BEAM BASED ALIGNMENT AND COD CORRECTION FOR THE SIAM PHOTON SOURCE

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Abstract

The first systematic Beam based Alignment (BBA) and COD correction attempt for the Siam Photon Source (SPS) has been performed. Automated measurements were carried out using Matlab OPC Toolbox, interfacing to the accelerator control system. Calculations of theoretical parameters were performed with Accelerator Toolbox via Matlab interface. Since the Beam Position Monitors (BPMs) were not properly calibrated beam based calibrations were carried out. Preliminary calibration factors for each BPM were obtained by normalizing BPM signals to modelled corrector magnet responses. Measurements of offsets between BPM and quadrupole centers were performed by quadratic fitting for minima of orbit response to changes of quadrupole strengths. The resulting offsets were superimposed to the BPM readings. COD correction was then performed.

INTRODUCTION

The Siam Photon Source (SPS) has been in operation with currently three beamlines completed and opened for users. The machine performance has constantly been improved, including the recent energy upgrade from 1 to 1.2 GeV [1]. However, proper correction of the closed orbit has not been carried out. Many obstacles contribute to the difficulties for carrying out the COD correction. In the past, the machine control system lacked a good user interface system to enable fast and reliable beam measurements. This major obstacle has been solved by installation of Matlab OPC Toolbox to enable real time interface and programming via Matlab [2]. A project for proper COD correction and orbit stabilization has then been under way. Results of beam based BPM calibration, beam based alignment (BBA) measurements and COD correction are presented in this report.

BEAM BASED BPM CALIBRATION

The SPS contains 16 horizontal and 12 vertical corrector magnets, 28 quadrupole magnets and 20 BPMs. It is unfortunate that the BPMs of the SPS were not properly calibrated prior to installation. Dismantling the BPMs for recalibration at this stage is not a preferable option. It was therefore decided that a beam based calibration should be attempted. The calibration was carried out by calibrating the measured orbit responses to the theoretical values, i.e.

$$\Delta = \frac{\theta\sqrt{\beta_i \beta_j}}{2\sin \pi\nu}\cos\left(\left|\mu_i - \mu_j\right| - \nu\pi\right), \quad (1)$$

where θ is the corrector kick angle, β the beta function, μ the phase advance, ν the betatron tune, and where the subscript i and j indicate the values at the BPM and the corrector positions, respectively. This calibration method therefore relies on the knowledge for corrector magnet characteristics and the theoretical model of the storage ring. The corrector magnets were accurately measured for the B-I slope and effective magnetic lengths [3]. The storage ring theoretical model was obtained by fitting the measured beta function and betatron tunes [4]. From the measured beta functions the four-fold symmetry of the ring is reasonably reproduced. For simplicity, the symmetry was therefore kept in the fitted model. The measured and fitted beta functions are shown in Figure 1. The model is used in Accelerator Toolbox [5] for calculations.

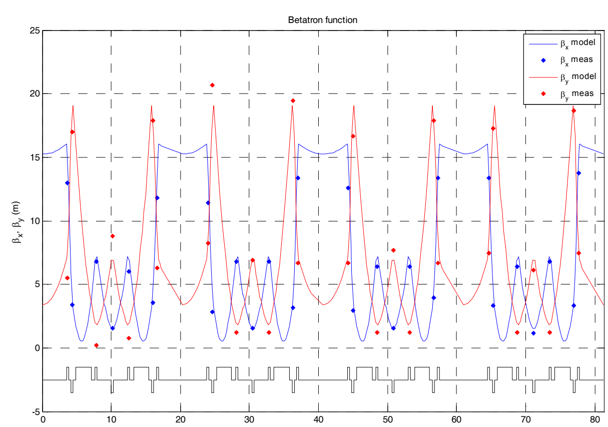

Figure 1: Measured and modelled beta functions

Even though this will contribute some errors to the calibration it is expected that the results should be good enough for preliminary COD correction. Moreover, it is hoped that this should at least give a reasonable working system to perform a more systematic refinement such as that using LOCO [6].

Automated measurements of the response matrix were carried out by varying corrector currents and measuring orbit responses. The calibration factors in the horizontal and vertical planes for each BPM were then calculated by averaging the ratios between the model and measured responses for all corrector magnets. The final calibration factors for horizontal and vertical planes were then obtained by averaging the factors obtained for all BPMs

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in each plane. The results gave the calibration factors of 17.40 in the horizontal and 51.80 in the vertical planes. These calibration factors are then set to the control system for BPM readings.

BPM OFFSET MEASUREMENTS

A Matlab program has been written for automated BPM offset measurements, using OPC Toolbox for interfacing with the machine control system. The offset between the electrical center of a BPM and the magnetic center of an adjacent quadrupole is determined from the position where orbit response to a change in the quadrupole current is minimum. The method carried out at the ALS [7] is adopted here. Firstly, a target BPM is chosen together with the adjacent quadrupole. Next, the program chooses the theoretically most effective corrector at that quadrupole position. The beam orbit inside the quadrupole is then moved to a certain position by setting the current of the chosen corrector, after which the beam position from the BPM signal is recorded. The quadrupole trim coil current is then varied (by ±3 A) and the beam position in all the 20 BPMs are recorded. The merit function is then calculated by

$$M(I_C)=\sum_{i=1}^{20}\left(\Delta_i^+-\Delta_i^-\right)^2 , \qquad (2)$$

where $M(I_C)$ indicates the merit function being the function of corrector current, Δ^+ and Δ^- are the orbit responses for positive and negative changes of the quadrupole trim coil current, respectively, and where the subscript i indicate the BPM number. The corrector current is then changed again to move and record the beam orbit. The procedure for calculating the merit function is then repeated. Since the orbit response to the change in quadrupole current is linear with the beam position in the quadrupole this merit function is therefore quadratically dependent on the corrector current. The whole procedure is repeated until a parabola is obtained for the merit function. A quadratic fit is then performed to obtain the parabola minimum. The minimum of $M(I_C)$ therefore indicates the corrector current where the beam position in the quadrupole gives minimal response to changes in qudrupole strength. This position is therefore taken as a quadrupole magnetic center. The beam position inside the BPM at this orbit can then be interpolated from the linear dependence of the BPM signal to the corrector current. This value of beam position inside the BPM is therefore the required BPM electrical offset regarding to the quadrupole magnetic center.

An example of the user interface panel for the offset measurement is shown in Figure 2. Twenty BPM readings were averaged for each orbit during the measurement. Results of the measured offsets are shown in Figure 3. It was found that some of the offsets are quite large. Values for mechanical offsets from misalignments measured during the previous shutdown are also shown for comparison. It is seen that the mechanical misalignments contribute very little to the BPM offset. The measured offsets are therefore believed to be real, to within the measurement errors. These measured offsets are compensated prior to COD correction.

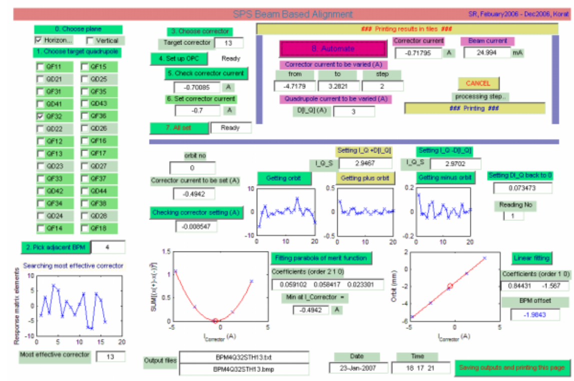

Figure 2: User interface panel for BPM offset measurement code

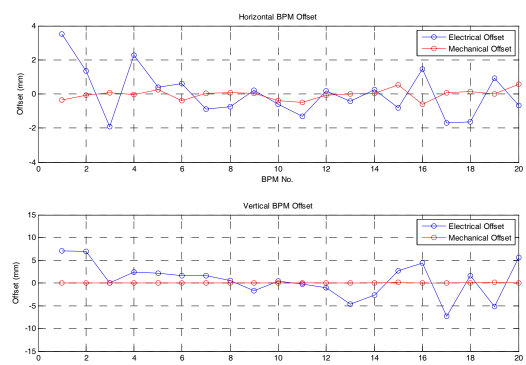

Figure 3: Results of BPM offset measurements. Measured offset from mechanical misalignments are also shown for comparison.

COD CORRECTION

Preliminary COD corrections were performed at the beam energy of 1.2 GeV by solving the matrix equation,

$$\mathbf{A}\cdot\boldsymbol{\theta}+\mathbf{b}=0\,, \qquad (3)$$

where $\mathbf{A}$ is the orbit response matrix and $\mathbf{b}$ the column matrix for BPM readings. The solution $\boldsymbol{\theta}$ is the column matrix for the required corrector kick angles to correct the COD. The above equation was solved using Singular Value Decomposition (SVD). The solution was then superimposed on the corrector settings for COD correction. It was found that the correction was able to reduce the RMS of the COD by approximately 87% (horizontal) and 58% (vertical) of the uncorrected orbit. The RMS of the residual COD is approximately 0.4 mm (horizontal) and 0.8 mm (vertical). The CODs before and after the correction are shown in Figure 4. This COD correction result is now temporarily used during the beam service by

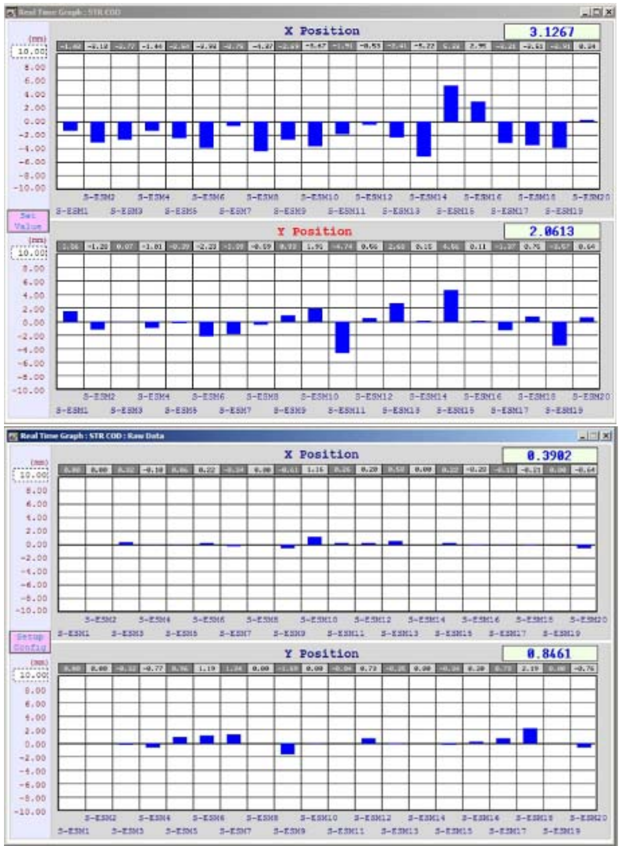

Figure 4: COD before and after COD correction.

scaling down the obtained corrector currents to 1 GeV injection energy. It is expected that there may be many parameters contributing to the difficulties in correcting the residual COD. In addition to calibration errors there also appear to be large noises in the BPM signals. Reproducibility of the COD correction is, however, good enough for the beam service at this stage. Works on BPM noise analyses and reduction, together with better calibration and more accurate offset measurements to improve the efficiency and reproducibility of COD correction are now underway. Systematic response matrix analyses using LOCO [6] is also being carried out.

CONCLUSION

Beam-based calibration of BPMs in the SPS has been carried out. The measured response matrix was calibrated to the model obtained from beta function and betatron tune fitting. The calibration factors for horizontal and vertical planes were obtained by averaging of the response ratios for all corrector magnets and BPMs. The BPM-Quadrupole offsets were then measured with Matlab programming interfacing via OPC Toolbox. The measured offsets were compensated prior to COD correction. The COD correction was performed by solving the response matrix equation using SVD. The result was able to reduce the COD by approximately 87% in the horizontal and 58% in for vertical plane.

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