OPERATIONAL PERFORMANCE IN 2.5 GEV FULL ENENRGY INJECTION AT PLS

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Abstract

The PLS has provided 2.5 GeV electron beam to users of beam lines since Jan. 2000. During Jan. 2000 to Oct. 2002, 2 GeV electron beam was injected from the linac to the storage ring and the storage ring had used energy ramping process to increase the beam energy to 2.5 GeV. Instead of energy ramping process, we have used the 2.5 GeV full energy injection from the linac to the storage ring since Oct. 2002. We present the activities on the stability and reliability of the linac for 2.5 GeV operation, stabilities of injection kicker and septum magnets in the storage ring, orbit correction of COD due to leakage field of the septum magnet, and a DC bump for beam injection. Orbit stabilities and global orbit correction on the operation of 2.5 GeV full energy injection are also presented.

INTRODUCTION

In September 1995, PLS started to operate with 2 GeV electron beam in the range of 100 mA of the beam current. Since then, the operation of PLS has aimed to realize stable operation with higher beam current and higher beam energy. One of the major factors to limit the operation with higher beam current was the coupled-bunch instabilities driven by the HOMs of rf cavities. By optimizing of the cavity temperature, betatron tune, bunch filling pattern and chromaticity, it was possible to suppress the instabilities. During Jan. 2000 to October 2002, the beam energy in the storage ring was raised from 2 GeV to 2.5 GeV by energy ramping. PLS has been operating successfully by 2.5 GeV full energy injection from the linac since October 2002. The issue about the energy ramping to achieve the 2.5 GeV beam will be discussed. The operational performance and beam parameters that are related to the 2.5 GeV full enenrgy injection are presented.

LINAC

PLS linac had injected 2 GeV electron beams to storage ring from September 1994 to October 2002. During that time, linear accelerator had used as 2 GeV injector to the storage ring. At the end of 1997 one klystron modulator system and two accelerating columns were installed to the linac to add energy of 150 MeV. The module consists of one klystron of 80 MW peak, a modulator of 200 MW peak and one pulse compressor. The linac has been continuously improved to raise stability and reliability in the system, as well as to raise injection energy to 2.5 GeV. Current overall system availability is around 95 %. PLS linac has total 12 modules with 44 accelerating structures. Accordingly, PLS linac could increase injection energy to 2.5 GeV by using the 12 accelerating modules. However, several issues had to be realized before performing the 2.5 GeV full energy injection: stability and reliability of the linac in 2.5 GeV, optics optimization and energy stability of the linac in 2.5 GeV. The linac includes 13 beam current monitors and 12 beam profile monitors for the diagnostics of the beam. The delivery rate of the beam mainly depends on the beam optics and RF phase control. The beam loss rate on 2.5 GeV full energy injection shows around 30% in the linac.

Beam dynamics issues affect the PLS linac performance. Figure 1 shows beam sizes in optics of the present 2.5 GeV linac. Investigation on tolerance for beam injection and alignment of accelerator components is also being performed[2]. In the early period of 2.5 GeV operation, the RF phase due to changes of temperature and cooling water influenced beam energy and beam quality. The RF phase variation of high power is being controlled by adjusting the RF phase of the driving signal for klystron through IPA system. The PLS 2.5 GeV linac has satisfactorily served as full energy injector to the storage ring since the October 2002.

STORAGE RING

The PLS was designed to store the electron beam up to 2.5 GeV. There are two ways to store the beam of 2.5 GeV: first way is to ramp the beam of 2 GeV in the storage ring to 2.5 GeV and second way is to perform the full energy injection from the linac.

The full energy injection way has merits in several facts: in machine stability, shorter injection time, orbit stabilty and so on. However, several issues in the storage ring had to be solved to realize the 2.5 GeV full energy injection: power stabilities in the injection kicker magnet and septum magnet, and effect of leakage field in the septum magnet on the beam orbit. In the following subsections we will discuss these issues that are investigated to perform the 2.5 GeV full energy injection.

Energy Ramping and De-ramping

During January 2000 to April 2001, 2 GeV beam was injected from the linac to the storage ring and then the beam was ramped to 2.5 GeV. In order to re-fill the beam current at 2.0 GeV, a 2.5 GeV beam was dumped and degaussing was performed. Then the 2.0 GeV beam was injected and ramped to 2.5 GeV. In the ramping process the energy increment rate in bending and Q2 power supplies varied as the beam energy increases. This is because the relationship of magnet field strength and MPS current is not linear due to insufficient synchronization. It also showed large variations in betatron tunes during the ramping process. Both vertical and horizontal betatron tunes were merged at approximately 0.25 at the starting of ramping in order to prevent beam loss during the ramping process because the betatron tunes hit the third-order resonance. Energy ramping under on resonance also caused significant changes in beam lifetime due to enlarged vertical beam sizes.

During May 2001 to October 2002, it was possible for 2.5 GeV beam to de-ramp without beam dumping to 2.0 GeV in the new energy ramping system. The energy increment rate per step in the new energy ramping system is constant per step during the energy ramping: 0.32% per step for bending and 0.30% per step for other magnets. New energy ramping control system showed better synchronization than the previous energy ramping control system. In addition to the energy ramping, the new ramping control system could also decrease the beam energy from 2.5 GeV to 2.0 GeV (de-ramping), at the same rate but in the reverse direction with the energy ramping. The operation could be performed without merging the betatron tunes at approximately 0.25 at the start of ramping. The variation of closed orbit distortion during energy ramping was reduced by a factor of 1.5 compared to that of the previous ramping system. Practically no beam loss was noted during the ramping at the speed which requires 1.3 min to increase from 2 GeV to 2.5 GeV. The ramping speed was about four times faster in the new ramping system than in the previous ramping system.

Magnet Power Supply

The LC resonance frequency of 18 Hz in the bending magnet power supply was observed in beam position monitors and an undulator beam line. When the LC values in the filter were changed, beam signal with the same components were also obserevd in the beam position monitor and the undulator beam line on normal operation. Then, the LC filter was changed to structure of the (LC+RC) filter. The circuit has the values of $L1$= 2 mH, $L2$= 1 mH, $C1$=34000 μF, $C2$=6800 μF and $R = 0.6\Omega$. Then we could observe that the ripple component of 18 Hz was greatly reduced. By decreasing integral constant of error amplifier from 10 μ to 1 μ, we increased bandwidth of current-control loop. Then the current stability was improved from 100 ppm to 50 ppm. Further, current stability was also improved from 50 ppm to 15 ppm as DCCT of current-control loop was replaced.

Injection

The injection system in the PLS storage ring consists of a Lambertson-type septum magnet and four injection kicker magnets. When we perform the 2.5 GeV full energy injection, leakage field of the septum magnet is increased and rms value of the vertical COD increases about five times. Orbit correction to reduce the orbit deviations due to the leakage field was sufficiently performed.

The four kicker magnets are operated by single power modulator for local bump orbit. The current requirement in the kicker magnets is 22500 A for 2.5 GeV, while it is 19500A for 2 GeV operation. The maximum capacity of the modulator is 24000A. On the other hand, when we utilized a DC bump that was consisted of two bendings and two correctors, it was shown that beam injection was could be performed with current of the kicker magnet of 19500A.

Beam Lifetime

In the present operation of the 2.5 GeV, Touschek effect is a dominat factor that determines the beam lifetime. The gas scattering and gas-bremsstrahlung give minor effect on the beam lifetime. If we estimate the beam lifetime due to the gas-scattering, gas-bremsstrahlung and intra-beam scttering processes, it gives the beam lifetime around 18.9 hours in beam current of 180 mA under the vacuum pressure of 0.6 nTorr. Horizontal and vertical apertures are $100\sigma_x/\beta_x$ and $100\sigma_y/\beta_y$, respectively. Energy aperture is 1.5%. It is shown that the beam lifetimes obtained from the simulation well agree with ones obtained on normal operation.

Beam Instabilities

During the user operation between Jan. 2000 and July 2000, the number of bunches was 468 that was equal to the harmonic number. Operated tune was 14.26 and 8.15 in horizontally and vertically, respectively. We observed resonant frequency of 831.8 MHz in beam spectrum due to transverse higher order mode in rf cavities.

Since September 2000, we have changed the number of bunches and betatron tune for the user operation. At present, the number of bunches is 400 and operating tune is 14.28 and 8.18 in horizontally and vertically, respectively. We don't observe resonant frequency in beam spectrum due to rf HOMs. The beam at the 2.5 GeV can be stably stored up to 200 mA. At present higher beam current than 200 mA is limited by total rf power. On the other hand, the beam current of 450 mA at 2 GeV could be stored without using of trasnsverse and longitudinal feedback systems.

Orbit Stability

The dominant source of orbit fluctuation in the storage ring is slow drift due to temperature variations and gap change of insertion device. There are three major causes of thermal variations: 1) variation in air temperature of the ring tunnel, 2) variation in the low conducting water temperature, and 3) variation in underground movement. Gap change in the insertion device is the next largest source of slow orbit distortion. The horizonatl orbit is mainly affected by the gap of insertion device. Without orbit feedback, orbit drifts of rms 30 micron to rms 100 micron have been observed on normal opration of 10 days period.

Global Oribt Correction

A global orbit feedback system was installed on the PLS storage ring to correct horizontal and vertical orbit distortion. The system that consists of 96 BPMs and 140 correctors has been tested to suppress orbit fluctuation due to the orbit drift. The closed orbit distortion was measured and excitation currents of the correctors were calculated with the SVD method. Rms horizontal and vertical closed orbit distortion before the global orbit correction were 1.1 mm and 1.2 mm, respectively. After global orbit corrections the rms orbits were reduced to 0.2 mm and 0.4 mm, respectively. The difference orbit (orbit drift) relative to the operational orbit of the PLS storage ring was around rms 70 micron and it was also corrected by using of the global orbit correction. Then the orbit drift could be suppressed to the level of less than rms 10 micron. It means that the global orbit feedback system is demonstrated and is effective to suppress the orbit drift in the PLS. Global orbit orrection will be applied every after beam injection. The real-time feedback system will be prepared to provide more stable beam. With the global orbit correction on the operation, we expect that orbit drift will be greatly decreased and photon beam stability at the beam lines will be more improved.

Beta function

Beta-function correction that includes compensation of gradient error, correctors error and BPMs error is being performed to minimize the horizontal and vertical beam sizes and to restore design periodicity of the storage ring. Measured horizontal beta function before and after the correction in the present 2.5 GeV lattice is shown in Figure 2.

Linear Coupling and Chromaticity

Linear coupling constant is estimated by measuring tunes close to the coupling resonance. The minimum separation of tunes are obtained by measuring of the horizontal and vertical tune variations as a function of quadrupole power supply current. The coupling constant is shown to be 0.8 % on operation. When skew quadrupoles are excited, minimum achievable coupling constant is around 0.15 %. Measured natural horizontal and vertical chromaticities are -16.6 and -12.3, respectively. Chromaticity is 0.7 and 1.1 in horizontal and vertical directions, respectively.

Broadband Ring Impedance

Broadband ring impedance was estimated by measuring bunch-lengthening in the ring. Longitudinal impedance was analyzed through a R+L model. The results are estimated to be around R= 800Ω and L= 14 nH.

CONCLUSION

In this report, we presented various activities that were performed to achieve the 2.5 GeV full energy injection operation in the PLS storage ring and linac. Operational performance and beam parameters of the linac and the storage ring are also described.

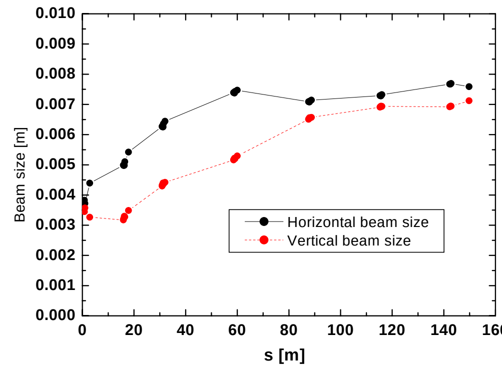

Figure 1: Beam sizes in the optics of the present 2.5 GeV linac.

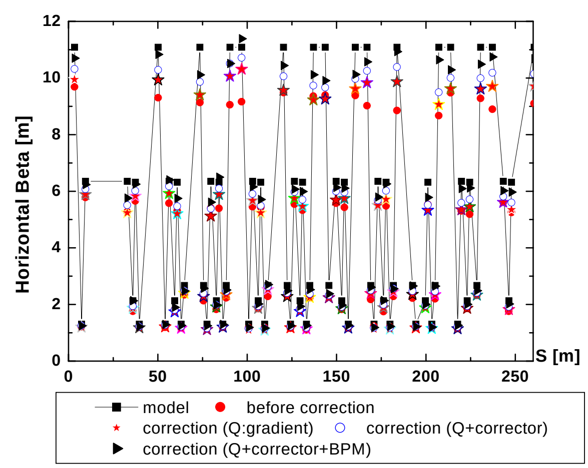

Figure 2: Horizontal beta-functions in the present 2.5 GeV storage ring

REFERENCES

[1] Pohang Light Source Design Report 1992.

[2] Eun-San Kim, PAC2001, p.1945, Chicago, June 2002.

[3] H. Heo, E.-S. Kim and S.-H. Nam, In these Proceedings.