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MAGNETIC ERROR EFFECTS OF THE STORAGE RING FOR THE SOUTHERN ADVANCED PHOTON SOURCE*

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Abstract

There are various magnetic errors in the actual accelerator, which will significantly affect the beam quality and machine performance. The diffraction-limited storage ring (DLSR) of the Southern Advanced Photon Source (SAPS) will use a large number of ultra-high gradient quadrupoles and sextupoles, which, in turn, leads to the tight tolerance of beam parameters to magnetic errors. Based on a recent lattice design of the SAPS, the influence of various magnetic errors on lattice parameters has been evaluated.

INTRODUCTION

The Southern Advanced Photon Source (SAPS), which proposed to be built in Dongguan, is a storage ring light source with beam energy of 3.5 GeV. Related studies have been made on the lattice design for these years.

A hybrid 7BA design for the SAPS has been made, as shown in Fig. 1 [1]. This design comes with a 31.7 pm·rad natural emittance, ~ 4% MA and the dynamic aperture (DA) ~5 mm in x plane and 3.5 mm in y plane respectively. The main parameters are listed in Table 1. More details of this design and related studies are shown in Ref. [1].

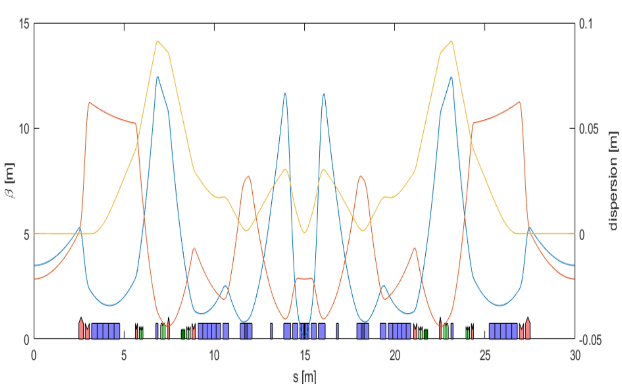

Figure 1: Layout and optical functions of the candidate lattice designed for the SAPS. The blue, red, green, dark green blocks represent dipoles, quadrupoles, sextupoles and octupoles, respectively.

A large number of ultra-high gradient quadrupoles and sextupoles in the diffraction-limited storage ring design lead to tight tolerance of beam parameters to magnetic errors. For the fourth generation storage ring in the world, the magnetic error effects have been analysed and corrected [2-6]. Therefore, it is essential to evaluate the effect of various magnetic errors on lattice parameters of SAPS. The simulation of error effects can also provide information about the manufacture tolerance of the hardware. In this paper, we present the results of our first attempt to take errors into consideration. Accelerator Toolbox (AT) [7] has been used for the calculation.

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Table 1: SAPS Recent Lattice Design Parameters

Parameters	Values
Beam energy E_0	3.5 GeV
Circumference	1080 m
Natural emittance	31.7 pm·rad
Working point (x/y)	81.23/64.18
Corrected chromaticity (x/y)	+5/+5
Beta functions at LSS	3.49/2.85 m
Energy loss per turn	0.898 MeV
Energy spread	1.1×10^{-3}
Momentum compaction	1.38×10^{-5}

ERROR SETTENGS

At present, the SAPS error study covers some common errors in practical accelerator as below:

Alignment and Rotation Angle Error

The alignment technique of SAPS would occupy a significant place. The elements on one girder would have the capability of micro-motion adjustment. Even so, alignment error will still make beam injection difficult and have a big influence on beam performance.

In this study, we assumed 30 μm for misalignment and 100 μrad rotation in r.m.s error for magnet element.s

Magnet Field Error

For each magnet, a random relative error is added to the original field. Considering that the magnet field would have been corrected in the future, the scale for different type magnets list as blow:

- Dipoles: 0.03%;
- Quadrupoles: 0.02%;
- Sextupoles: 0.03%.

THE DISTORTION OF THE CLOSED ORBIT AND BEAM OPTICS

With the above error setting, the distortion of the closed orbit and beam optics of the SAPS lattice have been recorded and analysed.

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Closed Orbit Distortion

The misalignment of quadrupoles and the field errors of dipoles affect the closed orbit a lot. 700 random errors are used to calculate the influence on the closed orbit, as shown in Fig. 2. The maximum RMS closed orbits are ~ 2 mm and 3.6 mm for x and y, respectively.

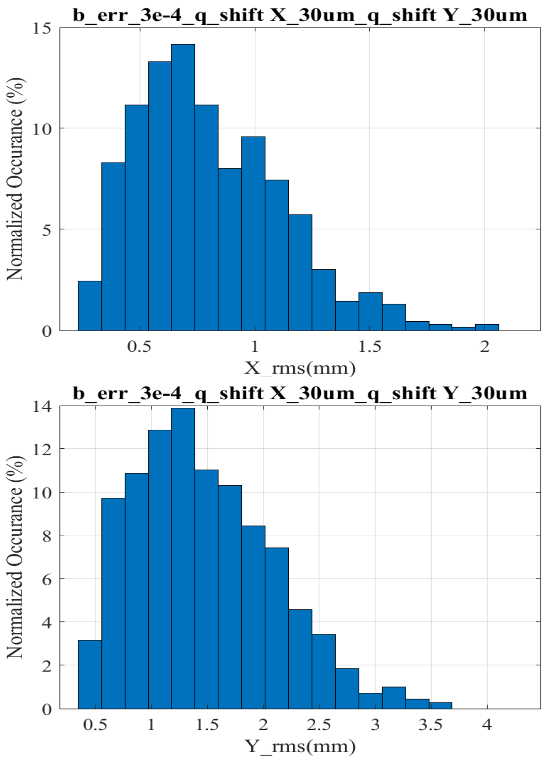

Figure 2: The RMS distribution of the closed orbits with the 30 μm misalignment of quadrupoles and the 0.03% field errors of dipoles (700 seeds).

Beam Optics

The misalignment of sextupoles and the field errors of quadrupoles affect mainly the beam optics. 700 random errors are used to calculate the influence on beam optics, as shown in Fig. 3. The maximum RMS beta-beatings are ~ 9.5% and ~ 6% for β_x and β_y, respectively. Meanwhile, the maximum tune-shifts are ±0.02/±0.015 for ν_x and ν_y respectively, as shown in Fig. 4.

DYNAMIC APERTURE

Through AT code, we can track dynamic aperture (DA) of the SAPS lattice with magnetic errors. To get a statistic analysis of error effects, 50 seeds are used to generate many cases for simulation.

The DA tracking results are shown in Fig. 5. Compared with bare lattice, the DA decreased obviously with error effects. The DA with closed orbit distortion is 1.6/2 mm and the DA with beam optics distortion is 2.8/3 mm. In other words, the DA reduction caused by the closed orbit distortion is more serious than that caused by the optics distortion.

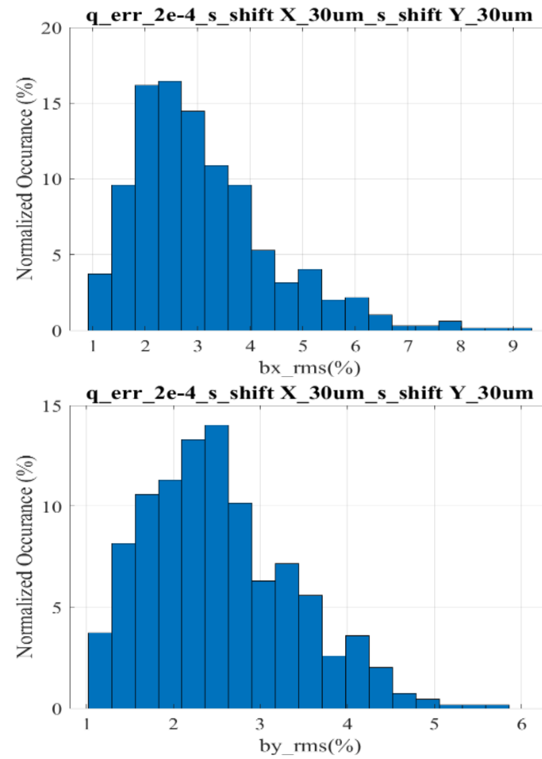

Figure 3: The RMS distribution of the beta-beatings with the 30 μm misalignment of sextupoles and the 0.02% field errors of quadrupoles (700 seeds).

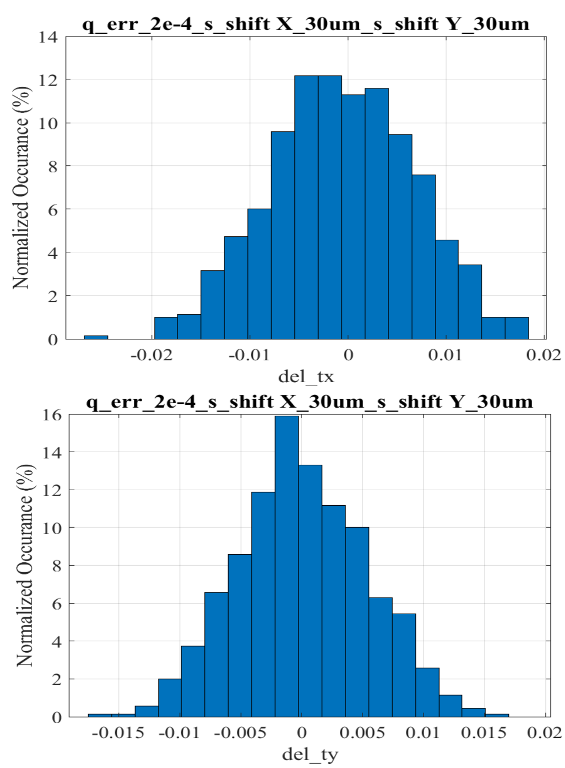

Figure 4: The tune-shifts with the 30 μm misalignment of sextupoles and the 0.02% field errors of quadrupoles (700 seeds).

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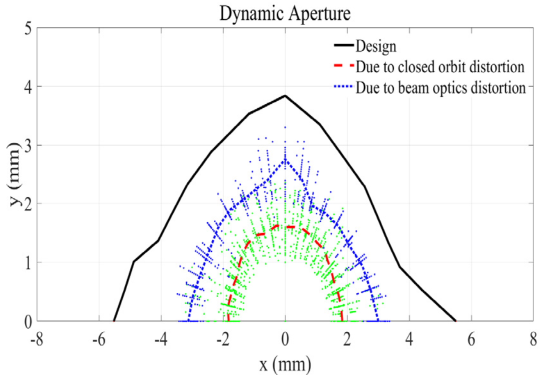

Figure 5: DA tracking result. (Black line): bare lattice DA; (red dot): 50 cases tracking result with closed orbit distortion caused by the misalignment of sextupoles and the field errors of quadrupoles; (red line): average DA with closed orbit distortion; (blue dot): 50 cases tracking result with beam optics distortion caused by the misalignment of quadrupoles and the field errors of dipoles; (blue line): average DA with beam optics distortion.

SUMMARY

As described above, we provided a procedure to study the error effects on a recent lattice design of SAPS, including the closed orbit, beam optics and the dynamic aperture affected by magnetic field errors and misalignment. Next step, more studies will be done to correct the magnetic errors systematically. In the future, the lattice will be optimized repeatedly, and the study on the magnetic errors will be improved accordingly.

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