NEW ELECTRON GUN SYSTEM FOR BEPCII

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Abstract

The new electron gun system for BEPCII has been put into operation since Nov. 2004. The article describes the design, experiment and operation of this new system. The design current of the gun is 10 A for the pulse lengths of 1 ns single bunch and two bunches with repetition rate of 50 Hz. The gun is operated with a pulsed high voltage power supply which can provide up to 200 kV high voltage. Computer simulations have been carried out in the design stage, including simulation of the gun geometry and beam transportation. Some important relation curves are obtained during the experiment. Two-bunch operation is available and some elementary tests have been performed. New scheme of the gun control system based on EPICS[1] is also presented. The practical operation shows that the design and manufacturing is basically successful.

INTRODUCTION

The electron gun used for BEPC is a triode electron gun equipped with the Y824 (EIMAC) cathode-grid assembly[2], 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 positron for BEPCII, a new electron gun that can emit higher current needs to be developed, and also the technique of two pulses generation[3] is adopted. The new gun can not only produce short 1ns pulse beam (single bunch and two bunches) for BEPCII, but also produce 2.5μs long pulse beam for Beijing Slow Positron High Current System. Table 1 shows the specifications[4] of the new electron gun of BEPCII.

Table 1: Specifications of the Electron Gun for BEPCII

Type	Thermionic Triode Gun
Cathode	Y796 (EIMAC) Dispenser
Beam Current (max.)	>10A
High Voltage of Anode	150–200kV
Bias Voltage of Grid	0–500V
Operation Mode 1	1 ns Single Bunch
Operation Mode 2	1 ns Two Bunches
Operation Mode 3	2.5 μs Single Bunch
Repetition Rate	12.5, 25, 50 Hz

COMPUTER SIMULATIONS

In order to achieve the design goal, its necessary to use an electron gun of high performance and large emission current. Consulting the design of KEKB, PEPII and CESA, a conventional thermionic triode gun with the Y796 (EIMAC) cathode-grid assembly is used in the BEPCII electron gun. Y796 is a cathode-grid assembly with cathode area of 2 cm^2. When it works with narrow pulse, the emission current density can be up to 10 A/cm^2. According to other laboratories' electron gun systems[5, 6, 7] that have been put into operation, Y796 is satisfactory for the requirements of BEPCII.

EGUN[8] program is used to optimize the shape and dimensions of focusing electrode and anode. The beam simulation result is shown in Fig. 1.

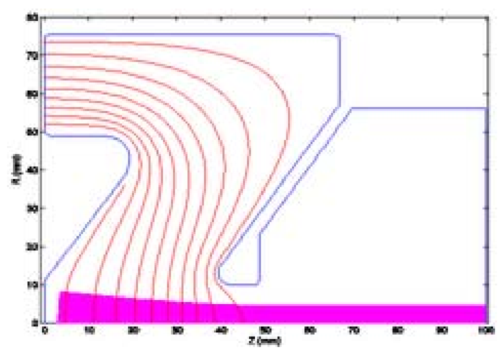

Figure 1: Beam Profile Simulated by EGUN

Corresponding beam parameters including emittance and TWISS parameters are listed in Table 2. These parameters are calculated after the gun anode (distance is 80 mm to the gun cathode), and the high voltage is 150 kV.

The simulation results show that the perveance is about 0.22 μP, and the beam emittance is about 16 π·mm·mrad, which can easily satisfy the requirements of BEPCII.

According to the successful experiences of KEKB and DESY, 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 bunching system.

Except EGUN program, PARMELA[9] code is also utilized to simulate the beam transport process from the gun anode to the entrance of the pre-buncher. The input parameters for PARMELA code, such as emittance and TWISS parameters are the results from EGUN. The magnetic field data is from the result of POISSON. One typical result is shown in Fig. 2.

With such magnetic field arrangement, the beam can be successfully transported into bunching system with more flexibility, which is shown in Fig. 3. The simulation results also show that the beam emittance at the exit of bunching system is not affected much during this transportation process). The calculated capture efficiency of the bunching system is about 67%, and the beam emittance (1σ) after

Table 2: Calculated Beam Parameters Under different Beam Currents

Beam Current	Emittance	Nomalized Emittance	Beam Radius	Alpha	Beta	Gamma
(A)	($\pi \cdot$ mm $\cdot$ mrad)	($\pi \cdot$ mm $\cdot$ mrad)	(mm)	(m/rad)	(rad/m)	
5	29.58	24.21	3.834	1.3906	0.6412	4.5755
6	26.53	21.71	4.377	0.1741	0.9024	1.1418
7	25.76	21.07	4.909	-1.4687	1.1431	2.7619
8	22.95	18.77	5.46	-3.9207	1.5515	10.5527
9	22.65	18.53	6.004	-6.5917	1.8702	23.7672
10	20.56	16.81	6.567	-10.5445	2.4203	46.352
11	19.25	15.73	7.15	-15.3319	3.0169	78.2497
12	19.52	15.95	7.72	-19.6564	3.4567	112.0661

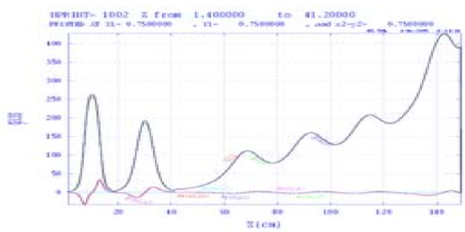

Figure 2: Magnetic Fields between Anode and Pre Buncher

the first accelerating tube is about 2.5 mm·mrad.

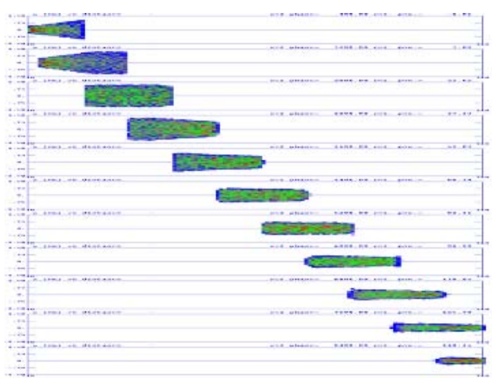

Figure 3: Transportation Process Simulated by PARMELA

CONTROL SYSTEM UPGRADE

Because the whole BEPCII control system will be gradually upgraded to EPICS system, new control system of the electron gun is also needed. The key element of this new control system for electron gun is an Control Logix5000 PLC produced by Allen Bradley[10] , 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 monitoring and control components which are also on the high voltage deck. For high voltage separation, the PLC communicates with the main control PC through Ethernet. Some OE and EO modules are used for signal conversion.

With the EtherIP[11] driver written by Kay-Uwe Kasemir, the new control software is easily developed under EPICS system and has been put into use since last Oct.

SYSTEM TEST AND MEASUREMENTS

After simulation, mechanical design and fabrication, the new electron gun is tested on the test bench. New pulsed power supply which can provide 200 kV high voltage is used in this test bench. Typical gun characteristics are shown in Fig. 4, the gun current as a function of gun high voltage under different heater power, and in Fig. 5, the gun current as a function of grid voltage. In Fig. 4, grid bias voltage is set to 100 V, and the grid pulser output is about -460 V. In Fig. 5, filament power is fixed to about 30 W.

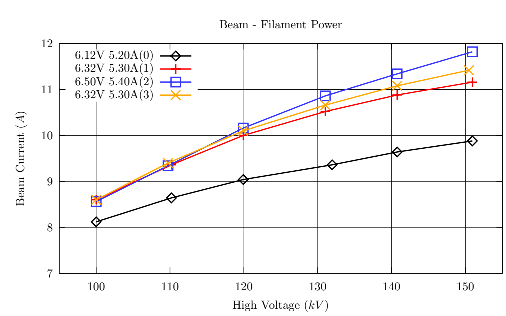

Figure 4: Emission Current as a Function of High voltage under Different Heater Powers

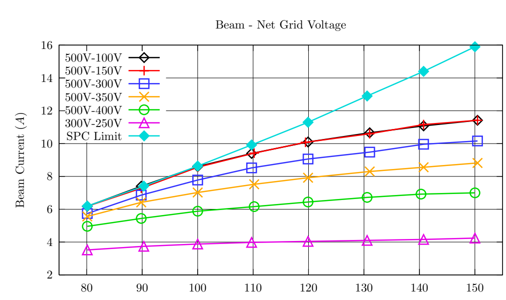

Figure 5: Emission Current as a Function of High voltage under Different Grid Voltage

Two bunch operation is also tested on the test bench. Two 10 A, 1.5 ns beam pulses are successfully obtained (shown in Fig. 6). 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 of future BEPCII operation.

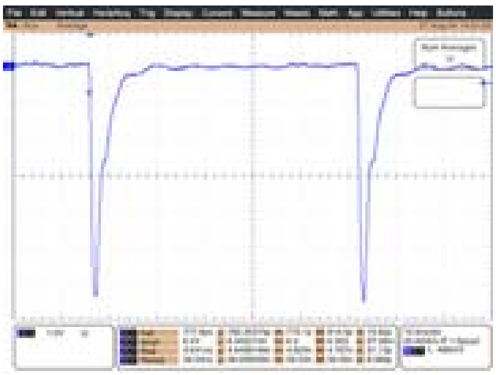

Figure 6: Two bunches with 56 ns spacing obtained at the test bench

After the test, the new electron gun system was installed into the tunnel and put into operation since Nov. 2004. Some kind of unstable phenomenon is observed on the first two screen monitors, which later is proved to be some kind of charge and discharge happend on the ceramic screen because of the low beam energy. At the gun exit, the beam current monitor shows that the beam current is about 10.8 A. At the exit of first accelerating tube, the beam current is about 7.2 A, which shows that the capture efficiency is almost the same as simulation prediction.

Emittance also has been measured by changing the quadrupole strength and measure the beam spot size on screen monitor. the preliminary result shows that the emittance at the exit of first accelerating tube is about 3.2 mm·mrad at 40 MeV, which is larger than simulation result. The emittance measurement result at the end of linac is about 0.14 mm·mrad at 1.3 GeV.

SUMMARY

Now the gun is operated under 150KV high voltage, with repetition rate of 25 Hz. Beam current is about 11 A at the gun exit. The beam pulse length is about 1.5 ns, which is a little larger for our future system, because our linac is lack of sub harmonic bunchers and the ring frequency will be 500 MHz in the future. This problem is expected to be resolved in the next few months. At this moment, this gun has been operated for more than half a year, which shows that the design, manufacturing and operation of the new electron system are basically successful.

REFERENCES

[1] http://www.aps.anl.gov/epics/

[2] Eimac Technical Data 8755, Varian EIMAC Division, 301 Industrial Way, San Carlos, California 94070.

[3] S.Ohsawa, et al., “Pre-Injector of the PF 2.5-GeV Linac for the KEKB and its Performance”, Proc. Of the International Workshop on e+ e- Sources and Pre-Accelerators for Linear Colliders, Schwerin, Germany, Sept.29-Oct.4, 1994, pp.465-479.

[4] PEI Guo-Xi et al. “Overview of BEPCII Linac Upgrade. Preliminary Design Report of BEPCII-Linac”, IHEP-BEPCII-SB-03, 2002.6

[5] H.Iwata, et al., “Development of an Electron Gun for the KEK Positron Generator”, KEK Preprint 89-95, September 1989.

[6] F.Sannibale, M.Vescovi, R.Boni, F.Marcellini, G.Vignola, “DAΦNE Linac Commissioning Results”, DANE Technical Note BM-2, Frascati, April 4, 1997.

[7] Roland F. Koontz, Roger H. Miller, T. O. McKinney, and Alan R. Wilmunder. “SLAC Collider Injector, RF Drive Synchronization and Trigger Electronics and 15 AMP Thermionic Gun Development”, *IEEE Trans. Nucl. Sci.*, 28:2213–2215, 1981.

[8] W. B. Herrmannsfeld, “EGun - an Electron Optics and Gun Design Program”, SLAC Report 331, October 1988.

[9] Lloyd M. Young. “Parmela”.

[10] http://www.ab.com

[11] http://ics-web1.sns.ornl.gov/˜kasemir/etherip/

[12] Isamu Sato, et al., “Design Report on PF Injector Linac Upgrade for KEKB”, KEK Report 95-18, March 1996, pp.273-275.

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