GLOBAL COD CORRECTION OF SAGA-LS STORAGE RING

H. Ohgaki#, Institute of Advanced Energy, Kyoto University, Kyoto, 611-0011, Japan
Y. Iwasaki, S. Koda, Y. Takabayashi, K. Yoshida, T. Tomimasu, SAGA Light Source, Tosu, 841-0002, Japan

Abstract

SAGA Light Source (SAGA-LS) [1] is a medium size light source facility which starts user-operation from February, 2006. The stored beam orbit has been corrected by a closed orbit correction system consisted of 24-beam position monitors (BPMs), 40-steering magnets and PC-LabView based control system [2]. The singular value decomposition (SVD) method has been applied for the global closed orbit distortion (COD) correction by using a measured response matrix (S-matrix). As the result, the standard deviation of the orbit error around the ring was reduced to 10 μm both for horizontal plane and for vertical plane. The linear lattice of the ring has been calibrated to reproduce the measured S-matrix. The calibrated lattice well reproduces the S-matrix, but does not reproduce the machine function so well. The machine function shows a beta-beating in vertical plane.

INTRODUCTION

A storage ring dedicated for the synchrotron radiation facility requires a low emittance and a stable beam. Therefore, a closed orbit distortion (COD) should be corrected to obtain the expected performance of the ring. For instance a large COD in an RF cavity wakes severe microwave instabilities. Moreover, since the modified Chassman-Green type lattice employs non-zero dispersion in long straight section, the COD should be small for the beam injection. SAGA-LS storage ring uses 0.6-m dispersion in the long straight section, the COD must be kept below 3.2 mm in horizontal direction and in 8.4 mm in vertical direction [3].

Orbit correction with a measured response matrix (S-matrix), which is defined as beam motion at the beam position monitor (BPM) per unit kick by steering magnets, has been applied in many storage rings and showed good results without any complex modelling [4,5]. The measured S-matrix is inverted by using the singular value decomposition (SVD) method. The product of the inverted matrix and the difference orbit gives the incremental kick strengths required to correct the orbit. In SAGA-LS storage ring, an orbit correction system has been developed by using 24-BPMs, 40-steering magnets and built-in SVD routine in the LabView running on the SAGA-LS control system.

COD CORRECTION

For the first step, each BPM centre was measured with the stored beam variation as a function of the quadrupole strength located just downstream the measured BPM. SAGA-LS storage consists of 3-quadrupole families (40-quadrupole magnets). Each quadrupole magnet has correction winding and thus it can be controlled independently.

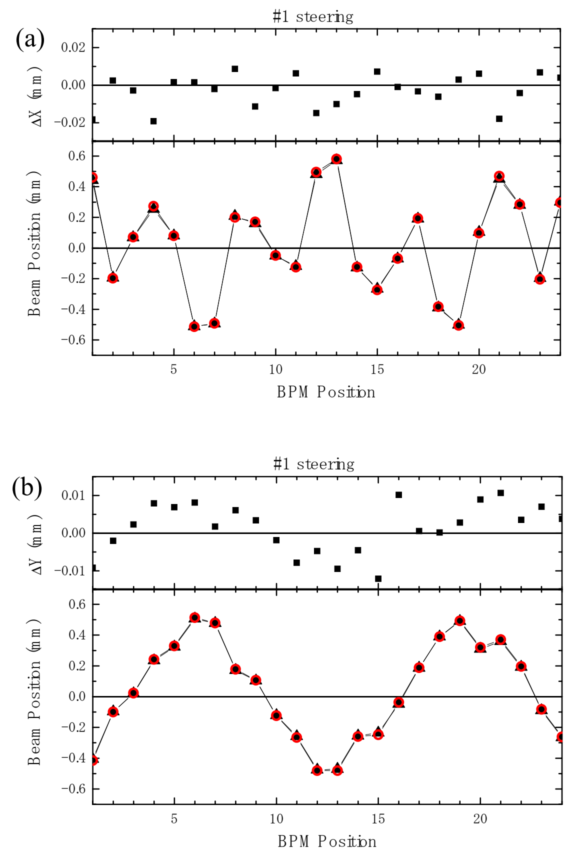

Figure 1: Beam motion against (a) the horizontal kick and (b) vertical kick. The square dots show measured S-matrix component and the circular dots show calculated one. Top graphs display difference between the measured S-matrix and the calculation.

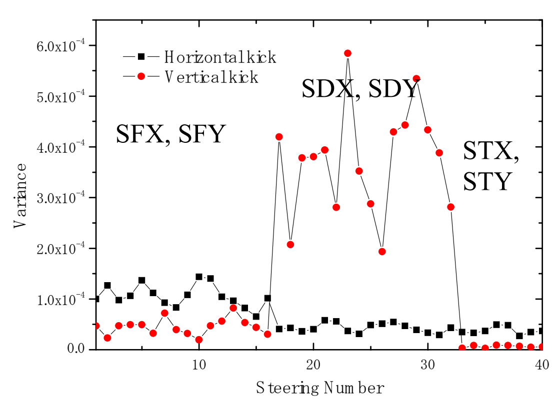

Figure 2: Beam motion to the diagonal axis.

#ohgaki@iae.kyoto-u.ac.jp

Second, the S-matrix has been measured by changing the kick angles of the steering magnets one by one and by reading the beam position with all BPMs. The changed kick angle ($\delta\theta$) was +0.1 mrad. The S-matrix elements were calculated as

$$S_{ij} = \delta x_i(+0.1mrad) / \delta\theta_j, \qquad (1)$$

where δx_i is the beam position at the i-th BPM kicked with the j-th steering magnet. Figure 1 shows a typical beam motion (S-matrix component) to (a) horizontal kick and (b) vertical kick. In these figures the square dots show measured S-matrix component and the circular dots show calculated one which will be discussed in the next section. Top graph of fig.1 displays difference between the measured S-matrix and the calculation. We also measured the beam motions in the diagonal plane (fig.2). These motions would mainly come from the misalignment of the steering magnets. The vertical steering magnet from #17 to #32 (SDY, steering in sextupole) shows extremely large coupling and may be good to removed from the orbit correction. In this paper, however, we used all steering magnets for the COD correction.

Third, the inverse matrix was calculated with built-in function of the LabView. This function uses the SVD algorithm and any singular value less than the 'tolerance' is set to zero. The measured S-matrix was used for the input matrix. Then, the orbit correction was done for the horizontal plane and the vertical plane, respectively. The measured beam position (a) before and (b) after the COD correction are shown in figure 3. The standard deviation of the beam position, which was 2.39 mm in the horizontal plane and 1.20 mm in the vertical plane before the COD correction, was reduced to 10 μm in each plane. The maximum values of the kick angle were 0.8 mrad in horizontal plane and 0.5 mrad in vertical plane under the condition of the 'tolerance' of 0.05 and 0.02, respectively. The residual value of COD, 10 μm in each plane, is small enough as a comparison with the BPM noise which is about 10 μm. Figure 4 shows a snap shot of the COD correction GUI running on the PC-LabView system. Upper graph shows the BPM readout (white line), expected orbit after COD correction (red line) and BPM offset (blue line). Bottom graph shows the present strengths of the steering magnets (white bars) and calculated strengths for the next correction (red squares).

At the present stage, the COD correction has been performed after the ramp-up procedure. This means only one time in an injection sequence. Due to the thermal expansion of the vacuum chamber, the BPM readout drifts about 0.1 mm for 2 hours after the ramping. Figure 5 shows the drift of the beam position readout from the BPM #8-x and that from a position sensor located at the BPM #8 as a function of time. Figure 5 also shows the stored beam current. As is shown in fig.5 the BPM drift does not indicate the drift of the electron beam trajectory, but shows the movement of the physical position of BPM. Since the optical measurement from user port reported that there has been no serious drift in the SR light, we will start a periodic COD correction after the vacuum chamber is fixed.

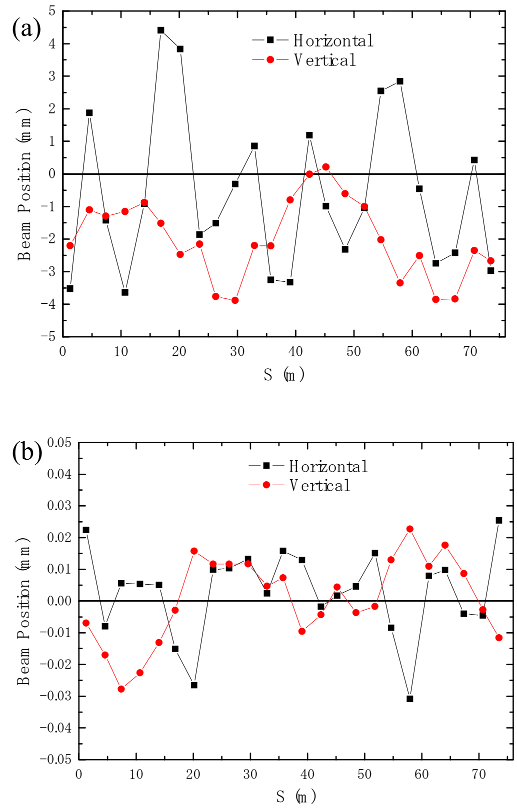

Figure 3: An example of the measured beam position (a) before and (b) after the COD correction.

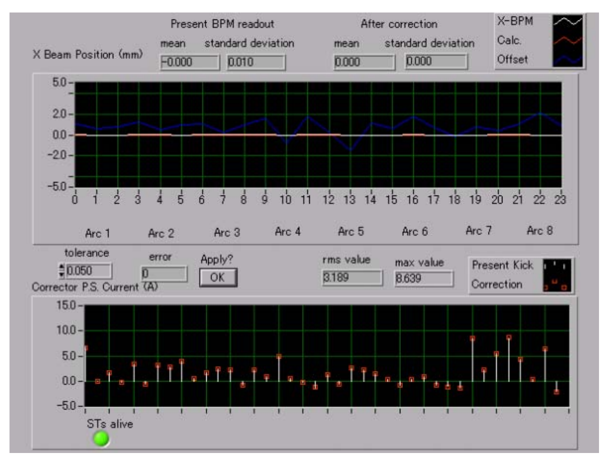

Figure 4: A snap shot of the COD correction GUI running on the control PC. Upper graph shows the BPM readout (white line), expected orbit after COD correction (red line) and BPM offset (blue line). Bottom graph shows the present strengths of the steering magnets (white bars) and calculated strengths for the next correction (red squares).

 1-4244-0917-9/07/$25.00 ©2007 IEEE

LATTICE CALIBRATION

The calibration of the ring lattice using S-matrix measurement was also important to understand the machine. As is shown in figure 1, the lattice of the storage ring has been fitted to the measured S-matrix. The fitting knobs were 40-quadrupoles, 48-BPM gains, and 80-kicking angles. The COD trajectories were calculated by TRACY2. As the result, the measured COD trajectories can well be reproduced by the calibrated lattice. The standard deviation of the difference between measured S-matrix and that with calculation was less than 10 µm in each plane. We found that the difference between the fitting result of the quadrupole strengths and these from the magnetic field measurement, were small, 0.2%, both in QF family and in QD family. On the other hand, the difference was about three times as large as in QFA family (0.7%). This may come from the accuracy of the dispersion measurement. Figure 6 shows the measured machine functions and these from calculation, (a) βx and (b) βy, after the COD correction. The standard deviations of the difference between calculation and measurement are (a) 0.9 m and (b) 1.5 m, respectively. Besides, a large beating is seen in the vertical beta function (fig.6 (b)). We are going to reduce the beta-beating by using the calibrated lattice parameter. Consequently, the calibrated lattice excellently reproduces the S-matrix, but does not reproduce the machine function so well.

CONCLUSIONS

COD correction of the stored beam in SAGA-LS storage ring has been performed. The COD correction system consists of 24-BPMs, 40-steering magnets. The SVD method has been used for the COD correction algorism by using a measured S-matrix. As the result, the standard deviation of the orbit error around the ring was reduced to 10 µm both for horizontal plane and for vertical plane whose original values were 2.39 mm and 1.20 mm, respectively. The maximum values of kick angle were 0.8 mrad in horizontal and 0.5 mrad in vertical. The ring lattice has been calibrated by fitting the measured S-matrix. The result shows that the difference between measurement and calculation was less than 10 µm in each plane. The calibrated lattice successfully reproduced the S-matrix, but did not reproduce the machine function so well. A large beta-beating in the vertical beta-function was observed. Further studies are needed for reducing the beta-beating.

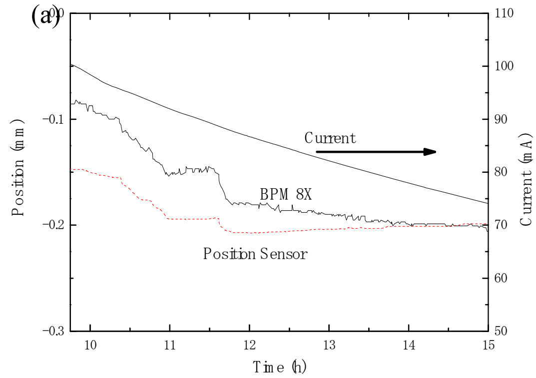

Figure 5: Horizontal beam position read by BPM #8 as a function of time. Dotted line indicated the position readout from the position sensor located at the BPM #8. The stored beam current is also displays.

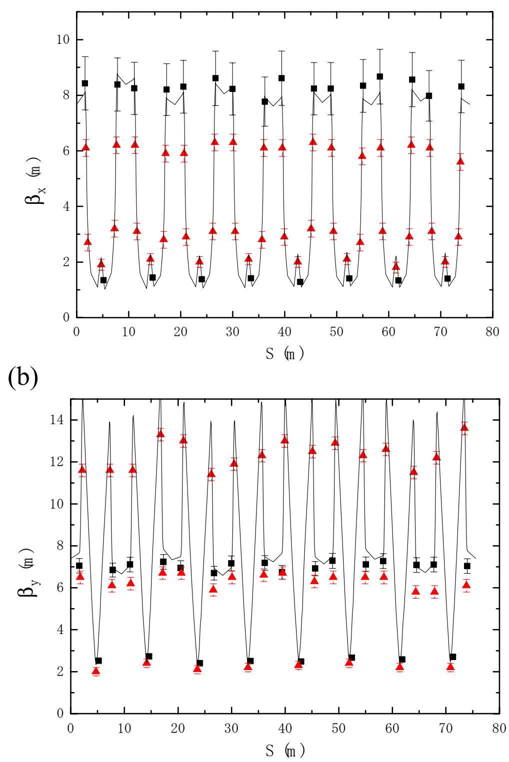

Figure 6: Measured and calculated machine functions after the COD correction. (a) Horizontal beta function and (b) vertical beta function. The square dot shows the beta function measured by the BPM and the triangular dot shows the beta function measured by the quadrupole.

REFERENCES

[1] T. Tomimasu, et al., “Commissioning of SAGA Light Source”, Proc. of the PAC2005, pp.4021-4023 (2005).
[2] H. Ohgaki, et al., "PC-LABVIEW BASED CONTROL SYSTEM IN SAGA-LS", Proc. of the PAC2005, pp. 3976-3978(2005).
[3] T. Tomimasu, H. Ohgaki, Y. Iwasaki, SAGA Synchrotron Light Source Design Report (2002).
[4] J. Safranek, “Experimental determination of storage ring optics using orbit response measurements”, Nucl. Instr. and Meth. A 388, p. 27-36 (1997).
[5] D. Robin, J. Safranek, W. Decking, “Realizing the benefits of restored periodicity in the advanced light source”, Phys. Rev. ST-AB, v. 2, 044001 (1999).