INJECTOR LINAC UPGRADE FOR THE BEPCII PROJECT

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Abstract

BEPCII- an upgrade project of Beijing Electron Positron Collider (BEPC) is a factory type of e+e- collider. It requires its injector linac to have a higher beam energy (1.89 GeV) for on-energy injection and a higher beam current (40 mA e+ beam) for a higher injection rate (≥50 mA/min.). The low beam emittance (1.6πmm-mrad for e+ beam, and 0.2πmm-mrad for 300 mA e- beam) and low beam energy spread (±0.5%) are also required to meet the storage ring acceptance [1]. Hence the original BEPC injector linac must be upgraded to have a new electron gun with its complete tuning system, a new positron source with a flux concentrator, a new RF power system with its phasing loops and a new beam tuning system with orbit correction and optics tuning devices. These new components have been designed, fabricated, tested and now being installed in their final positions, which are described in this paper. The beam commissioning is expected to start from October of 2004.

INTRODUCTION

BEPCII is an upgrade project of Beijing Electron Positron Collider with a high luminosity of $1\times10^{33}\,cm^{-2}s^{-1}$ in the Tau-Charm energy region (2-5 GeV) in the centre of mass. The full energy injection with a high injection rate of > 50 mA/min (ten times of present value) for the e+ beam requires the original BEPC injector linac to be upgraded with its higher performances as listed in the Table 1.

Table 1: Beam Parameters of the BEPCII-Linac

	Unit	e- beam	e+ beam
Beam Energy	GeV	1.89	1.89
Beam Current	mA	~ 40	~ 300
Beam emittance	πmm-mrad	1.60	0.20
Energy spread	%	0.50	0.50
Injection rate	mA / min	> 50	> 300
Pulse repet. rate	Hz	50	50
Beam pulse length	ns	1.0	1.0

To meet these specifications, we need a new electron gun with its complete tuning system, a new positron source with a flux concentrator, a new RF power system with its phasing loop and a beam tuning system with the orbit correction and optics tuning. These new components have been designed, fabricated and now being installed in their final positions.

ELECTRON GUN SYSTEM

In order to increase the positron current as well as the injection rate, a new electron gun that can emit higher current is needed. A thermionic triode gun with a cathode-grid assembly of Y796 is employed with the gun beam parameters of 10 A, 1 ns, 10 nC, 150-200 keV and 50 Hz. The computed province is 0.22 µP. At the end port the beam radius is about 6.0 mm, and the emittance is 17.6 mm·mrad. The beam trajectories present that the current density is relatively uniform, which indicate a good beam performance. A Kentech pulser is employed which can be operated at 1ns of either one pulse or two pulses separated by about 56 ns for the two-bunch operation. Between the gun exit and the prebuncher, there are two focusing lens, two steering coils and two BPMs, and a profile monitor for having a well beam alignment and tuning, as shown in the Figure 1.

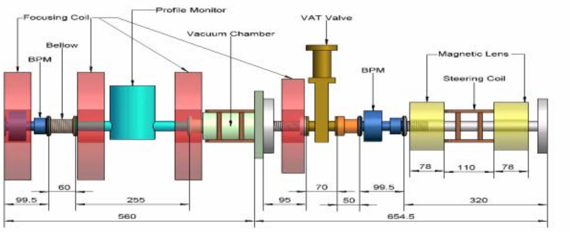

Figure 1: Components downstream the electron gun.

POSITRON SOURCE SYSTEM

A 250 MeV and 6 A primary electron beam at the e+ production target is designed. To have a maximum e+ yield, a tungsten target thickness is optimized at 8 mm and a primary e- beam spot size of 1.0 - 1.5 mm on the target is expected by the beam modeling. A flux concentrator (FC) of 10 cm long is employed to provide a maximum transverse acceptance of 0.31π (MeV/c)-cm, which provides the pulsed longitudinal magnet field of 5.3 T and 0.5 T at the input and output of the FC, respectively, with a 12 kA pulsed power supply. In the downstream FC, there is a 7.5 m long, 0.5 T, DC-solenoid to further focus the e+ beam and matches the beam into the downstream quadrupole focusing system. In addition to the available 15 triplet quads, 24 big aperture quads installed on the downstream accelerating structures will be employed to strongly focus the large emittance e+ beam. In order to bunch the beam longitudinally, the e+ beam is decelerated in the first 1 m of the structure just downstream the FC, and then to be soon accelerated with a high gradient so that the most of the positrons are bunched into a phase spread of $\pm5^0$ at the DC solenoid exit with the positron yield of 4.3%(e+/e-.GeV)[2]. The 8 accelerating structures of 3 meters long each in the e+ production system will be replaced by the new ones in order to have high stability and reliability in high gradient

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operation since some of these structures were a little damaged in the past operation.

All the components of the new positron source have been fabricated, inspected, pre-assembled and vacuum tested. A 12 kA pulsed power supply has been built and been operated with the existing e+ converter. It works well as expected. The flux concentrator has its inductance of 0.95µH, and a measured mechanic resonance frequency of 37 Hz as simulation predicted. The magnetic fields of the FC and DC solenoid have been well measured. The following pictures show the FC and the positron converter chamber.

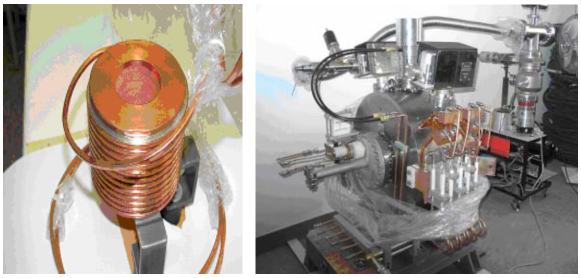

Figure 2: FC (left) and Positron converter chamber (right).

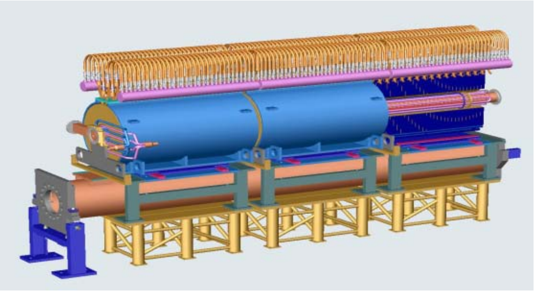

Figure 3: Positron focusing and accelerating system.

RF POWER SUPPLY SYSTEM

There are 16 klystron units in the linac. Downstream the positron target, there are 12 regular acceleration sections i.e. one klystron drives 4 SLAC type acceleration structure with a SLED. To increase the e+ energy from present 1.3 GeV to 1.89 GeV and to increase the primary e- beam energy for a higher e+ yield, the RF power system must to be upgrade to have higher power output and higher stability. 50 MW klystrons are needed to replace the original 30 MW HK-1 klystrons. All the 16 modulators will be rebuilt for 50 pps, 360 A beam current and 320 kV beam voltage with a target stability of ±0.1% provided by a De-Qing system. The pulse waveform of the new modulator is as shown in Figure 4. In the total 16 klystrons, there are two TH-2128C (45 MW), two SLAC-5045 (65 MW) and twelve E-3730A (50 MW). A new klystron test stand has been built, and two new klystrons /modulators have been put into operation already.

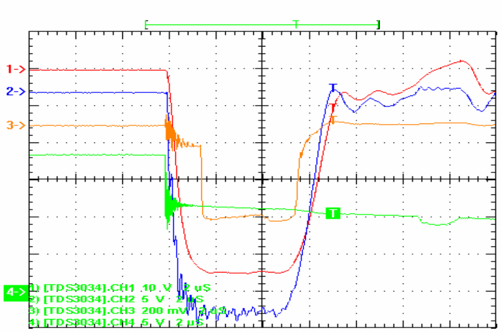

Figure 4: The modulator's pulse waveform

1) Beam voltage, 2) Beam current, 3) RF output.

PHASE CONTROL SYSTEM

A phase control system is being developed with the following measures. The maximum energy method is adopt to define the optimum phase, which appears preferable to the beam loading and beam induced methods.

A PAD system of I/Q demodulator type is used to monitor the phase with accuracy of 0.2° and amplitude. The new IϕA. units have been developed with its minimum insertion loss of 2 dB, maximum decay of 20 dB and phasing range of > 360°. A reference line of the phase stabilized co-axial type is used for its easy maintenance and cheaper than the optical type. The existing co-axial driving line can be further used by controlling the cooling water temperature within ±0.1°C.

A master oscillator with high stability of phase and output power is demanded. To have the effective phasing system development, many measured data have been taken in the existing RF system, including the phase variation with the temperature, with the EM noise, etc. A prototype of the phase control system was made for the 1st RF unit, and a very good experimental result of this control unit has been obtained with the phase control within ±2° as shown in the Figure 5. The Figures 6 shows the BEPCII-Linac phasing system and its constitutions.

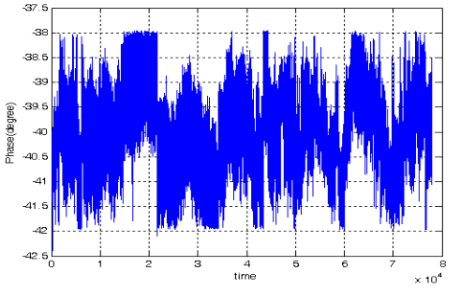

Figure 5: Phase control result with the prototype unit.

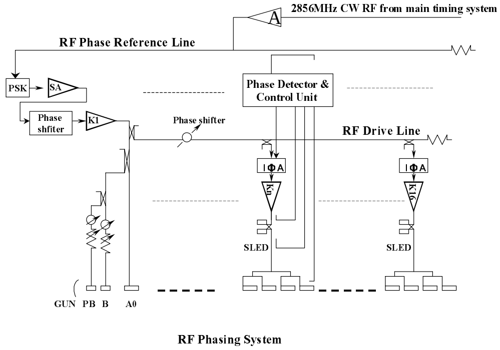

Figure 6: RF Phasing System.

BEAM MODELING

Positron beam simulations. With TRASPORT, EGS4, PARMELA and LIAR codes, the e+ beam performance at the production target and transportation in the linac are simulated. Table 2 shows that about 40 mA e+ with specified emittance and energy spread is expected. The 24 large aperture quads “riding” on the acceleration structures are needed to improve the transmission for the larger emittance positrons out of focusing solenoid. Beam initial offset of 0.3 mm, and 0.2 mm misalignment of the RF structures and quads are taken into account The orbit correction provided by 19 Strip-line BPMs and 19 sets of correctors is needed to meet the design goal of the beam performance.

Table 2: Simulation results for the e+ beam

Posit.	Ener. (MeV)	Curr. (mA)	Emitt. (m.rad)	ΔE/E (%)	Phase Spr. (o)	e^+ Yield (e^+/e^- .GeV)
Target	1 -14	80	3.08E-3	---	---	5.58%
Solen. exit	89.45	53	29.2E-6	±8.6	±16	3.67%
Linac -end	1890	42	1.42E-6	±0.5	±5.0	2.92%

Electron beam simulations. With EGUN, TRANSPORT, PARMELA and LIAR codes, the electron beam performances are simulated and are listed in Table 3 and Table 4. The 1.89GeV electron beam with small emittance and energy spread is not a problem, but the primary electron beam size on the converter target is an important issue because it’s very sensitive to the positron yield. A beam size of less than 1.5 mm is expected, and the confinement mainly comes from the quads chromaticity due to the low energy (250 MeV) and large energy spread caused by the bunching. The other contributions come from the dispersive and wakefield effects due to the initial beam offset and machine misalignments. The orbit correction is needed to meet the design goal of the beam performance.

Table 3: Simulation results for the e- beam

Position	Energy (MeV)	Curr. (A)	Emitt. (m-rad)	ΔE/E (%)	Phase Spread (o)
Gun exit	0.150	1.5	42.5E-6	---	±180
Pre-injector	39	1.0	4.14 E-6	±1.5%	±5
Linac -end	1890	0.6	0.18 E-6	±0.5 %	±5

Table 4: Simulation results for the primary e- beam at the target

Position	Energy (MeV)	Current (A)	Emittance (m-rad)	Beam radius (mm)
Gun exit	0.150	10.0	17.1E-6	6.5
Pre-injector	40	6.5	2.79E-6	3.4
On target	1890	6.0	0.75 E-6	1.5

SUMMARY

1) A new electron gun, a new positron source, a new RF power system with phasing loops, 8 new acceleration sections and some modified RF components for the BEPCII injector linac upgrade are designed, fabricated, tested and being installed in their final positions. A new electron and positron beam from this linac is expected by this fall.

2) By controlling the phasing error within $\pm 2^0$, Quads /BPM/structure’s alignment error within ±0.2 mm, and modulator’s voltage jitter within ±0.1%, the beam performance at the linac exit can meet the design goal with the aid of orbit correction system[3].

REFERENCES

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[3] S.H. Wang, P.D. Gu, et al, High Energy Phys.and Nucl. Phys., 2003, **27** (2):173.