A STUDY FOR LATTICE COMPARISON FOR PLS 2 GEV STORAGE RING

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Abstract

TBA and DBA lattices are compared for 1.5-2.5 GeV synchrotron light source, with particular attention to the PLS 2 GeV electron storage ring currently being developed in Pohang, Korea. For the comparison study, the optimum electron energy was chosen to be 2 GeV and the circumference of the ring is less than 280.56 m, the natural beam emittance no greater than 13 nm. Results from various linear and nonlinear optics comparison studies are presented.

I. INTRODUCTION

This paper considers the Chasman-Green option for the Pohang Light Source (PLS) storage ring lattice. Currently, the PLS storage ring lattice has a triple bend achromat structure with circumference of 280.56 m. The bending magnet does not have a gradient on it. Total 12 quadrupoles are employed with nominal working points set at (14.28, 8.18). Detailed performance characteristics for the PLS 2 GeV lattice are reported separately in this conference [1]. Alternatively, However, one can consider an equally well candidate such as double bend achromat structure for the lattice of a third-generation synchrotron radiation source.

In this paper, we compare the present design of the TBA lattice with the DBA structure. The lattice of interest has been optimized to energy of 2 GeV, with maximum 2.5 GeV. In order to make a reasonable comparison with TBA structure, we have chosen the following boundary conditions:

- comparable circumference of the ring
- same superperiodicity
- same working points
- comparable natural emittance
- comparable β functions at the insertion symmetry
- comparable maximum β functions.

These boundary conditions are not the necessary conditions. For example, for DBA lattice, one can consider a lattice with higher superperiodicity such as 14 instead of 12. In our study, however, this case is not considered, because one can design a DBA lattice with comparable emittance if TBA lattice does not employ a gradient bending magnet.

In the following, we describe some characteristics of the DBA lattice which was designed based upon the above considerations. First, we present the linear optics of the lattice, together with the ring parameters. Next, we discuss some nonlinear problems, such as momentum-dependent and amplitude-dependent effects, sensitivity to magnet errors and magnetic multipole effects.

II. LINEAR OPTICS

In its simplest form, the DBA lattice employs one or two quadrupole(s) in the dispersive section between the two bending magnets. The function of this quadrupole is to match η'_x at the symmetry point. With this scheme, however, it is difficult to control both β and η in the dispersive section, which may be required to reduce the beam emittance. In the extended DBA structure, instead of placing one or two quadrupoles in the dispersive section there are three or four quadrupoles, which allows easy control of the lattice functions. Fig. 1 shows the lattice structures of DBA and TBA for our comparison study. The total circumference of the ring for DBA lattice is 269.76 m which can be compared with 280.56 m for the TBA lattice. The reason for larger circumference for TBA lattice is simply because for our TBA lattice the bending magnet does not

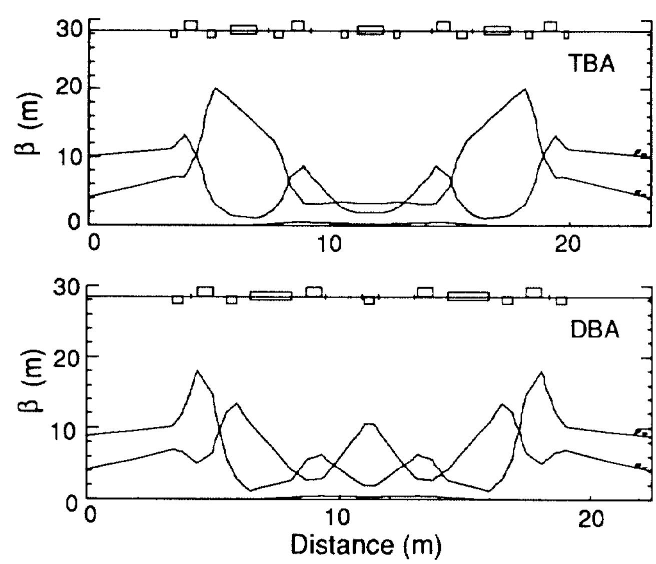

Figure 1: DBA and TBA lattices

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have a gradient on it. Since the number of bending magnet in a TBA lattice is greater than that of a DBA, with given energy the total circumference of a TBA tends to be larger. The ring has a total 12 superperiodicity, thus it can supply 10 straight sections for placing wigglers and undulators. The remaining two straight sections are for the beam injection and the placement of the RF cavity.

The scheme with three quadrupoles in the nondispersive section allows us to match the α values as well as to control β (or tune) at the center of the insertion region where the insertion device is placed. The nominal tunes for both lattices are set at ν_x=14.28 and ν_y=8.18 to avoid any lower-order structure resonances and to minimize the sextupole-induced resonances.

In both cases, two sextupole families (SF and SD) are employed at the dispersive section. The location of these sextupoles are marked in Fig. 1. In Table I, the machine and beam parameters for both lattices are illustrated.

	TBA	DBA
Energy (GeV)	2	2
Circumference (m)	280.56	269.76
Emittance (nm)	12.1	12.9
ν_x, ν_y	(14.28,8.18)	(14.28,8.18)
Superiodicity	12	12
ξ_x, ξ_y	$(-23.4, -18.2)$	$(-28.0, -15.2)$
Sextupole strength (m^{-2})	$-6.47, +4.49$	$-6.44, +7.8$
Number of Sextupole families	2	3
Straight section (m)	3.4	3.4

Table 1: Lattice and Beam Parameters

For the user's point of view, allowing the flexibility in tuning the lattice is sometimes required. This is because some experiment, such as the one utilizing the undulator radiation, requires high β value at the insertion region. On the other hand, the experiment with wiggler radiation demands low β value. Therefore, in designing the lattice, it may be desired for a lattice being able to provide with a wide range of tunability. The lattice shown in Fig. 1 has been designed in such a way that at the center of the insertion region, β_x can be extended from 2 m to 20 m and β_y from 2 - 30 m, without affecting the tunes. The integer part of the tunes can also be changed by four units showing the lattice has an ample flexibility.

III. NONLINEARITY AND HARMONIC CORRECTION

The addition of the two families of the chromaticity correcting sextupoles introduces the inevitable nonlinear magnetic fields in the storage ring. These sextupoles limit the maximum oscillation amplitude of a particle, thus defining the dynamic aperture. The requirement of a large dynamic aperture for a third-generation synchrotron radiation source is not obvious because of extremely small nature of the beam size. On the other hand, however, having a lattice with larger dynamic aperture has an advantage so that good injection efficiency and long lifetime of a beam can be ensured.

Fig. 2 shows the dynamic aperture for both lattices with chromaticity correcting sextupoles only. In the DBA structure, the dynamic aperture can be effectively increased by addition of one or two harmonic correcting sextupole families in the non-dispersive section. The strength of these sextupoles can then be obtained from the first-order canonical perturbation theory [2] or computer program such as MAD. In our case, only one family of the harmonic correcting sextupole is employed. The theoretical amplitude-dependent tune shifts in terms of harmonic expansion are given by:

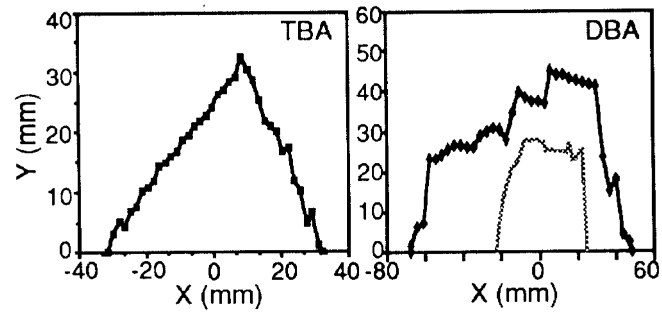

Figure 2: Dynamic aperture

$$
\begin{aligned}
\Delta\nu_x &= M_{11}J_{1x} + M_{12}J_{1y} \\
&= -18N_x^2\epsilon\sum_m\left[\frac{A_{3m}^2}{3\nu_x - m} + \frac{3A_{1m}^2}{\nu_x - m}\right] \\
&\quad +18N_y^2\epsilon\sum_m\left[\frac{2B_{1m}A_{1m}}{\nu_x - m} - \frac{B_{+m}^2}{\nu_+ - m} + \frac{B_{-m}^2}{\nu_- - m}\right] \\
\Delta\nu_y &= M_{21}J_{1x} + M_{22}J_{1y} \\
&= 36N_x^2\epsilon\sum_m\left[\frac{2B_{1m}A_{1m}}{\nu_x - m} + \frac{B_{+m}^2}{\nu_+ - m} + \frac{B_{-m}^2}{\nu_- - m}\right] \\
&\quad +9N_y^2\epsilon\sum_m\left[\frac{4B_{1m}^2}{\nu_x - m} - \frac{B_{\pm m}^2}{\nu_\pm - m}\right] \qquad (1)
\end{aligned}
$$

where A_{nm} and B_{nm} are the usual distortion functions. For our DBA lattice without chromaticity correcting sextupoles only, the result is

$$M_{11} = -2808,\ M_{12} = M_{21} = -1479,\ M_{22} = +1292. \quad (2)$$

By addition of a harmonic sextupole between Q1 and Q2, the sum of the harmonic components can be minimized and the resulting amplitude-dependent tune shifts are given by

$$M_{11} = -406,\ M_{12} = M_{21} = +90,\ M_{22} = -819. \quad (3)$$

The strength of the harmonic correcting sextupole is $K_2l = 1.12m^{-2}$, which is relatively weak compared to the strength of the chromaticity correcting sextupoles.

From the above, we see that all terms for the amplitude-dependent tune shift are substantially decreased. The resulting dynamic aperture is shown in Fig.2 which indicates a marked improvement of the dynamic aperture.

Nonlinear momentum-dependent tune shifts are also depicted in Fig.3. This figure shows that the DBA lattice has a stronger nonlinearity with momentum than the TBA lattice.

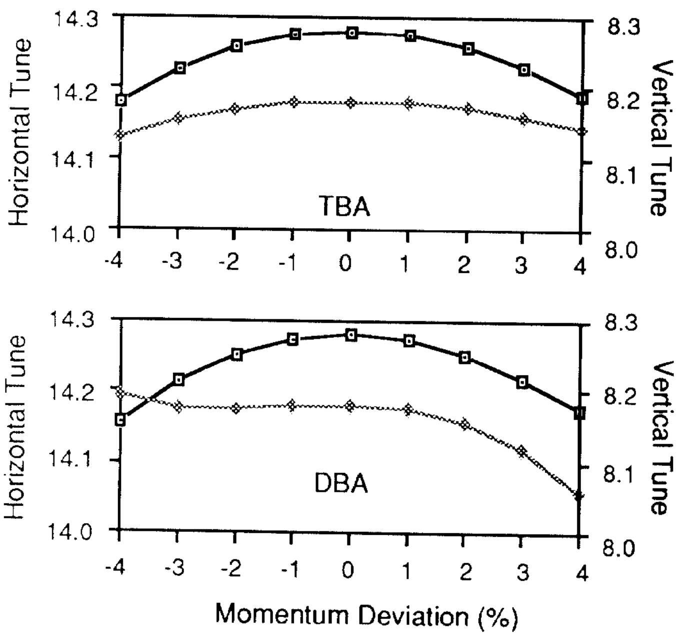

Figure 3: Nonlinear momentum dependent tune shifts for TBA and DBA lattices respectively

IV. CLOSED ORBIT DISTORTION

A salient feature of a third-generation synchotron light source is such that the lattice is very sensitive to the closed orbit distortion. We set our tolerance values such that the rms error of the bending field is 0.1%, rms misalignment error of quadrupole 0.15 mm, rms rotation error of quadrupole 0.5 mrad. Analytical estimation for the TBA and DBA lattices considered here yields,

$$\bar{x} \approx 6mm, \quad \bar{y} \approx 7mm \quad DBA \tag{4}$$

$$\bar{x} \approx 4mm, \quad \bar{y} \approx 9mm \quad TBA \tag{5}$$

These analytical estimation can be more elaborated if one uses the computer. With twenty different machines, the resulting rms closed orbit distortions at the insertion symmetry have been calculated by using MAD6 and RACETRACK. The results indicated that the computer calculation is similar to the analytical estimation.

The reduction in dynamic aperture for both cases is delineated in Fig.4. This indicates that both lattices are very sensitive to the closed orbit distortion. The dynamic aperture with closed orbit distortion for DBA lattice is seen to be larger than that of the TBA lattice. For both cases, however, the closed orbit distortion can be effectively reduced by employing a number of correctors.

V. EFFECT OF MAGNETIC MULTIPOLES

For the study of the effect of magnetic multipoles on the beam, we have chosen the multipole components used for Advanced Light Source lattice [1]. Program MAD6 was used for the analysis.

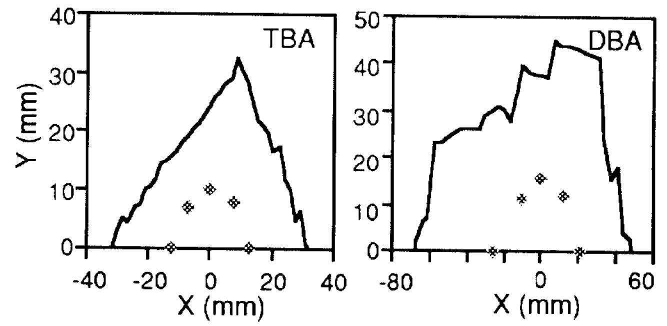

Figure 4: Dynamic aperture for TBA and DBA lattices with closed orbit distortions

Fig.5 shows the dynamic aperture with both systematic and random multipole components present in the ring. DBA lattice is seen to be more sensitive to the magnet multipole errors.

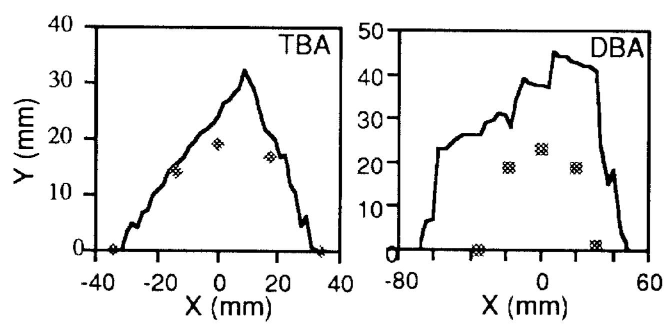

Figure 5: Dynamic aperture for TBA and DBA lattices with magnetic multipole errors

VI. SUMMARY

TBA and DBA lattices are compared for the PLS 2 GeV light source. Both lattices show comparable performance. DBA lattice has larger dynamic aperture when harmonic correcting sextupole is introduced. DBA lattice, however, indicates a larger nonliear momentum dependent tune shifts and sensitivity to the magnetic multipole errors. In conclusion, however, both types of the lattice can be equally well candidate for a third-generation synchrotron radition source.

VII. REFERENCES

[1] J. Choi et al, "Magnetic Lattice of the Pohang Light Source" in these conference proceedings

[2] K.Y. Ng, "Distortion Functions" FN-455