ACCELERATOR PHYSICS ISSUES AT THE 2.5 GeV PLS STORAGE RING

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Abstract

Over the past decade, Pohang Light Sourec(PLS) has served the synchrotron light source with 2.0 GeV to 2.5 GeV electron beam. We present several accelerator physics issues that have been investigated to raise the performance of the light source at the 2.5 GeV storage ring. We show the results of studies on effects of six insertion devices on the lattice, a low-beta lattice for undulator, a low-emittance lattice and a low-alpha lattice, and show effects of these lattices on the beam dynamics in the storage ring.

INTRODUCTION

In Dec. 1994 the PLS storage ring started to operate with a 2-GeV electron beam. Since Sep. 2002 the storage ring has being operating with a 2.5-GeV full energy injection from a linac[1]. There has been many user's demand for more bright X-ray sources at the 2.5 GeV operation. The PLS lattice consists of triplet bending achromat(TBA) lattice with 12 superperiods[2]. We show the results on investigation of lattices that have been investigated in order to provide more brilliant synchrotron radiation. In the next section, we show the effects of insertion devices at the ring on the beam parameters and show optics compensation to minimize their effects. A lattice design of low-beta for In-vacuum undulator is shown in Sec. III. In Sec. IV, we show a low-emittance achromat lattice with the emittance of 10.3 nm that may provide about 1.5 times larger brilliant synchrotron radiation than the present lattice with an emittance of 18.9 nm. In Sec. V, we show design of a lattice for quasi-isochronous ring that may produce sub-picosecond bunch length. The last section is devoted to the conclusion.

EFFECTS OF THE INSERTION DEVICES ON THE LATTICE

We investigated the effects of the insertion devices on the betatron tune, the beta function, the energy spread and the emittance in the storage ring. Table 1 presents the parameters of the insertion devices in the PLS. Table 2 presents variations of the emittance, the energy spread, the vertical tune and the beta-function that are obtained from analytical calculations and numerical calculations (parenthesis) performed by using of SAD[3]. When the six insertion devices are included in the ring, it is shown that the emittance is decreased from 18.8 nm to 15.8 nm, and the energy spread is increased by 0.7%.

Figure 1(a) and (b) show the dynamic apertures in the center of a straight section when the six insertion devices are not included and are included, respectively. The Figure shows that the insertion devices make considerably reduce the dynamic apertures in both the horizontal and the vertical directions. The dynamic apertures are shown in the cases of -1%, 0%, and 1% momenta deviations. From the tracking simulations, we could see that the HFMX and the HFMS gave the largest effect on the dynamic aperture.

Figure 2(a) shows the lattice when the insertion devices are not considered in the ring. Figure 2(b) shows the lattice when the six insertion devices in Table 1 are included in the ring. Figure 2(b) shows that both the vertical beta function and the horizontal dispersion function are distorted due to the six insertion devices. Then the vertical betatron tune is varied from 8.18 to 8.237. We performed optics matching to minimize the distortion of the lattice functions. For the matching, the Q4, Q5 and Q6 quadrupoles are independently contolled in the individual superperiod that includes the insertion device. Figure 2(c) shows the compensated optics in which the Q4, Q5, and Q6 quadrupoles, in addition to the Q1, Q2, and Q3 quadrupoles, are used to match smoothly both the β-function and the dispersion function in the six insertion devices to the normal superperiods.

Table 1: Parameters of the insertion devices at the PLS

	Length	**Period**	**Magnetic field**	**Pole gap**
HFMX	2.05m	14cm	2.02T	14mm
U10	1.6m	10cm	1.32T	16mm
U7	4.3m	7cm	0.99T	16mm
EPU6	1.5m	6cm	0.69T	18mm
In-Vacu.	1m	2cm	0.728T	5mm
HFMS	2.05m	14cm	2.20T	14mm

Table 2: Effects of the insertion devices in the 2.5 GeV ring on the beam parameters

	$\Delta\epsilon/\epsilon$	$\Delta\sigma_\delta/\sigma_\delta$	$\Delta\nu_y$	$\widehat{\Delta\beta/\beta}$
HFMX	-5.8%	0.2%	(0.02) 0.02	(16%) 14%
U10	-2.1%	-0.2%	(0.006) 0.007	(4.8%) 4.5%
U7	-2.6%	-0.7%	(0.01) 0.01	(8.0%) 6%
EPU6	-0.5%	-0.09%	(0.001) 0.002	(0.8%) 1%
In-Vacu.	-1.0%	-0.09%	(0.001) 0.002	(0.8%) 1%
HFMS	-5.8%	0.2%	(0.02) 0.02	(16%) 14%

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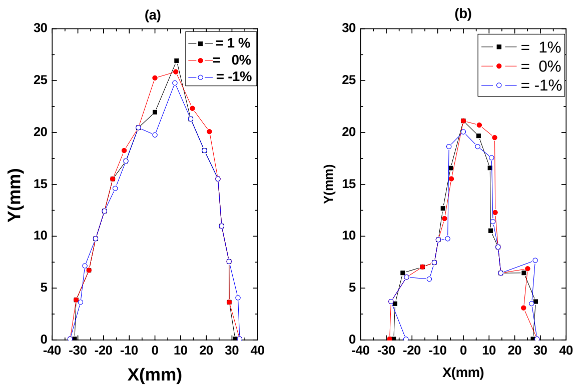

Figure 1: Dynamic apertures at the center of the straight section: (a) without the insertion devices ($\nu_x = 14.28$ and $\nu_y = 8.18$) and (b) with the six insertion devices ($\nu_x = 14.28$ and $\nu_y = 8.237$).

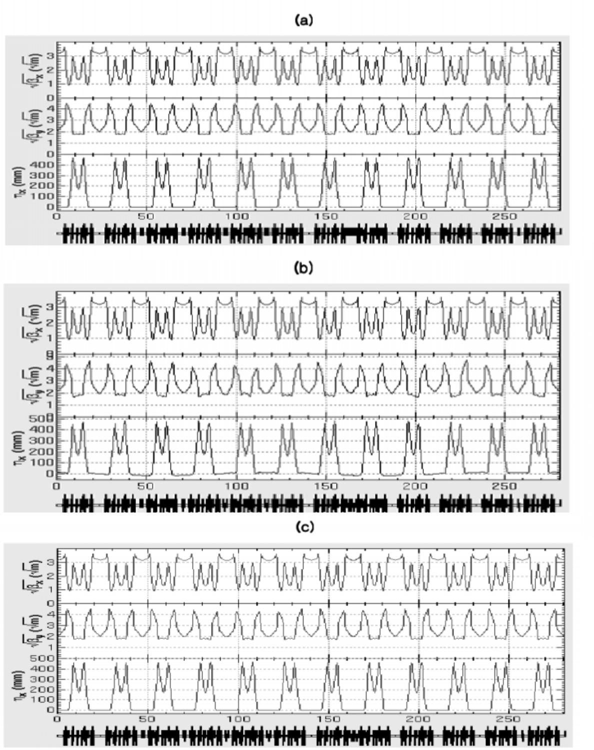

Figure 2: Optics at the 2.5 GeV ring: without the insertion devices, (b) with the six insertion devices, and (c) with the six insertion devices and optics compensation.

A LATTICE FOR LOW-BETA IN IN-VACUUM UNDULATOR

A low-beta lattice in the ring was designed to provide more brilliant synchrotron radiation in a undulator. In particular, low-beta lattice for the In-vacuum undulator with small gap is important because reduced beta-function results in decreasing of the usable undulator gap. Reducing of available undulator gap will increase the maximum K value and extend the tuning range to lower energies. Figure 3 shows that it is possible to reduce locally vertical beta-function at the center of the straight section in the In-vacuum undulator from 4 m to 2 m. We could get a betatron tune of ν_x=14.17 and ν_y=8.31 that shows comparatively large dynamic aperture from the tracking method. From these results, it is shown that the low-beta lattice in the 2.5 GeV ring has a sufficient dynamic aperture. It is also shown that the dynamic aperture in the low-beta lattice has a tolerance of about 150 μm rms in the alignment error of the quadrupoles.

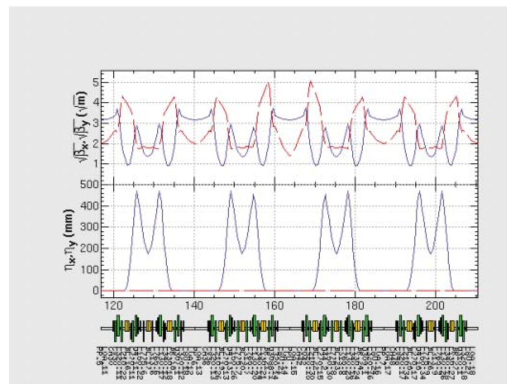

Figure 3: A designed lattice for low-beta in the In-vacuum undulator at 10th cell in the ring. Vertical beta-functions (red one) with a low-beta and with normal-beta in the straight sections are 2 m and 4 m, respectively.

A LATTICE FOR LOW EMITTANCE

A lattice with emittance of 10.3 nm at the 2.5 GeV was designed to produce more brilliant synchrotron radiation than the present lattice with emittance of 18.9 nm. Figure 4 shows an optics with achromat in the emittance of 10.3 nm. It is necessary to estimate how a sufficient dynamic aperture for beam injection and storage into the ring can be obtained in the low emittance lattice. The dynamic apertures in the lattice without and with machine errors were examined by a tune survey to search for a large dynamic aperture. The optimal tune was chosen on the view point of dynamic apertures obtained from a tune survey by a simulation method. It is shown that the low emittance lattice may provide a sufficient dynamic aperture in the storage ring, as shown in Figure 5.

A QUASI-ISOCHRONOUS LATTICE FOR SUB-PICOSECOND BUNCH LENGTH

Figure 6 show design of a lattice for quasi-isochronous storage ring that may produce sub-picosecond bunch

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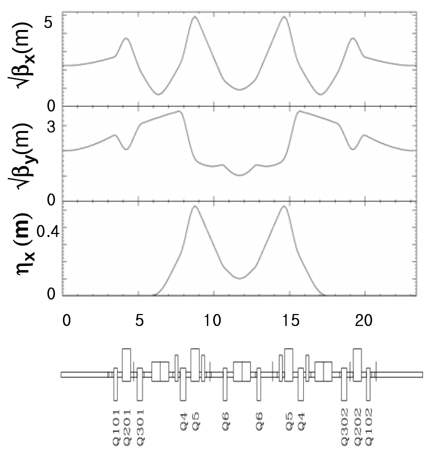

Figure 4: A lattice with emittance of 10.3 nm at 2.5 GeV.

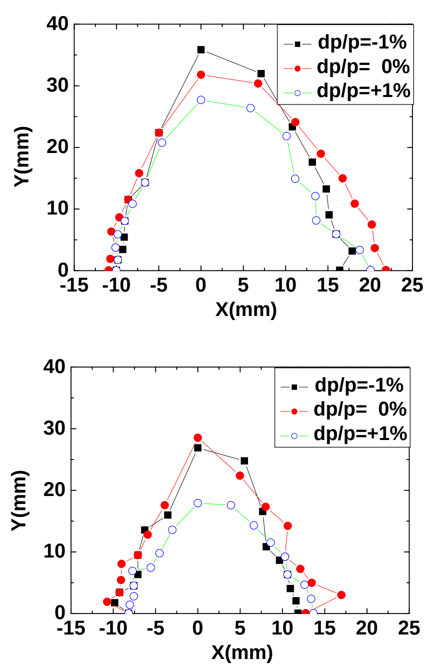

Figure 5: Dynamic apertures in the lattice with the emittance of 10.3 nm. (Top) Without machine errors, (bottom) with machine errors.

length. Small momentum compaction factors in the ring could be obtained by varying the dispersion function to be negative values in the positions of bending magnets. The shortest bunch length in the quasi-isochronous mode is estimated to be less than 1 ps, which is three tenth of that of the normal operation. The relation between the momentum compaction factor and the bunch length that can be obtained in the quasi-isochronous ring is shown in Figure 7. The bunch length as a function of the momentum compaction factor is estimated by the dispersion function ranging from 0.08 m down to -0.18 m. The effects of second-order momentum compaction factor on the transverse and longitudinal particle dynamics in the quasi-isochronous ring were also investigated. Our studies indicate that it is possible to operate the ring in a quasi-isochronous mode and is possible to control bunch length by means of changing the momentum compaction factor in the ring. We found out that a quasi-isochronous ring in the PLS makes it possible to produce the bunch length in sub-picosecond range.

CONCLUSION

Accelerator physics issues at the 2.5 GeV PLS have been investigated in order to raise the performance of the light source. Major work will be focused to utilize newly designed lattices in near future. It is expected that the newly designed lattices will provide sources for more brilliant radiation at the 2.5 GeV PLS storage ring.

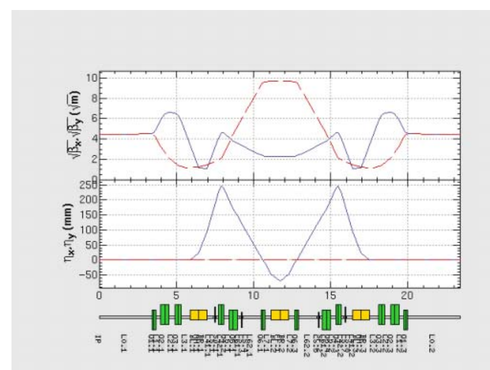

Figure 6: A designed lattice for the quasi-isochronous mode in 2.5 GeV ring. Momentum compaction factor is 6.8×10^{-6}.

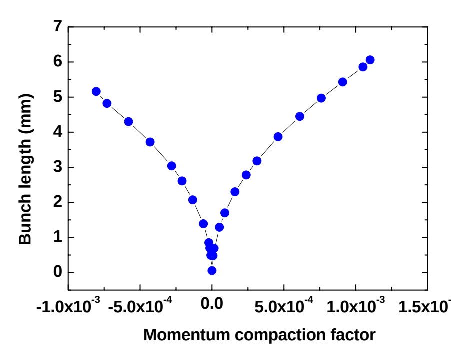

Figure 7: Rms bunch length as a function of the momentum compaction factor in the 2.5 GeV ring.

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