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Design of the BEPCII electron gun system*

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Abstract: BEPCII upgrading project needs a new high current electron gun. The design stage such as physical design, mechanical design and control system design of this new electron gun is described. The emission current is designed to be higher than 10 A for the pulse width of 1 ns with repetition rate of 50 Hz. The gun will operate with a pulsed high voltage power supply which can provide up to 200 kV high voltage. Computer simulations and optimizations have been carried out in the design stage, including the gun geometry and beam transport. EGUN and DGUN codes are used to simulate the gun geometry, and the results show that the perveance is about 0.22 $\mu A \cdot V^{-3/2}$, and the emittance at gun exit is about 16 $\pi \cdot$ mm $\cdot$ mrad. PARMELA code shows that the electron beam can be easily transported to the end of the first accelerating tube with a capture efficiency of 67% and root mean square emittance of 25 mm $\cdot$ mrad. New scheme of the gun control system based on EPICS is also presented. Two-bunch operation mode and 2.5 μs long pulse operation mode are available in the control system.

Key words: Electron gun; Design; Simulation; Beam transport; Control system

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The electron gun used for BEPC is a conventional thermionic triode electron gun equipped with Y824 (EIMAC) cathode-grid assembly[1], working at 80 kV high voltage with 2.5 ns pulse width, and the beam current is about 5 A. In order to increase the injection efficiency of positron for BEPCII, a new electron gun which can emit higher current needs to be developed, and the technique of two-pulse generation[2] is adopted. The new gun can not only produce 1 ns short pulse beam (both single bunch and two bunches) for BEPCII, but also produce 2.5 μs long pulse beam for Beijing Slow Positron High Current System. Table 1 shows the specifications of the new electron gun for BEPCII.

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

type	thermionic triode gun
cathode	Y796 (EIMAC) dispenser
beam current (max.)/A	>10
voltage of anode/kV	150～200
bias voltage of grid/V	−400～0
operation modes	1 ns single bunch, 1 ns two bunches, 2.5 μs single bunch
repetition rate/Hz	12.5, 25, 50

1 Gun geometry

In order to achieve the design goal, it is necessary to use an electron gun of good performance and high emission current. Consulting the designs of KEKB, PEP-Ⅱ and CESA, a conventional thermionic triode gun with the EIMAC Y796 cathode-grid assembly is chosen for BEPCII. Y796 is a cathode-grid assembly with 2 cm^2 cathode area. When it works with narrow pulses, the emission current can be higher than 12 A. According to other laboratories' electron gun systems[4-5] that have been put into operation, Y796 can meet the requirement of BEPCII.

EGUN[6] program is used to optimize the shapes and dimensions of the focusing electrode and anode. The beam simulation result is shown in Fig. 1.

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Corresponding beam parameters, including emittance and TWISS parameters are listed in table 2. The parameters are calculated after the gun anode (the distance is 80 mm from the cathode) at 150 kV high voltage. The simulation results show that the perveance is about 0.22 $\mu A \cdot V^{-3/2}$, and the beam emittance is about 16 $\pi \cdot$ mm $\cdot$ mrad, which can easily satisfy the requirements of BEPCII linac. DGUN program is also used to check the results. The beam characteristics simulated by DGUN are shown in Fig. 2.

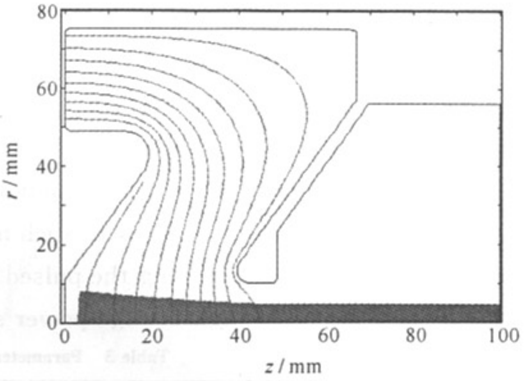

Fig. 1 Beam profile simulated by EGUN

Table 2 Calculated beam parameters under different working current

beam current /A	emittance /($\pi \cdot$ mm $\cdot$ mrad)	normalized emittance /($\pi \cdot$ mm $\cdot$ mrad)	beam radius /mm	α	β /(m $\cdot$ rad^{-1})	γ /(rad $\cdot$ m^{-1})
5	29.58	24.21	3.834	1.390 6	0.641 2	4.575 5
6	26.53	21.71	4.377	0.174 1	0.902 4	1.141 8
7	25.76	21.07	4.909	−1.468 7	1.143 1	2.761 9
8	22.95	18.77	5.460	−3.920 7	1.551 5	10.552 7
9	22.65	18.53	6.004	−6.591 7	1.870 2	23.767 2
10	20.56	16.81	6.567	−10.544 5	2.420 3	46.352 0
11	19.25	15.73	7.150	−15.331 9	3.016 9	78.249 7
12	19.52	15.95	7.720	−19.656 4	3.456 7	112.066 1

The calculated perveance is almost the same, while the beam emittance is a little different because of different definitions of the two programs.

To easily operate at 200 kV high voltage, the new electron gun uses a 310 mm long ceramic insulator. Besides the anode and focusing electrode, the cathode supporting structure also needs careful consideration. Finally a cone-shaped stainless steel supporting structure is chosen, and the shapes of the shielding electrodes hare also been carefully optimized. The electric field distribution is shown in Fig. 3.

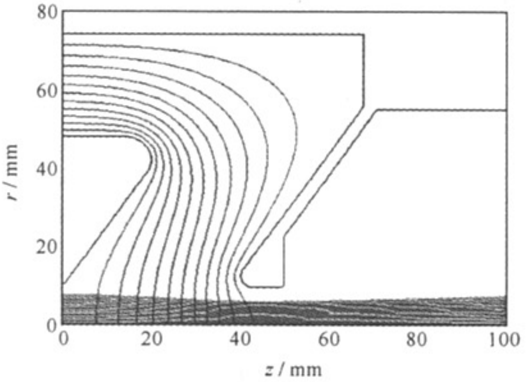

Fig. 2 Simulation result of DGUN

After finishing the gun structure simulations, the mechanical design mainly concerned to vacuum system and mechanical supporting system is also performed and the final result is shown in Fig. 4.

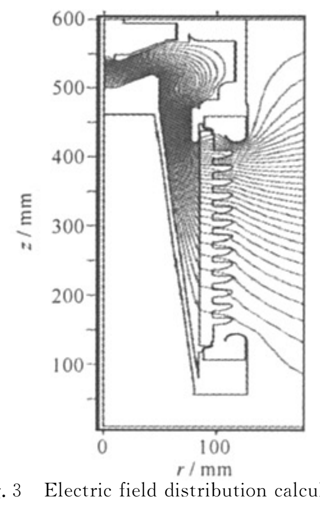

Fig. 3 Electric field distribution calculated by POISSON[7]

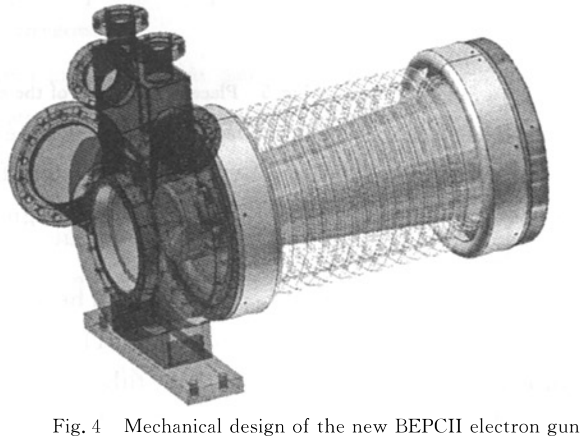
Fig. 4 Mechanical design of the new BEPCII electron gun

2 Pulsed high voltage power supply

The increase of the initial beam energy can deminish the space charge effect and thermal effect, so the gun is better to work at higher voltage. Taking into account the problems of all aspects, the new gun is expected to operate at 150 kV, and up to 200 kV in the future.

The ceramic envelope of the current gun can hardly withstand DC voltage higher than 120 kV, and it is also very hard to operate in the air with such high DC voltage, so we need to adopt a pulsed power supply for higher operating voltage. By using the pulsed power supply, the design goal is much easier to achieve. Main parameters of this pulsed high voltage power supply are listed in table 3.

Table 3 Parameters of the pulsed high voltage power supply

pulse voltage (max.)/kV	200
pulse width (flat top)/μs	2.5
repetition rate/Hz	50
thyratron type	CX1536
capacitance of PFN/nF	14
node number of PFN	16
transform ratio of transformer	1 : 12
impedance of second stage/kΩ	1.8
matching resistance/kΩ	1.82
absorbed power/kW	5

3 Beam transport

According to the successful experiences of DESY[5] and KEKB[8], two magnetic lenses, two sets of steering coils and several focusing 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 with more flexibly and reliably. After compromising with some installation problems, the placement scheme of the elements is shown in Fig. 5.

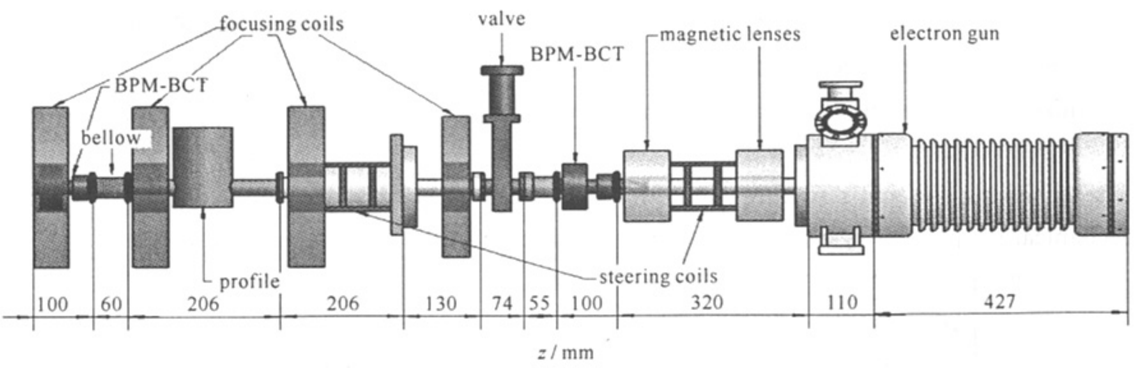

Fig. 5 Placement scheme of the elements from the gun to the bunching system

PARMELA[9] code is utilized to simulate the beam transport process from the gun anode to the exit of the first accelerating tube. The input parameters for PARMELA code, such as emittance and TWISS parameters are the results from EGUN, while the magnetic field data are from the result of POISSON (a typical result is shown in Fig. 6).

With such arrangement, the beam can be successfully transported to the end of the first accelerating tube with a capture efficiency of about 67%. The simulation result also shows that the rms (root mean square) beam emittance at the exit of the first tube is about 25 mm · mrad. Beam parameters, such as beam rms emittance and beam radius simulated by PARMELA during the whole transport process, are shown in Fig. 7.

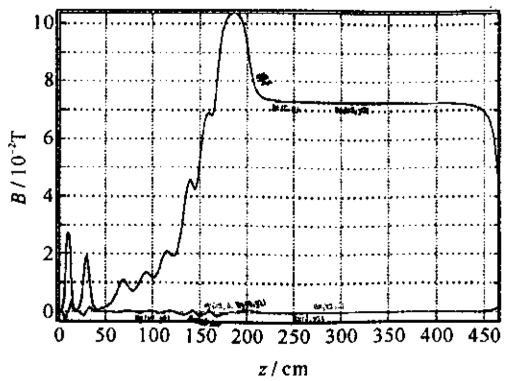

Fig. 6 Magnetic fields from the gun to the first accelerating tube

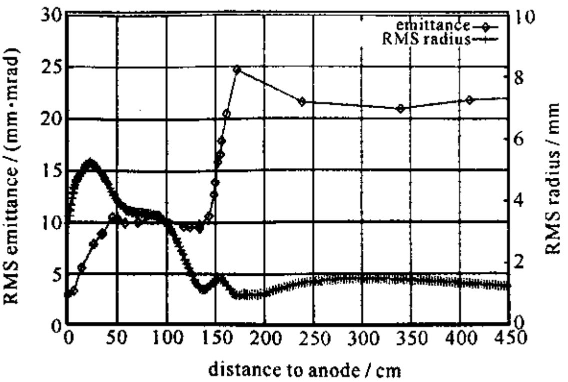

Fig. 7 Transport process simulated by PARMELA

4 Control system upgrade

Because the whole BEPCII control system is to be gradually upgraded to EPICS[10] system, a new control system of the electron gun is needed to build based on EPICS. The gun control system arrangement is shown in Fig. 8. The key element of this new control system of the electron gun is an Allen-Bradley RS-LOGIX PLC, which is put on the high voltage deck. Through the AD and DA modules, this PLC controls the filament power supply, bias power supply, pulser and other monitors and control components which are also on the high voltage deck. The PLC communicates with the main control PC through Ethernet, with some O/E and E/O modules for network conversion and high voltage isolation.

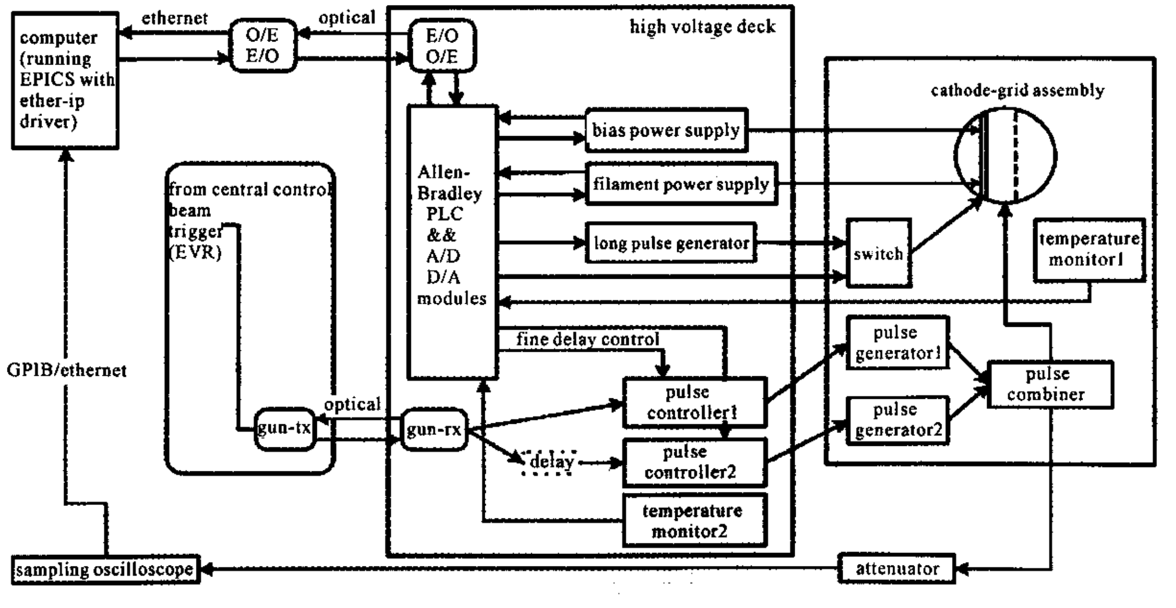

Fig. 8 Control system arrangement

New control software is developed under EPICS system and has been put into test on our test bench. The test result shows that both the hardware and the software are applicable for our system.

5 Summary

The design of a new electron gun system for BEPCII includes many aspects, such as physical design, mechanical design, power supply design, control system design, etc. The emission current of the gun is higher than 10 A for the pulse width of 1 ns with repetition rate of 50 Hz. The gun will operate with a pulsed high voltage power supply which can provide up to 200 kV high voltage. EGUN and DGUN codes are used to simulate the gun geometry, the resulted perveance is about 0.22 $\mu A \cdot V^{-3/2}$, and the emittance at gun exit is about 16 $\pi \cdot mm \cdot mrad$. In order to decrease the possibility of arcing, POISSON program is used to optimize

the shape of shielding electrodes. PARMELA code shows that the electron beam can be easily transported to the end of the first accelerating tube, while the capture efficiency is better than 67% and the RMS emittance is 25 mm·mrad. New scheme of the gun control system based on EPICS is also presented, with two-bunch operation and 2.5 μs long pulse operation available.

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BEPCII 电子枪系统设计

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摘 要: BEPCII 改进工程需要更高流强的电子枪。新电子枪系统的物理设计、机械设计、控制系统设计等均进行了描述。电子枪的设计发射电流在脉宽为 1 ns 时大于 10 A,重复频率 50 Hz。将会采用脉冲电源来为电子枪提供最高 200 kV 的脉冲高压。在设计阶段,电子枪的几何结构和束流传输过程利用计算机模拟进行了优化。EGUN 和 DGUN 的计算结果表明导流系数为 0.22 $\mu A \cdot V^{-3/2}$,电子枪出口的发射度为 16 π·mm·mrad。PARMELA 的模拟结果表明束流能顺利地传输至第一根加速管末端,捕获效率为 67%,出口的均方根发射度为 25 mm·mrad。基于 EPICS 平台的电子枪控制系统设计也已完成,提供了全新的双脉冲运行模式和 2.5 μs 长脉冲运行模式。

关键词: 电子枪; 设计; 模拟; 束流传输; 控制系统