ISSUES ON BEAM DYNAMICS IN PLS-II

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Abstract

Pohang Light Source-II (PLS-II) is an upgrade project of the existing 2.5 GeV PLS. The circumference, beam current and energy of PLS-II storage ring are 281.82 m, 400 mA and 3 GeV, respectively. The upgrade project has many issues on beam dynamics. We investigated lattice optimization such as lattice corrections, dynamic aperture, selection of optimized tune and effects of insertion devices. MAD, SAD and Elegant have been used to the lattice optimization. We investigated the effects of machine errors and frequency map analysis at the lattice. PLS-II lattice includes double number of insertion devices than in the PLS and their effects on the beam dynamics are investigated.

INTRODUCTION

The upgrade project of 3 GeV includes emittance of 5.7 nm-rad, beam current of 400mA and 20 insertion devices. The 3 GeV ring with two combined bendings in one cell is newly constructed in the existing tunnel. The lattice functions for one cell are shown by Figure 1. The lattice has 6.8 m long and 3.7 m long straight sections in one cell.

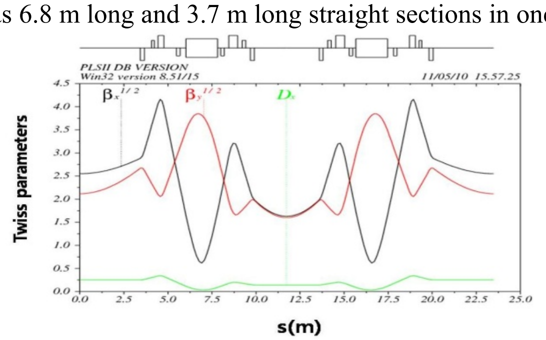

Figure 1: PLS-II has 12 cells. Lattice functions in one cell are shown.

EFFECTS DUE TO INSERTION DEVICES

Natural emittance can be described by synchrotron radiation integrals and is given by

$$\varepsilon_{x0} = C_q \gamma^2 \frac{I_5}{I_2 - I_4},$$

where C_q is 3.83×10^{-13} m and γ is the Lorents factor. The synchrotron radiation integrals is defined by [1]

$$I_2 = \oint \frac{1}{\rho^2} ds \quad (1)$$

$$I_4 = \oint \frac{\eta_x}{\rho} \left(\frac{1}{\rho^2} + 2K\right) ds \quad (2)$$

$$I_5 = \oint \frac{\mathcal{H}}{|\rho|^3} ds, \text{ where } \mathcal{H} = \frac{\eta_x^2 + (\alpha_x \eta_x + \beta_x \eta_x')^2}{\beta_x} \quad (3)$$

The integrals are taken at the entire storage ring. K is the focusing function. β_x is the horizontal betatron amplitude

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and α_x is determined by $-\beta_x'/2$. η_x is the horizontal dispersion and η_x' is differential of the horizontal dispersion. Natural emittance is then varied due to effects of insertion devices.

$$\varepsilon_x = \varepsilon_{x0} \left(\frac{1 + \frac{\Delta I_5}{I_5^0}}{1 + \frac{\Delta I_2 - \Delta I_4}{I_2^0 - I_4^0}} \right), \quad (4)$$

where the subscript 0 denotes the value of without insertion devices. The parameters of three types of insertion devices are listed in Table 1. Figure 2 shows the emittance variation for the number of insertion device of ID2. The emittance shows an agreement between MAD8 and Eq. (4).

Table 1: Parameters of insertion devices of PLS2

Name of ID	Length of ID	Peak Field (Tesla)	Number of ID
ID1	1.96 m	2.0	3
ID2	2 m	1.2	7
ID3	3.99 m	1.0	10

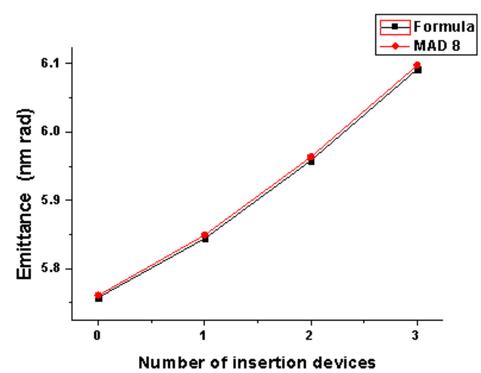

Figure 2: The emittance variation for the number of ID2.

Table 2 shows for the variations of the emittances that are calculated by MAD8 and the formula Eq. (4).

Table 2: Emittance due to effects of each IDs

ID Length	Number of IDs	Emittance (nm-rad)	
		MAD 8	Formula
w/o ID	0	5.7610	5.7580
1.96 m	1	6.1831	6.1776
2 m	1	5.8202	5.8150
3.99 m	1	5.8494	5.8441
ALL ID	20	7.5596	7.5528

ESTIMATION OF NONLINEAR EFFECTS

Frequency map analysis can be used to determine the underlying resonances that affect the stability of electrons and momentum apertures. Nonlinear effect of storage ring may deteriorate the performance of light source. We simulated the frequency map with 1000 particles and 1000 turns. The result of frequency map analysis of the bare lattice is shown by Figure 3.

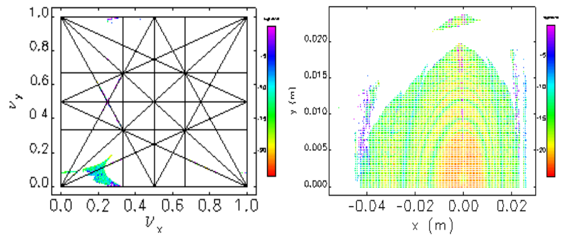

Figure 3: Frequency map of the bare lattice.

The horizontal and vertical tunes of the bare lattice are 15.28 and 9.18, respectively. It shows 22mm horizontal dynamic aperture and 18mm vertical dynamic aperture.

Frequency Map Analysis by Insertion device

We investigate the effects of insertion devices on on-momentum frequency map analysis.

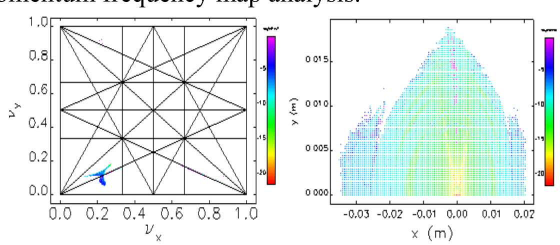

Figure 4: Frequency map for 3 ID1.

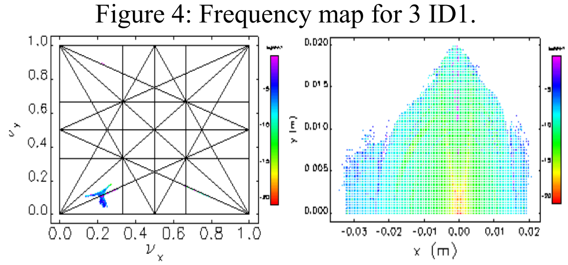

Figure 5: Frequency map for 7 ID2.

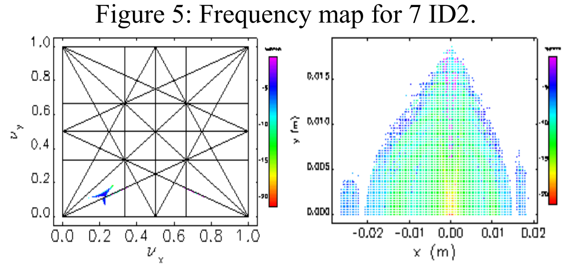

Figure 6: Frequency map for 10 ID3

In cases of ID1 and ID3, vertical direction of dynamic aperture is reduced. ID3 greatly affects horizontal dynamic aperture. Smaller dynamic aperture may lead the reductions of efficiency of beam injection and beam life-time.

COMPENSATION OF MACHINE ERROR

The main perturbations on the beam dynamics from misalignment and field errors of bending, quadruple and sextupole magnets can reduce the dynamic aperture and induce growth of emittance. Also, distortions break the periodicity of the lattice function and phase advance between sextupoles, which can lead to stronger resonances and reduce dynamic aperture. We assume that the errors have gaussian distribution. Alignment error, tilt error and field error are given by 100 μm rms and 0.2 mrad rms and 0.05% rms, respectively.

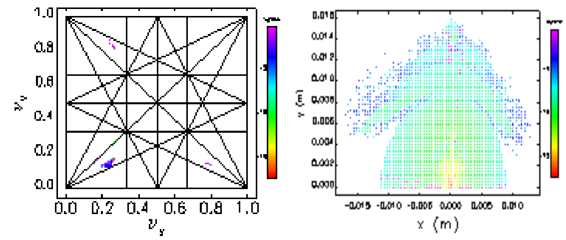

Figure 7: Frequency map for the machine errors and 20 insertion devices.

In the Figure 7, the frequency map shows around 8mm in horizontal direction. The lattice is sensitive to machine errors. It is caused by lattice function distortion and closed orbit distortion. It is necessary to minimize distortions of the lattice due to machine errors through optics matching to obtain a dynamic aperture that is as large as possible. We performed compensation of the emittance growth and tune correction by globally correction. For this, we performed corrections of the closed orbit distortion and chromaticity with lattice function matching.

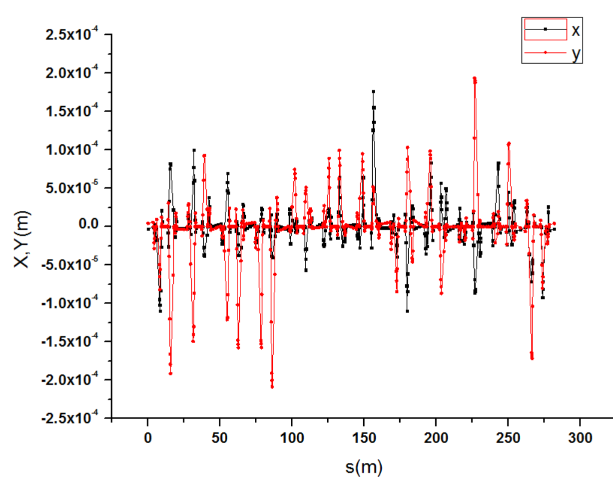

Figure 8: Beam orbit after correction closed orbit distortion.

The PLS-II lattice is composed of 12 superperiods, each one consisting of 4 family sextupole. The correctors will be installed with sextupole magnets. In the Figure 8, amplitude of the orbit is below 200 μm. Emittance was compensated to 7.56 nm-rad from 9.34 nm-rad. We performed the global lattice function matching with tune correction using by quadrupole and chromaticity correction by sextupole and closed orbit correction by corrector. The result of lattice function matching is shown by Figure 9.

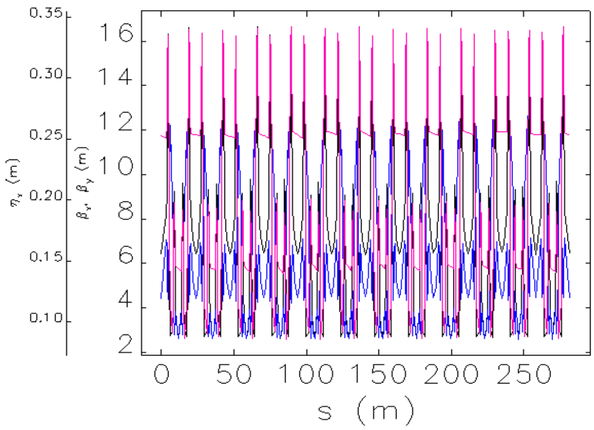

Figure 9: Lattice function after the optics matchings. (β_x : Black, β_y: Blue, η_x : Pink)

Figure 10 shows the dynamic aperture after lattice function matching, chromaticity correction and orbit correction. It is shown that the machine errors and 20 insertion devices greatly affect the dynamic aperture.

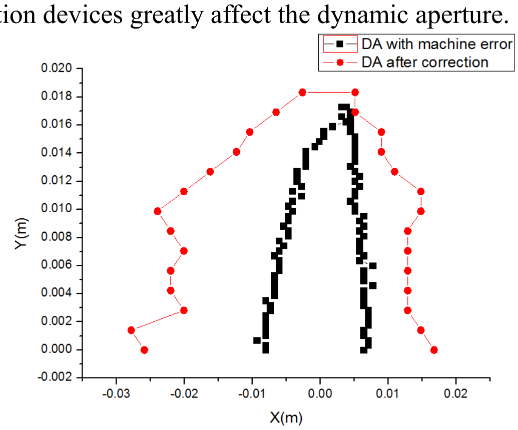

Figure 10: Dynamic apertures of PLS-II at the center of the straight section. ν_x=15.28, ν_y=9.18. After corrections (red) and before corrections (black).

The horizontal dynamic aperture with the machine errors gives 7mm. It is compensated to 17 mm by the optics corrections. Figure 11 show the frequency map after the optics corrections.

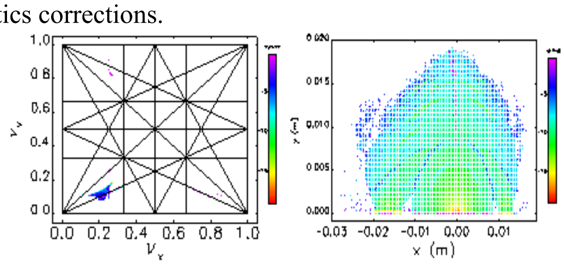

Figure 11: Frequency map after the optics corrections in the lattice with machine errors and 20 IDs

EMTTANCES WITH VARIATIONS OF TUNES AND DISPERSION

We investigated emittance variances by changing the horizontal tune and the value of dispersion. The results are shown in Figure 12. The emittance at horizontal tune of 16.28 and dispersion of 0.22 m shows an emittance of 5.12 nm-rad.

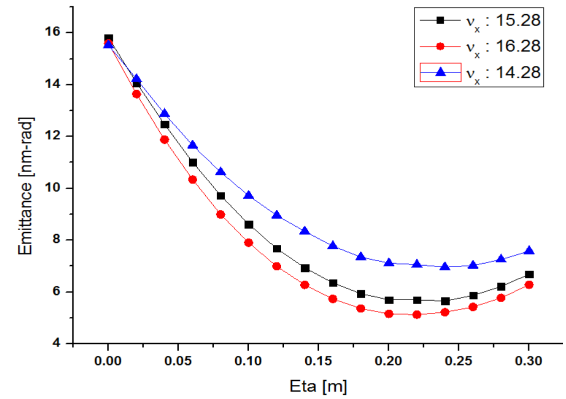

Figure 12: Emittances versus different horizontal tunes and dispersions.

SUMMARY

The beam dynamics issues of the PLS-II have been investigated by Elegant and MAD and SAD. We considered the effects of machine errors and insertion devices. ID1 gives larger emittance growth than the other insertion devices. The lattice of PLS-II is sensitive to machine errors. It can be suppressed by lattice function matching, in result, which shows dynamic aperture an enough for the beam injection. After the optics corrections, the lattice shows horizontal and vertical dynamic apertures of 17 mm and 18 mm, respectively.

REFFERENCES

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