power supply which can provide up to 200kV high voltage. Some important correlation curves are obtained during the experiment. Two-bunch operation is available and some elementary tests have been performed. The measurement results including beam current and beam emittance show that the simulations performed during design stage are roughly consistent with the practice. The practical operation shows that the design and manufacture are basically successful.

Key words electron gun, operation, experiment, simulation

1 Introduction

The electron gun used for the BEPC is a conventional thermionic triode gun equipped with the EIMAC Y824 cathode-grid assembly[1], been working at 80kV high voltage with 2.5ns pulse width, and the beam current is about 5A. In order to increase the injection efficiency of the positron for the BEPCⅡ, a new electron gun that can emit higher current is developed, and also the technique of two pulse generation[2] is adopted. Table 1 lists the main specifications of the new electron gun for the BEPCⅡ.

Table 1. Main specifications of the electron gun for the BEPCⅡ[3].

parameter	unit	
type		thermionic triode gun
cathode		Y796 (EIMAC) dispenser
beam current (max.)	A	>10
high voltage of anode	kV	$150\sim200$
bias voltage of grid	V	$0\sim-400$
operation mode 1		1ns single bunch
operation mode 2		1ns two bunches
operation mode 3		2.5μs single bunch
repetition rate	Hz	12.5, 25, 50

2 Experiments on test bench

After physical analysis, computer simulation, mechanical design and fabrication, the new electron gun is tested on the test bench. New pulsed power supply which can provide 200kV high voltage is used.

One Faraday cup is mounted after the anode of the electron gun, and a TEK 3054B oscilloscope is directly connected to it. 10A electron beam was successfully obtained when we applied 150kV high voltage. The flat top width of the pulsed power supply output is about 3μs, as shown in Fig. 1.

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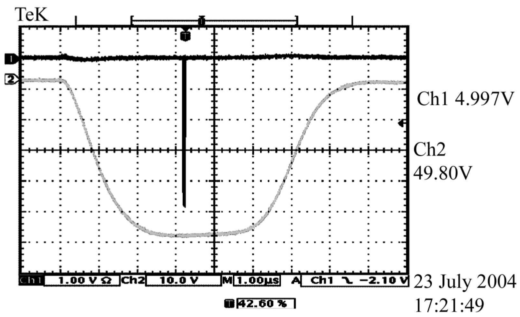


Fig. 1. HV pulse monitor signal (channel 2) and beam signal (channel 1).

Typical gun characteristics are shown in Fig. 2, which shows the gun current as a function of gun high voltage under different heater power; and in Fig. 3, which shows the gun current as a function of grid bias voltage. In Fig. 2, grid bias voltage is set to a fixed value, −100V; and the pulser output is also fixed, about 460V. In Fig. 3, filament power is fixed to about 30W, and the anode high voltage relative to cathode is 150kV.

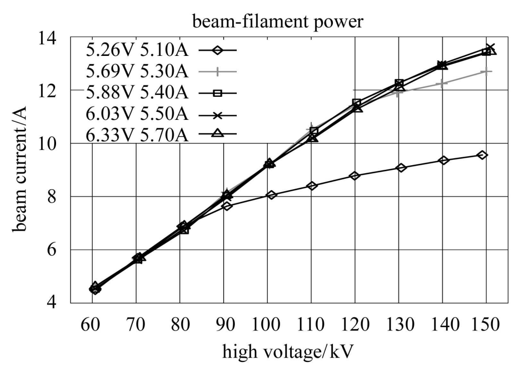


Fig. 2. Beam current as a function of high voltage under different heater powers.

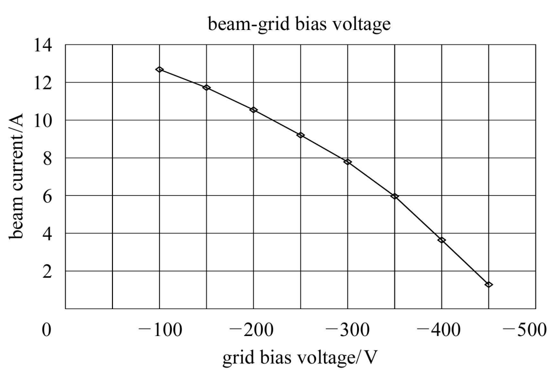


Fig. 3. Beam current as a function of grid bias voltage.

The two bunch generation is also tested. Two 10A, 1.5ns beam pulses are successfully obtained (shown in Fig. 4). The time interval between these two pulses is 56ns and can be adjusted with the step of a few ps, which can meet the requirement of two bunch injection for the future BEPCⅡ operation.

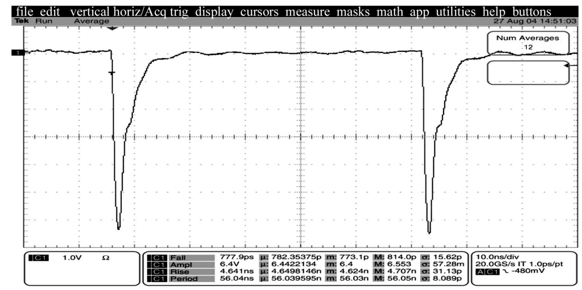


Fig. 4. Two bunches with 56ns spacing obtained at the test bench.

3 Operation status

The new electron gun system for the BEPCⅡ is installed into the linac tunnel in October, 2004. After some tests and adjustment, it has been put into practical operation since last Nov.

Fig. 5 is the monitored pulse signal applied on cathode, which is attenuated about 40dB and then measured by a TEK 7154B oscilloscope. Because the lack of fast OE/EO modules, the pulse signal is measured without high voltage applied. The pulse amplitude on the oscilloscope is about 4.6V, so the real amplitude is about 460V. The pulse width at half amplitude is about 950ps and the width at 100V is about 1.5ns. Because the bias voltage is set to about 100V, the beam length from the gun is believed to be about 1.5ns, which is longer than the expected 1ns, and needs to be shortened by other means in the future.

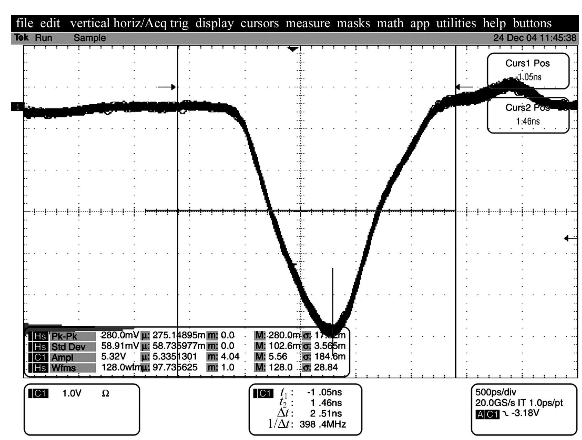


Fig. 5. Monitored pulse signal applied on cathode in the linac tunnel.

Fig. 6 shows a typical waveform of the first two beam current monitors-BCT1 and BCT2. BCT1 is placed after the gun exit, and BCT2 is placed at the exit of first accelerating tube. The amplitude of BCT1 signal is about 900mV, which corresponds to about 10.8A beam current. BCT2 signal is about 600mV, which corresponds to about 7.2A beam current. The result shows that the new electron gun can provide electron beam greater than 10A and the beam transport efficiency during bunching process is about 67%, which is consistent with the computer simulation results.

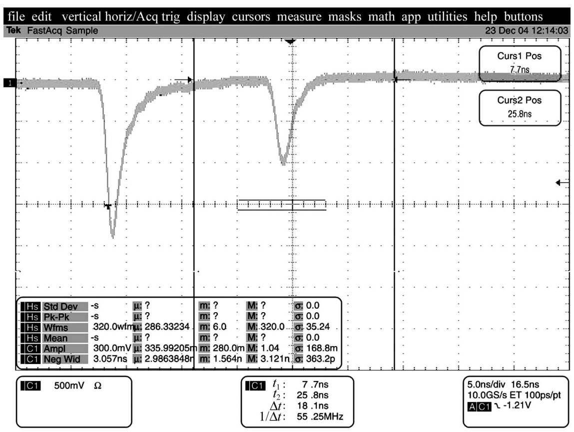


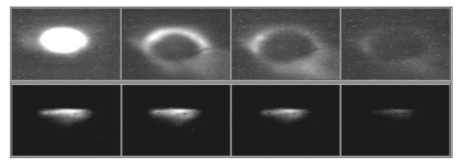
Fig. 6. Signals of BCT1 and BCT2 on the oscilloscope.

The output range of the bias voltage power supply is from 80V to 600V, the precision is better than 0.1%, and the long term stability is better than 0.5V, which are enough for the gun operation.

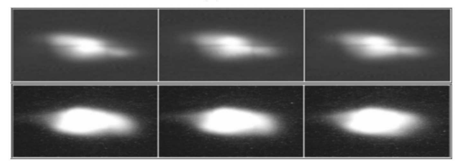
The filament power supply can provide 0 to 50W heater power. The filament current during normal operation is about 5.3A, and the actual voltage applied on the cathode filament is about 6V.

During normal operation, the pulsed power supply is working at 150kV high voltage and 25Hz repetition rate. The preliminary measurement result of monitoring signals shows that the output high voltage stability is better than 0.8%.

Some kind of charge and discharge phenomenon is observed on the first two PRs (beam profile monitor, also known as screen monitor) during measuring the beam profile. The beam spot image changes periodically, as shown in Fig. 7(a). While on the other profile monitors, such phenomenon does not happen. The beam profile keeps rather stable, as shown in Fig. 7(b). The reason is that the low energy electrons accumulate on the ceramic screen, then the beam feels the force produced by the accumulated charge and distortion occurs. When the charge is large enough, some kind of discharge or arcing will happen, and the beam will change to its original state. When the beam energy is high enough, this kind of phenomenon will not happen. The beam energy is only 150keV at the first PR and 180MeV at the second PR. That's why this kind of phenomenon is only observed on the first two screens.



(a)



(b)

Fig. 7. (a) Beam profile changes periodically on PR1 and PR2; (b) Beam profile keeps correspondingly stable on PR3 and PR5.

The beam emittance is also measured during linac operation, and the measurements are done by the Q-Scan method[4], that is measure the beam spot size on the screen monitor while change the quadrupole strength. At first, the measured beam emittance at A_0 (the first accelerating tube) exit is about 3.96mm·mrad, while the corresponding beam energy is about 42MeV and the energy spread is about 4.25%. This value is larger than 2.5mm·mrad, which is the predicted beam emittance including all kinds of errors such as magnet alignment errors and beam impedance effect. One reason is the charge and discharge phenomenon mentioned above. Because we use PR2 as our measuring target, this kind of phenomenon will cause measurement error of the beam spot size. Another reason is the brightness saturation when we measure the beam spot through optical lenses and digital camera. Corresponding to the Gaussian distribution of the beam cross section, the measured brightness data of beam spot should also be Gaussian. But because of the limited dynamic range of lenses, the captured brightness data has obvious flat top, which will cause the “measured” beam size larger than practical value.

Then we turn to measure the beam emittance before positron target, where the beam energy is about 182MeV and the beam intensity 5.5A. The aperture of the camera is tuned to be small enough and some intensity attenuation lenses are added, then we finally get the peak value of Gaussian distribution on the beam spot image. The measured emittance is 0.74mm·mrad. Assuming that the normalized emittance will keep constant between A_0 and positron target, we can deduce that the beam emittance at A_0 exit is about 3.2mm·mrad at 42MeV, which is 1.3 times of the predicted value.

The beam emittance at the exit of linac is also measured. The preliminary result is about 0.14mm·mrad at 1.3GeV and 500mA. Then we can deduce that the beam emittance will be 0.10mm·mrad at 1.89GeV. This elementary measurement result shows that the emittance of linac beam is satisfactory for the design.

4 Summary

The new electron gun system for the BEPCⅡ is now operated under 150kV high voltage with repetition rate of 25Hz. The beam current is about 11A at the gun exit. Now the beam pulse length is about 1.5ns, which is a little large for our future system, because our linac is lack of sub-harmonic bunchers and the ring frequency will be 500MHz in the future. This problem is expected to be solved in the next year by means of adding one sub-harmonic buncher. At this moment, this gun has been operated for more than half a year, which shows that the design, manufacture and operation of the new electron system are basically successful.

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BEPCⅡ电子枪系统测试与运行*

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摘要 2004年7月BEPCⅡ新电子枪系统在测试台进行了测试, 同年11月投入BEPCⅡ直线加速器运行. 描述了新电子枪系统的测试与运行状态. 电子枪设计电流10A, 脉宽1ns, 重复频率50Hz, 脉冲高压200kV, 提供单脉冲和双脉冲运行模式. 通过实验获取了一些重要的关系曲线, 同时进行了初步的双脉冲测试. 流强及发射度测量等测试结果表明设计阶段的计算机模拟数据与实际情况基本相符. 从电子枪实际运行状况来看, 其设计与制造是成功的.

关键词 电子枪 测试 运行 模拟

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