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ELECTRON GUN LONGITUDINAL JITTER: SIMULATION AND ANALYSIS *

Liu Ming-shan, Pei Shi-Lun, Chi Yun-long, Sui Yan-feng, IHEP, Cas Beijing 100049, China

Abstract

Electron gun timing longitudinal jitter is fatal not only for electron beam performance but also for positron yield in routine operation of Beijing Electron Positron Collider (BEPCII) Linac, which has been observed many times practically. We simulated longitudinal jitter effect of electron gun using PARMELA during one cycle and analyzed its results about beam performance including average energy, energy spread, emittance and longitudinal phase of reference particle. It is concluded that longitudinal jitter of gun trigger time is seriously for maintaining good beam performance and stable operation, which also gives a salutary lesson to any other longitudinal jitter which can affect beam bunching in pre-injector.

INTRODUCTION

In 2006, the sub-harmonic bunching (SHB) system was installed on BEPCII linac pre-injector to obtain single bunch per beam pulse and to increase positron beam injection rate[1] from linac to storage ring, which is composed of electron gun, two sub-harmonic bunchers (SHB1 & SHB2), one 4-cell travelling wave buncher and a standard 3-m long accelerating structure[2-3] as shown in Fig. 1.

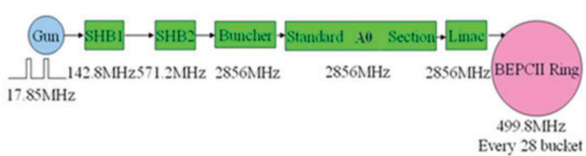

Figure 1: Schematic of the pre-injector.

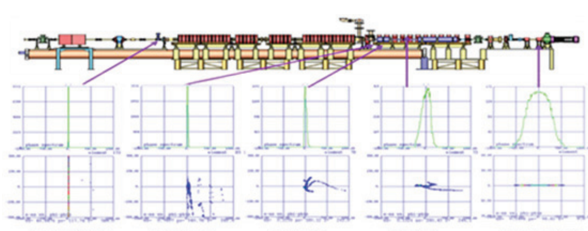

Figure 2: Schematic and simulation of bunching process.

Figure 2 is schematic of beam bunch process and simulation results at every bunch unit calculated by PARMELA when SHB system was designed[4]. The beam macro-pulse width at gun exit is 1ns FWHM with 1.6ns bottom width, after velocity modulation by SHB1 and SHB2, the beam length is ~900ps and 500ps at their exits without any real acceleration while it is ~60ps and ~10ps at buncher and A0 exit, respectively, beam energy is about 50MeV at A0 exit[3-5], which can be measured by an analysis magnet installed at A0 accelerator exit[6]. During bunch process, any variation in longitudinal sequence between pre-injector cells can be called longitudinal jitter that may deteriorate beam performance to some extent.

In order to ensure expected bunching results, physical tolerances in pre-injector were studied[7] when SHB system was designed, which are listed in Table 1. The electron gun is powered by a high voltage power supply and triggered by signal from timing system. SHBs are derived by independent power supplies with 142.8MHz and 571.2MHz microwave signals, As for buncher and A0 accelerator whose microwave comes from the 1st klystron, any perturbation of power and phase of its exporting microwave also give variation to beam performance. In other sense, timing stabilization between bunch cells in pre-injector was vital, any variation of them can cause longitudinal jitter.

Table 1: Physical Tolerance in the Pre-injector[8]

Jitter	Tolerance
Electron gun timing	±50ps
Electron gun high voltage	±0.4%
SHB phase	±1.5%
SHB power	±1.5%
Buncher phase	±2%
A0 accelerator phase	±2%

LONGITUDINAL JITTER MEASUREMENT

In electron gun trig system, electrons are emitted started by Trig On button and optimized by adjusting Delay or Fine Delay button in following operating interface as illustrated in Fig. 3. The units of them are nano-second and pico-second, respectively.

Figure 3: Operating interface of electron gun trigger.

For beam instrumentation, a beam current transformer (BCT1) is installed at gun exit, a beam current transformer(BCT2),a beam position monitor(BPM) and an Analysis Magnet are installed after A0 exit in sequence to measure beam parameters. The beam current and time

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interval between BCT1 & BCT2 signals can be measured according to waveforms of them displayed by an oscilloscope at the control room. Fig. 4 is schematic of beam current measurement principle.

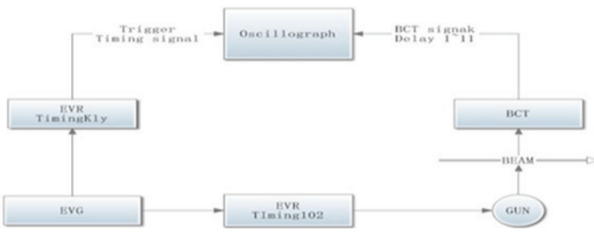

Figure 4: EVG and EVR measurement schematic.

EVG and EVR are event generator and event receiver of timing system, when single beam is bunched and measured as displayed in Fig. 5, the spot on profile monitor produced by Analysis Magnet is also captured displayed in Fig. 6, and then time interval between BCT1&BCT2 is observed and measured in Fig. 7, which is about 21.5ns with tolerance less than 100ps, the actual beam currents of them are about 10A and 9A, respectively, although BCT1 signal is less than BCT2 due to calibrating coefficient, the actual bunch efficiency is 90%1.

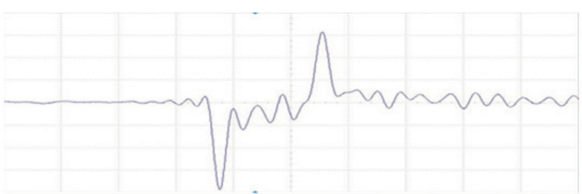

Figure 5: Oscilloscope waveform of BPM measurement.

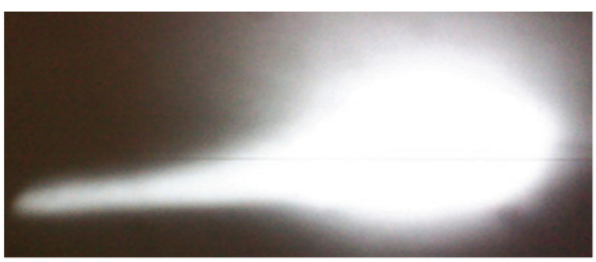

Figure 6: Spot on profile monitor.

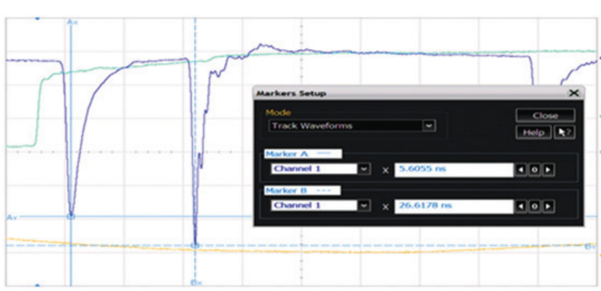

Figure 7: Oscilloscope waveform of BCT measurement.

If there exist instability in pre-injector cells, BCT2 signal decreased greatly compared with the normal situation caused by gun timing trigger jitter or position inconsistency between beam and SHBs or bunch microwave phase. Fig. 8 is one of jitter situations which describe BCT1&BCT2 unstable. Meanwhile, beam injection rate decreased or fluctuated[9].

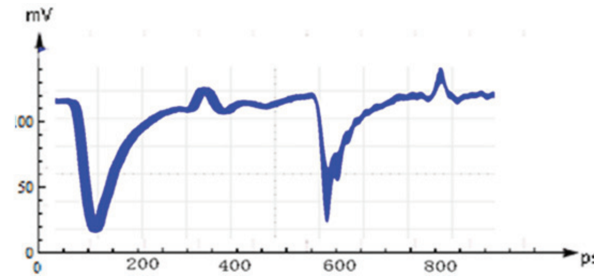

Figure 8: BCT1 & BCT2 jitters.

SIMULATION AND ANALYSES

In this paper, bunch process in pre-injector was simulated using PARMELA software with 5000 particles by just adjusting electron emitting time during one cycle remaining other prerequisites according to routine operation. Supposedly, gun trigger time has no longitudinal jitter, so beam parameters at A0 exit are calculated and shown in Fig. 9, which are composed of relative positions in X and Y directions, beam transverse section size, energy spread and phase of reference particle. Figure 10 is another beam parameters chart including average energy, energy spread, phase of the reference particle and emittance in Z direction, which is 47.569MeV, 10.3%, 18.15°, .01627cm•mrad (3δ), respectively.

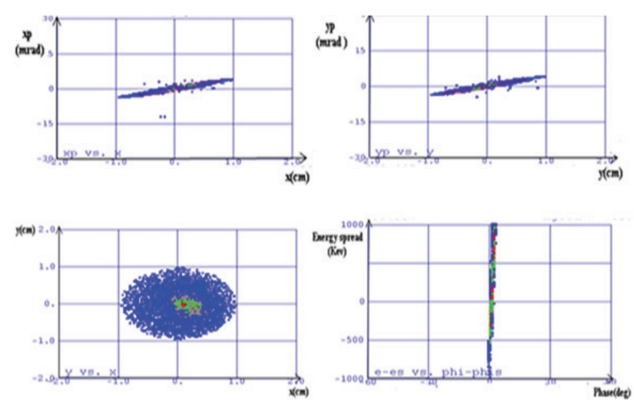

Figure 9: Beam transverse parameters at A0 exit.

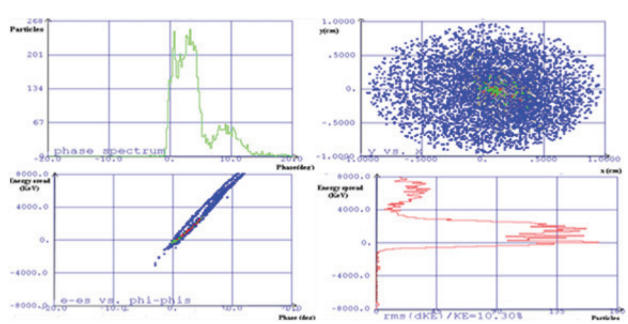

Figure 10: Beam parameters at A0 exit.

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In order to compare simulation results, 30ps jitter is taken as an instance to calculate beam parameter which is illustrated in Fig. 11 and Fig. 12, the corresponding parameters of average energy, energy spread, phase of the reference particle and emittance in Z direction were 51.6149MeV, 10.81%, 124.39°, 0.01302cm•mrad (3δ), respectively.

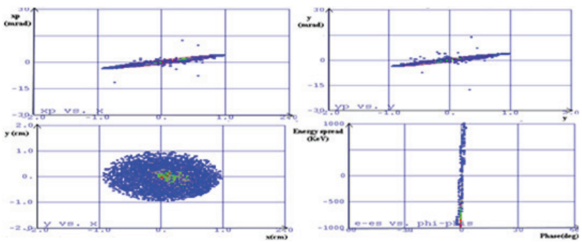

Figure 11: Beam transverse parameters at A0 exit with 30ps longitudinal jitter.

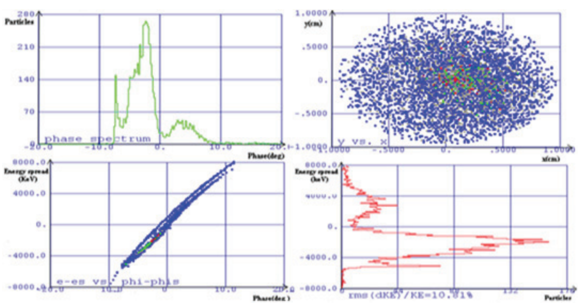

Figure 12: Beam parameters at A0 exit with 30ps longitudinal jitter.

In all, electron gun trigger timing longitudinal jitter was simulated in one cycle, beam parameters every step were collected and listed in Fig. 13, maximum and minimum comparison of beam parameters are listed in Table 2.

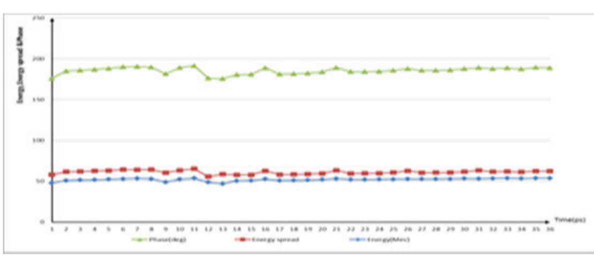

Figure 13: Beam parameters at A0 exit in one cycle.

Table 2: Minimum & Maximum between Parameters

Energy	**Energy spread**	**Phase**	**Emittance**
47.57(Mev)	6.89(%)	118.15(°)	0.00024 (cm.mrad)
53.65(Mev)	11.93(%)	126.28(°)	0.020 (cm.mrad)

From simulation results, it is obviously that electron gun trigger timing longitudinal jitter can affect beam performance including the average energy, energy spread, beam size and phase of reference particle. It will certainly affect the beam envelope in the downstream of linac that decreases injection rate definitely. Therefore, electron trigger timing can be adjusted to optimize electron beam longitudinal position for good beam performance and highly operation efficiency.

CONCLUSION

As an injector, it is necessary to control and lesson perturbation of electronic components for good beam performance, the electron gun trigger timing is more possible to be changed due to many invisible factors. In this paper, PARMELA simulations were done by changing gun trigger timing to analysis beam performance which was approximately agreeable to routine operation. It is concluded that any jitter in electron gun will deteriorate beam performance and affect the injection rate. On the other hand, this simulation is helpful for operator to obtain or improve beam performance by optimizing trigger time finely in the bunching process.

ACKNOWLEDGMENT

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