Magnet Lattice of the Pohang Light Source

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Features of the 2 GeV Pohang Light Source Accelerator are described. The lattice type is Triple Bend Achromat (TBA). The whole circumference of 280.56 m is composed of 12 cells each of which has 12 quadrupoles. The harmonic number is 468 ($= 2^2 \cdot 3^2 \cdot 13$) and the corresponding RF frequency is 500.082 MHz. The aimed natural emittance is 12 nm·rad. The description is mainly concerned with lattice poperties and Insertion Device (ID) effects.

I. LATTICE PROPERTIES

The Pohang Light Source (PLS) has a storage ring of 12 period mirror-symmetric TBA lattice. Its relatively long length of 280.56 m can accomodate 12 quadrupoles in each cell. This large number of quadrupoles provides flexibilities and a number of varieties. A standard β function plot is given in Fig. 1. Triplets of quadrupoles in the straight sections will be used for ID matching and triplets of quadrupoles in the achromat section are used for the control of dispersion function and phase advance as well as matching η_x'. Lattice specifications and beam parameters are listed in Table I. The bending magnets are rectangular and separated functioned. With the energy of 2 GeV, the rigidity $B\rho$ is 6.67 T·m. Magnet specifications are listed in Table II. Two pairs of sextupoles, one focusing and one defocusing, are used for chromaticity correction. The sextupole strength is low compared with other third generation machines.

Sextupoles have additional trim windings to correct the closed orbit distortions. Of the whole 48 sextupoles, 16 have another windings to control the skew quadrupole components arising from both quadrupole rotation error and vertical closed orbit distortion at the location of the sextupoles. The tune versus momentum plot resulting from chromaticity correction is shown in Fig. 2. As usual in TBA lattices, no harmonic correction sextupole is employed. Harmonic correction sextupoles improve dynamic aperture to some extent, but not as much as to justify the complexities and higher order fields induced by their presence.

For the analysis of multipole error sensitivity, we used essentially the same data as the one used in ALS of LBL[1].

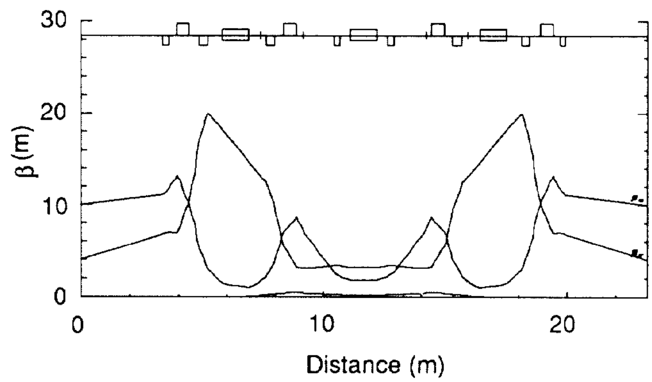

Figure 1: PLS Lattice

Critical Photon Energy (E_c)	2.8 keV
Natural emittance (m-rad)	1.21×10^{-8}
Natural energy spread, rms	6.8×10^{-4}
Bunch length, rms, natural (mm)	4.78
RF Voltage (MV)	1.8
Insertion straight length (m)	6.8
Bending radius (m)	6.303
Sextupole Strength ($1/m^2$)	
SF	4.49
SD	-6.48
Betatron tunes	
Horizontal (ν_x)	14.28
Vertical (ν_y)	8.18
Synchrotron tune (ν_s)	0.0115709
Natural chromaticities	
Horizontal (ξ_x)	-23.36
Vertical (ξ_y)	-18.19
Maximum beta functions (m)	
Horizontal (β_x)	13.17
Vertical (β_y)	20.0
Beta functions at ID center (m)	
Horizontal (β_x)	10.0
Vertical (β_y)	4.0
Maximum dispersion, η_x (m)	0.46464
Radiation loss per turn, dipoles (keV)	225

Table 1: PLS Parameter List

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Element	Length(m)	Strength
Q1	0.24	-4.28 T/m
Q2	0.53	10.13 T/m
Q3	0.35	-11.30 T/m
B	1.1	1.06 T
SD	0.2	-6.48 m^{-2}
Q4	0.35	-9.71 T/m
Q5	0.53	12.14 T/m
SF	0.2	4.49 m^{-2}
Q6	0.24	-5.30

Table 2: PLS Magnet Parameters

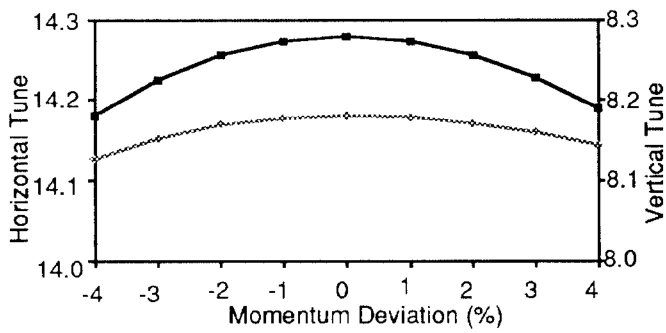

Figure 2: Momentum versus Tune

The notation we use is defined by the expansion

$$B_y(x) = B\rho \sum_n \frac{k_n x^n}{n!}, \qquad k_n = \frac{d^n B_y}{dx^n}. \tag{1}$$

The dynamic aperture with and without multipole errors is ploted in Fig. 3, which is the output of MAD6 after 300 turns. The graph shows that the PLS lattice has fairly strong rigidity against multipole components. Also more detailed analysis indicated that the random quadrupole component is dominantly influent on the dynamic aperture among multipoles. The random decapole components arising from corrector windings of sextupoles are not serious in our case, which gave negative effects in Elettra of Trieste[2].

II. CLOSED ORBIT CORRECTION

The closed orbit correction scheme is a key issue in the machine operation. In PLS, each cell has 9 beam position monitors, 8 horizontal correctors and 7 vertical correctors. Among them, 6 correctors are horizontal and vertical combined ones. These correctors can be used for global and local orbit correction. The maximum kick angle of correctors is designed to be 2.0 mrad. However, for the operation, 1.3 mrad is set to be the maximum by power supply. Additional corrector windings of the four sextupoles in a cell will be activated, two of them horizontally and the other

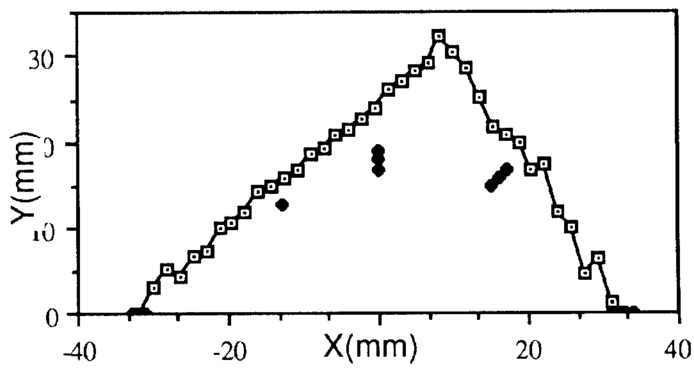

Figure 3: PLS Dynamic Aperture

two vertically. Because of this separation of sextupole correctors, their multipole effects are not so harmful.

The rms orbit distortion can be computed analytically as follows

$$x_{rms} = \frac{\sqrt{\beta_x}}{2\sqrt{2}\sin \pi\nu_x}\Bigg[\theta_B^2\left(\frac{\Delta B}{B}\right)^2_{rms}\sum_i \beta_{x_i} + (\Delta x_Q)^2_{rms}\sum_i (kl)_i^2\beta_{x_i}\Bigg]^{\frac{1}{2}}, \tag{2}$$

$$y_{rms} = \frac{\sqrt{\beta_y}}{2\sqrt{2}\sin \pi\nu_y}\Bigg[\theta_B^2(\Delta\phi)^2_{rms}\sum_i \beta_{y_i} + (\Delta y_Q)^2_{rms}\sum_i (kl)_i^2\beta_{y_i}\Bigg]^{\frac{1}{2}}, \tag{3}$$

where $\Delta B, \Delta\phi$, are bending magnet field error and bending magnet rotation error respectively. Also $\Delta x_Q, \Delta y_Q$ are horizontal and vertical misalignment errors of quadrupoles respectively. With errors of

$$\frac{\Delta B}{B} = 0.001, \Delta\phi = 0.5mrad, \Delta x_Q = \Delta y_Q = 0.15mm, \tag{4}$$

the above formula gives

$$x_{rms} \approx 4\text{mm}, \qquad y_{rms} \approx 9\text{mm}. \tag{5}$$

These analytic results are a little bit higher than computer calculation of MAD6. Higher value of y_{rms} than x_{rms} is a consequence of higher average value of β_y than β_x. After correction, these numbers are reduced to values less than 0.1 mm without monitor error. Fig. 4 and 5 display the typical closed orbit distortion before and after correction respectively.

III. INSERTION DEVICE EFFECTS

Insertion Devices not only break the linear optics of the lattice but also introduce higher order field components that may excite non-systematic resonances. The linear optics

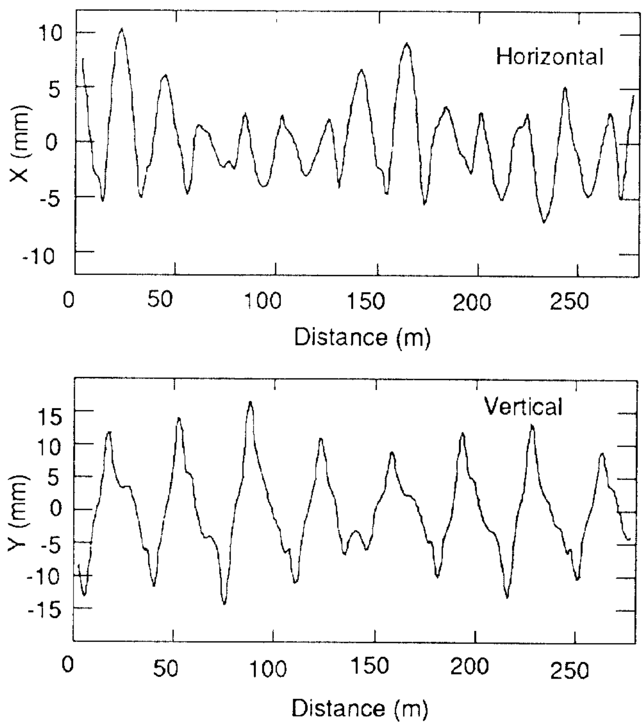

Figure 4: Closed Orbit Distortion Before Correction

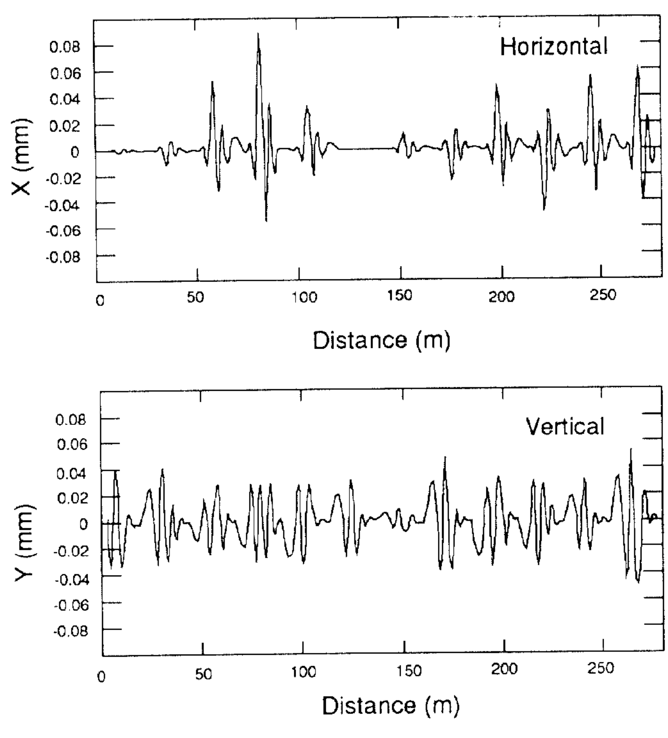

Figure 5: Closed Orbit Distortion After Correction

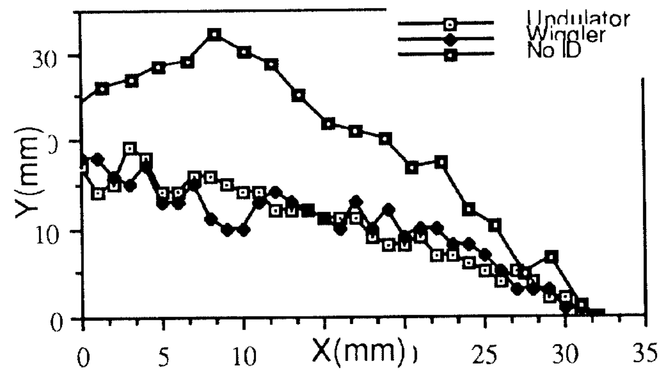

Figure 6: Dynamic Aperture with ID's

break comes from the vertical focussing of the ID's, which modifies the vertical tune and breaks the $\alpha = 0$ condition necessary to guarantee the closed orbit formation. This linear disturbances can be repaired to a certain degree by readjusting the three pairs of quadrupoles surrounding an ID. In PLS, each pair of quadrupole located on each side of the nondispersive region is connected in series to the power supply. The two pairs of quadrupoles are readjusted to reset $\alpha = 0$. This step is called 'α matching'. The remaining pair was chosen to be used for minimizing $\sqrt{\Delta\nu_x^2 + \Delta\nu_y^2}$, where $\Delta\nu_x$ and $\Delta\nu_y$ are tune changes due to ID's. This might be called 'tune matching'.

Even though the linear perturbations can be cured to some extent, the higher order perturbations can not be controlled and can not be estimated analytically. The only way we have is computer tracking. The code, *Racetrack*, was used for this purpose. Fig. 6 shows dynamic apertures for a single wiggler and an undulator respectively. The number of numerical integration steps were 100 for the wiggler and 50 for the undulator. We tracked two particles symmetrically at the same time, one in the positive x and the other one in the negative x. The resulting dynamic aperture is symmetric. In the figure this symmetric dynamic apertures are compared with the right half of the ideal case that is larger than the left half. Therefore the insertion devices reduce the dynamic apertures not as much as it looks in the figures. The dynamic apertures are reduced but still fairly large enough. The figure shows tune matching only.

IV. REFERENCES

[1] Alan Jackson, ESG Tech Note-103 NSAP-56

[2] F. Iazzourene, Sincrotrone Trieste, ST/M-TN-89/6