DESIGN OF A NEW LATTICE FOR POHANG LIGHT SOURCE

Eun-San Kim*
Pohang Accelerator Lab., POSTECH, Pohang, KyungBuk, 790-784 Korea

Abstract

A new lattice for low emittance at 2.5 GeV PLS storage ring was designed. We investigated the dynamic apertures in the lattice with the emittance of 10.3 nm to provide more brilliant synchrotron radiation. The dynamic apertures in the lattice without and with machine errors were examined by a tune survey to search for a large dynamic aperture. It was shown that how large were the dynamic apertures in the lattice compensated after corrections of a closed orbit distortions. The tune for the operation can be chose on the view point of dynamic apertures obtained from a tune survey by a simulation method. It is also shown that the low emittance lattice may provide a sufficient dynamic aperture in the storage ring.

INTRODUCTION

In December 1994, Pohang Light Source (PLS) started to operate with 2 GeV electron beam. During January 2000 to October 2002, the operational beam energy in the ring was raised from 2 GeV to 2.5 GeV by energy ramping and PLS has been operating by 2.5 GeV full energy injection from the linac since October 2002. The present operating lattice in the 2.5 GeV ring has quite the same structure with that of the 2.0 GeV which has an emittance of 12.1 nm. The present lattice with emittance of 18.9 nm shows a larger emittance by around three times than another third generation synchrotron light sources in the world. Accordingly, design efforts for low emittance lattice for a high-brilliance synchrotron radiation. The dynamic apertures in the lattice without and with machine errors were examined by a simulation method. Errors due to the magnetic field, alignment, rotation, length, kick of steering magnet and beam position monitor are considered to be machine errors in the simulation. We then also investigated how large dynamic apertures due to corrections of the COD are recovered in the lattice. Accordingly, we could choose the operating tune in the lattice from the dynamic apertures obtained by a tune survey. In the next section, we give an overview on the machine of the PLS ring. Section 3 shows an explanation how to perform the tune survey in the paper. Section 4 gives a general illustration of the dynamic aperture. The dynamic apertures which result from a tune survey for the low emittance are shown in Section 4. The last section is devoted to conclusions.

MACHINE OVERVIEW

Let us overview the machine parameters for 2.5 GeV at PLS. The basic lattice structure of the PLS ring is TBA. Configuration of magnets for the low emittance lattice will not be changed and so it would not affect the existing beam lines of synchrotron radiation. Typical parameters in the present operating lattice and designed the low emittance lattice are given in Table I. Here, H and V mean the horizontal and vertical directions, respectively. The strengths $1/m^2$ of the focusing and defocusing sextupole magnets to correct the chromaticities are also given.

DYNAMIC APERTURE

The dynamic aperture gives a description of the nonlinear effects arising from sextupoles to correct for the chromaticity and field imperfections of the magnets. In this stage of the design, it is necessary to estimate how large is the dynamic aperture of such a machine and how large is the dynamic aperture recovered by a correction of the COD. It is analytically difficult to obtain the dynamic aperture in the presence of nonlinear fields and thus in general it is obtained by a simulation method. The dynamic aperture is determined in a simulation as follows: first, set the initial amplitude of the betatron oscillation and track its amplitude through the ring’s components. If the initial amplitude performs stable betatron oscillation within a specified tune space to search for the optimal operation tune in the low emittance lattice. This point is a motivation of this paper. Accordingly, we investigated in detail the dynamic aperture for the lattice by a simulation method. The simulation was performed using the computer code Strategic Accelerator Design (SAD), which has been developed at KEK. The dynamic aperture in this simulation is defined as the maximum initial amplitude to give a circulation of 1000 turns. The simulation first shows the dynamic aperture for an ideal lattice without any

* eskim1@postech.ac.kr
amplitude by synchrotron radiation, we assume that 1000
turns is sufficient as a condition of stable betatron oscilla-
tion. Accordingly, we will investigate the dynamic aperture
by tracking 1000 turns in our simulation. Next, we discuss
how we evaluate the dynamic apertures which are obtained
by a simulation method. The dynamic apertures are esti-
ated in the position of straight section that insertion de-
vices are located.

TUNE SURVEY

The dynamic aperture has a relation with the betatron
tune. It is difficult to obtain analytically betatron tunes
which enable us to provide a large dynamic aperture. To
obtain a betatron tune which gives a large dynamic ap-
ture, the only method is to check the dynamic aperture by
changing the betatron tunes. Therefore, by changing the
betatron tunes it is possible to obtain a reasonable operating
point which gives a large dynamic aperture.

We perform tune survey for the optics. The following
method is applied for this tune survey: 1) The fractional
tune is changed from the starting point. 2) The variation
in the tune is done by 0.03 in a step and matching of the
optics is performed. The tune survey is performed over the
range between 0.0 and 1.0 in the horizontal and vertical di-
rections, respectively. Accordingly, the tune survey covers
a rectangular region in tune space (0 ≤ νx ≤ 1.0 and
0 ≤ νy ≤ 1.0). 3) The dynamic aperture is obtained by
averaging five points in the X − Y plane, as shown in Fig.
1.

OPTICS AND DYNAMIC APERTURE FOR
A LOW EMITTANCE LATTICE

Fig. 2 shows the optics for a low emittance of 10.3 nm
at 2.5 GeV and its optical functions. Fig. 3 shows the
dynamic aperture in the case that machine errors are not
included. The magnitude of the dynamic aperture is ex-
pressed in unit of beam size, and is shown as the average
value of five points in the X − Y plane, as shown in Fig. 1.
The particle momentum is kept at δP/P = 0 during tracking.
It is shown that the dynamic apertures are a little affected
to resonances of 2nνx = 12 × 3n and nνy = 12 × n. Here
n is integer. Next, we considered the effects of the machine
errors on the dynamic aperture. The magnitudes of the er-
rors considered in the simulation are listed in Table II. The
ers are assumed to have a Gaussian distribution with the
rms values given in Table II, and have been truncated by 3σ
in their distributions. It is also important to show how large
dynamic apertures in a ring with machine errors are recov-
ered by a correction of the COD. Fig. 4 shows the dynamic
apertures at the tune of νx = 17.64 and νy = 11.6 at the
center of a straight section. Fig. 4(a) shows the dynamic
apertures without machine errors. The dynamic apertures
are shown in the cases of -1%, 0% and 1% momenta de-
viations. Fig. 4(b) shows the dynamic apertures with ma-
chine errors and corrections of COD in Fig. 4(a). It shows
that vertical dynamic aperture is larger than the physical
aperture in the vertical direction. The COD in Fig. 4(b) is
1.5 mm rms and 3.64 mm rms in the horizontal and ver-
tical directions, respectively, before corrections of COD.
The COD in Fig. 4(b) is adjusted to 0.12 mm rms and 0.97
mm rms in the horizontal and vertical directions, respecti-
vely, after corrections of COD. It is shown that correction
of the COD is better performed in the horizontal direction
than in the vertical direction. From these results, we expect
that the PLS ring has a sufficient dynamic aperture in the
low emittance lattice after a correction of the COD, if the
machine errors are kept within the level given in Table II.

Table 1: Main parameters in the 2.5 GeV PLS storage ring

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Present lattice</th>
<th>New lattice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lattice type</td>
<td>TBA</td>
<td>TBA</td>
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<tr>
<td>Circumference</td>
<td>280.56 m</td>
<td>280.56 m</td>
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<tr>
<td>Natural emittance</td>
<td>18.9 nm</td>
<td>10.3 nm</td>
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<td>Momentum compaction</td>
<td>0.00181</td>
<td>0.00130</td>
</tr>
<tr>
<td>Energy spread</td>
<td>0.00085</td>
<td>0.00083</td>
</tr>
<tr>
<td>Synchrotron frequency</td>
<td>9.6 kHz</td>
<td>9.6 kHz</td>
</tr>
<tr>
<td>Betatron tune</td>
<td>14.28/8.18</td>
<td>17.64/11.6</td>
</tr>
<tr>
<td>Damping time(x/y/z)</td>
<td>280.56 m</td>
<td>280.56 m</td>
</tr>
<tr>
<td>Bunch length</td>
<td>7.6 mm</td>
<td>6.36 mm</td>
</tr>
<tr>
<td>Beam size(H) at ID</td>
<td>434 μm</td>
<td>223 μm</td>
</tr>
<tr>
<td>Beam size(V) at ID</td>
<td>27 μm</td>
<td>20 μm</td>
</tr>
<tr>
<td>Strength of sextupole</td>
<td>-6.4/4.4</td>
<td>-6.0/3.9</td>
</tr>
<tr>
<td>Energy aperture</td>
<td>1.5%</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

Table 2: Machine errors in a lattice

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Quad/Bending</th>
<th>Sextupole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic field error(rms)</td>
<td>0.02 %</td>
<td>0.04 %</td>
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<td>Alignment error(rms)</td>
<td>80 μm</td>
<td>80 μm</td>
</tr>
<tr>
<td>Rotation error(rms)</td>
<td>0.1 mrad</td>
<td>0.1 mrad</td>
</tr>
<tr>
<td>Length error(rms)</td>
<td>100 μm</td>
<td>100 μm</td>
</tr>
</tbody>
</table>

CONCLUSION

We investigated dynamic apertures in the designed low
emittance lattice at the 2.5 GeV PLS storage ring. If the
dynamic aperture is smaller than the physical aperture, it is
actually difficult to inject a beam into a ring, which results
in a bad beam lifetime. It is necessary to estimate the dy-
namic aperture of the machine for the successful operation
of a ring. Thus, it requires estimate of the effects on the dy-
namic aperture. Accordingly, we investigated in detail the
dynamic aperture for the low emittance optics in the PLS
ring. The dynamic apertures are obtained by scanning the
betatron tunes within a specified tune space. The results
of this simulation give an estimation for the requirement
that the lattice provides a sufficient dynamic aperture in the PLS ring. When we estimate the dynamic aperture by the tracking method, the dynamic aperture in the low emittance lattice with a correction of the COD is considered to be sufficiently large for storage. Future work will include studies of tolerance of COD to keep enough dynamic aperture and how to reach such a level of COD. Tune which show comparative large dynamic aperture in tune space is considered. The tune may be adopted as operating tune in the stage of commissioning for the low emittance ring.

Figure 1: Survey of the dynamic aperture in the \( X-Y \) plane. The dynamic aperture is obtained by averaging these five points.

![Diagram](image)

Figure 2: A low emittance lattice with emittance of 10.3 nm at 2.5 GeV.

**REFERENCES**


Figure 3: Dynamic apertures for tune survey in a low emittance lattice without machine errors. Most tunes show larger dynamic apertures than 70.

![Diagram](image)

Figure 4: Dynamic apertures in the tune of \( \nu_x = 17.64 \) and \( \nu_y = 11.6 \) at the position of straight section. (a) without machine errors and (b) with machine errors and after corrections of the COD in (a).