PRESENT STATUS OF THE BEPCII LINAC

Pei Guoxi* for BEPCII-Linac Group
Institute of High Energy Physics, IHEP, Beijing, P. O. Box 918, 100049, China

Abstract

After the major upgrades in 2005, the BEPCII injector linac has been commissioning and working smoothly for more than two years. A 1.89GeV, 61.5mA positron beam at the linac end has been obtained, and the highest injection rate into the ring of 80mA/min. at 50pps is reached, much higher than the design goal of 50mA/min. The machine is working stably, and the mal function was only about 2% in the past two years, including the system test and the commissioning.

INTRODUCTION

The BEPCII [1] is a factory type e^-e^+ collider with a luminosity of $1\times10^{33}\,cm^{-2}s^{-1}$ in the Tau-Charm energy region (2-5 GeV). On-energy injection scheme with an injection rate of > 50mA/min (almost twenty times of BEPC number) for e^+ beam requires the existing BEPC injector linac be upgraded with higher performance [2]. The BEPCII linac major upgrades were completed in 2005, and we got the first positron beam of ~50mA on March 19th. On December 23rd, 2007, an acceptance test group organized by the Chinese Academy of Sciences has fully checked the linac beam performance. The measured beam energy, current, emittance, energy spread, orbit and energy stabilities were well reached their design goals, as shown in Table 1.

Table 1: The Design and Reached Beam Performance

		Design	Reached
Beam Energy（GeV）		1.89	1.89
Beam Current（mA）	e^+	37	66
	e^-	500	550
Emittance（1σ,μm)	e^+	0.40	0.35 (x) 0.27(y)
	e^-	0.10	0.097 (x) 0.079 (y)
Energy spread（1σ,%）	e^+	0.50	0.37
	e^-	0.50	0.30
Repetition rate (Hz)		50	50
Beam orbit stability(mm)		0.30	≤0.15
Beam energy stability (%)		0.15	≤0.05
e^+ injection rate(mA/min.)		50	61.5

OPERATIONAL STATUS

From October, 2006, up to now, the BEPCII only had two shut down time [3, 4, 5]. One was from early August to early October, 2007, which was for the BEPCII interaction region installation. We also took this chance to replace 5# RF unit's waveguide, which was badly damaged and confined the high power transmission. The other one was from March to May, 2008, for the BESIII installation. General speaking, in almost 20 months, the linac performance was excellent. The mal function including those happened at system test and commissioning time was only about 2%. The positron beam current at the linac end exceeded 60mA, which is good for a much higher injection rate. The injection rate of 61.5mA/min. listed in Table 1 was an average number. Actually, the peak value often reached 80mA/min. at 50pps as mentioned in the abstract, which indicates the injector linac's capability. The switch time for electron and positron modes change was less than 10 seconds. And the highest electron energy has reached 2.7GeV, so in the operation for the BERF early this year the top off injection at 2.5GeV with one RF unit stand-by has been adopted as shown in Fig. 1.

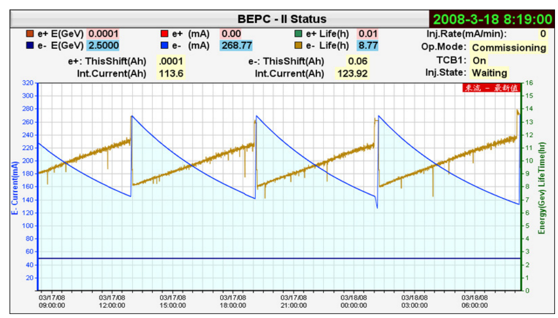
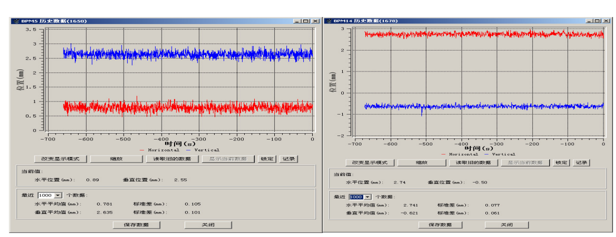


Figure1: The plot for top off injection.

In what follows we will present some details concerning the beam as well as machine stability issues.

Beam Orbit Stability

There are 19 BPMs along the linac. With these BPMs we can easily observe the beam position and the orbit stability. Figure 2 shows a good electron orbit at BPM5 and BPM14, the jitter is less than 0.1mm (1σ).



BPM5 BPM14

Figure 2: Beam position stability at BPMs 5 and 14.

Beam Energy Stability

The beam energy stability can be measured by the BPMs located at a large dispersion region in the beam transfer line. Figure 3 shows the plot of beam position varied within ±1.0mm, seen by a BPM in the e- beam transport line, where the dispersion function is 2.0m. It indicated that the beam energy jitter was about ±0.05%, much smaller than the beam energy spread (±0.5%).

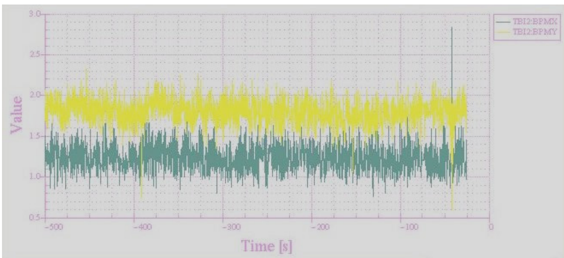


Figure 3: Beam energy stability.

Usually, the energy jitter comes from modulator's beam voltage pulse to pulse jitter, and the voltage stability within ±0.15% is essential. To reach the goal, a lot of measures have been used, including using a De-Qing circuit to stabilize the charging voltage, using a Thyristor voltage regulator with feedback control to stabilize the modulator DC voltage, and using a high precision stabilizer for the klystron filament.

The Problems Encountered

1) The unit 5# RF system arcing was a BEPC times' problem, and because of the tight budget we didn't replace them during the BEPCII linac major upgrades while hoped the problem could be solved through high power processing. After several times processing both in 2006 and 2007, the problem was still there. In July 5~6, 2007 we made an experiment again to identify the arcing place, and found it was at a branch waveguide right downstream the 3dB high power splitter, not in the RF structures as guessed before by analyzing the RF waveforms at different places as shown in Fig. 4.

Figure 4: The schematic of unit $5^{\#}$ RF system.

2) In middle of December, 2006, a big beam orbit oscillation (8~10mm) was observed at TEBPM1, a BPM located at the dispersion region (2m) of the electron transfer line. Because no correlated orbit oscillation was found at other linac BPMs, so we identified it was an energy jitter. After many correlation experiments we found that the arcing of a directional coupler load at the RF drive line caused 6º phase jitter of the 6# and down stream RF units, which agreed well with the observed orbit oscillation at TEBPM1. Figure 5 is the correlation plot between the phase of the 6# RF unit and orbit oscillation at TEBPM1.

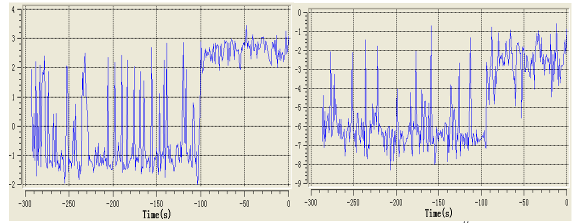


Figure 5: Correlation experiment plots of $6^{\#}$ phase jitter (left) and orbit oscillation at TEBPM1 (right).

3) In February, 2008, the machine worked at 5pps for the BSRF operation, and we found an energy jitter of 0.3~0.5% which came from linac, and electron energy was also lower than before. The phases and amplitudes of all the RF power sources, the timing system as well were checked with no problems. But when investigating beam voltage jitter at the first RF power source we found the RF pulse width was shorten because the modulator high voltage pulse was delayed by 0.7μs. The source was power line loose connection for the thyratron. After fixed the problem, the energy jitter disappeared.

4) Over Current Protection (OCP) sometimes occurred at the BEPCII modulators, which is a common problem for the conventional (resonant charging type) modulator, caused by continues conduction of the thyratron and will shut off main breaker of the modulator. The main causation of continues conduction is that it's difficult for a conventional modulator circuit to ensure enough recovery time for the thyrstron. For reducing thyratron continues conduction, normally we tune the reservoir voltage and operate it at lower gas pressure.

FUTURE PLAN

The existing BEPCII bunching system consists of an S-band pre-buncher and a buncher, and beam pulse width from the gun is about 1.6ns (bottom width). So the linac is not single bunch operation, while with one main bunch and some satellite bunches. The satellite bunches are troublesome and make operation not clean, and cause the beam instability. The sub-harmonic bunching system can solve all these problems with higher transmission efficiency. Figure 6 shows the compassion between the present bunching system and the system with two SHBs. Except the solid state RF amplifiers are under test, almost all the system constructions are completed, and waiting for installation. Figure 7 shows the SHB cavity tuning at the laboratory, pre-installation and alignment. Figure 8 is the pictures of SHB RF amplifier under test.

Once the SHB system completed, we can hope to adopt the two bunch acceleration mode so as to double the injection rate into the ring. The pulse generator and timing system are ready.

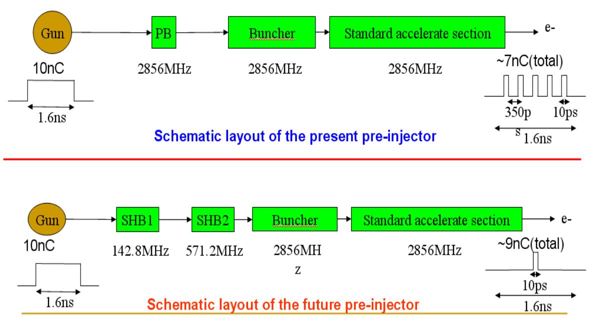


Figure 6: Bunching system compassion.

Figure 7: SHB cavity tuning (left) and system pre-installation (right).

Figure 8: Pictures of RF amplifier under test.

Recently, high energy physicists have interests in the energy region of 2.1~2.3GeV, and strongly request the BEPCII injector linac energy be upgraded to 2.3GeV. The design positron energy for the present linac is 1.89GeV, but can be increased up to 2.1GeV because of design margin. In order to realize 2.3GeV top off injection for positron beam, we need further upgrade the machine, and the simplest way is replacing four 50MW RF power sources with 80MW ones. The linac energy upgrade proposal has been submitted to Chinese Academy of Sciences, and waiting for approval.

SUMMARY

In last two runs, the BEPCII injector linac worked excellently for both the BSRF operation and the ring commissioning. All the design goals have been reached and passed the acceptance test organized by the Chinese Academy of Sciences. The highest injection rate into the ring even reached 80mA/min. at 50pps, much higher than the design goal of 50mA/min.

The SHB system as one of the second phase upgrades is in progress, but a little bit delayed and missed the chance to be installed during last machine shut-down. Now the system is almost ready, and waiting for next chance installation, hopefully in 2009 summer shut-down.

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