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OPTICS CALIBRATION FOR ROUTINE OPERATIONS IN TAIWAN PHOTON SOURCE

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Abstract

To ensure a stable performance of Taiwan Photon Source (TPS), we perform the calibration of accelerator optics using LOCO (Linear Optics from Closed Orbit) technique every month. After the optics and coupling corrections, the rms beta beatings in both planes are reduced to less than 1 %. The emittance coupling ratio is also restored to within the design value.

INTRODUCTION

The TPS light source is located in the NSRRC campus in Hsinchu, Taiwan. The lattice structure of the storage ring is comprised of 24 double bend (DB) cells and the natural emittance is 1.6 nm-rad. It is a 6-fold symmetry structure, i.e., 6 long straight sections (12 m) and 18 short straight sections (7 m) for the accommodation of injection elements, RF cavities and insertion devices (IDs). There are two bending magnets, ten quadrupoles and seven sextupoles in each DB cell [1-2].

The commissioning of TPS started in 2014 and the first synchrotron light from the storage ring was observed on December 31, 2014 [3]. The optics calibration started in the beginning of 2015. In the mid-2015, we installed 2 superconducting RF cavities, 10 insertion devices and 9 additional quadrupoles in three long straights to reduce the vertical betatron function in such long straights for small gap undulators. This lattice structure is called the double mini-betay (DMB) lattice [4]. The optical function of the DMB lattice is shown in Fig. 1. The major lattice parameters are shown in Table 1.

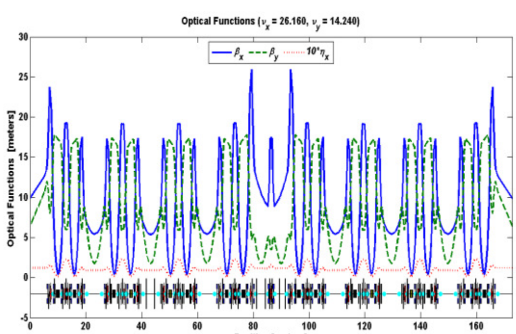

Figure 1: Optical functions of the DMB lattice.

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Table 1: Major Parameters of the DMB Lattice

Parameter	
Emittance (nm-rad)	1.6
α_1	2.4×10^{-4}
α_2	2.5×10^{-3}
ν_x / ν_y	26.160 / 14.240
σ (ps), RF = 3.2 MV	10.0
Natural Chrom. ξ_x /ξ_y	-74.7 / -28.7

RESULTS OF OPTICS CORRECTION

We started commissioning of DMB lattice in September 2015. Lattice correction with LOCO [5] procedure was needed because extra 9 quadrupoles were added. Before the optics correction, the beta beating was 12.92 % rms in the horizontal plane and 7.35 % rms in the vertical plane as shown in Fig. 2 and 3. After three iterations, the beta beating was reduced to 1.23 % rms in horizontal and 0.54 % rms in vertical, respectively.

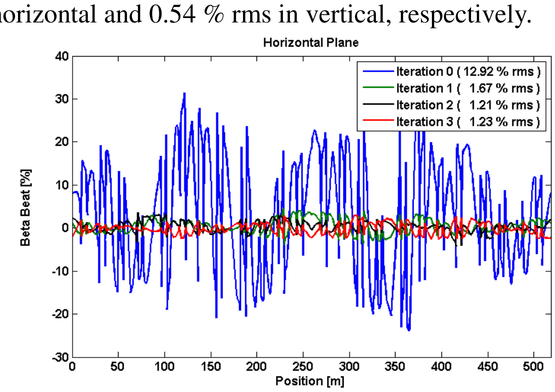

Figure 2: Beta beating in the horizontal plane.

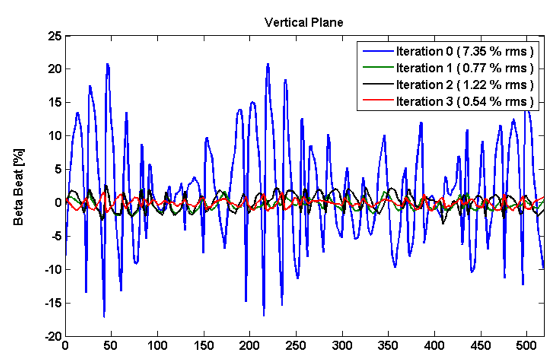

Figure 3: Beta beating in the vertical plane.

We used MATLAB-based high level applications [6-8] to measure the beta and dispersion functions after LOCO procedure as shown in Fig. 4-5. The vertical dispersion in real machine is mainly due to the coupling. To correct the

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horizontal and vertical dispersion simultaneously, we perform the coupled-plane correction with skew quadrupoles in LOCO procedure. After correction, the symmetry of dispersion function was restored and the vertical dispersion was reduced.

We also repeated the Beam-Based Alignment (BBA) [9] to find the BPM offsets, especially the new ones in the long straights. The measured BPM offsets with respective to nearby quadrupole centers were 0.34 mm rms in horizontal and 0.35 mm rms in vertical, respectively as shown in Fig. 6.

After BBA and orbit correction, the residual orbit deviation was reduced to 69.89 um rms in the horizontal plane and 36.99 um rms in the vertical plane as shown in Fig. 7.

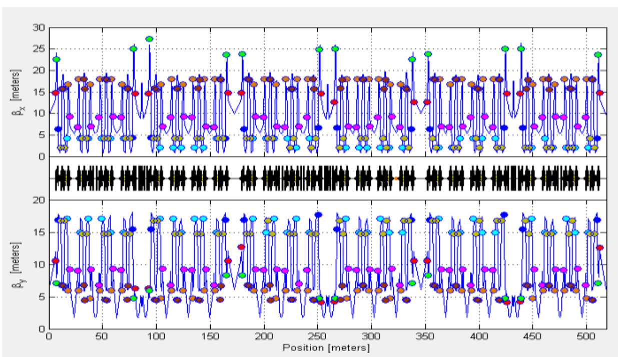

Figure 4: Beta function measurement after optics correction (color circle: measured data, blue line: LOCO result).

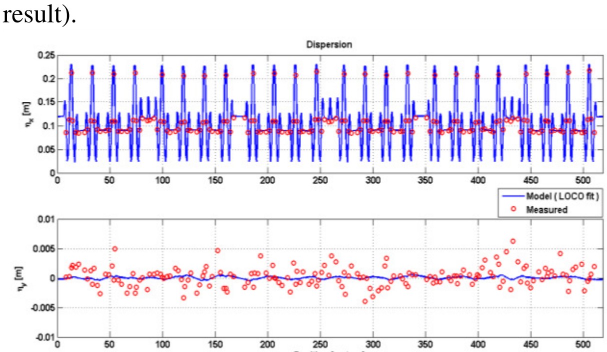

Figure 5: Dispersion function measurement after optics correction (red circle: measured data, blue line: LOCO result).

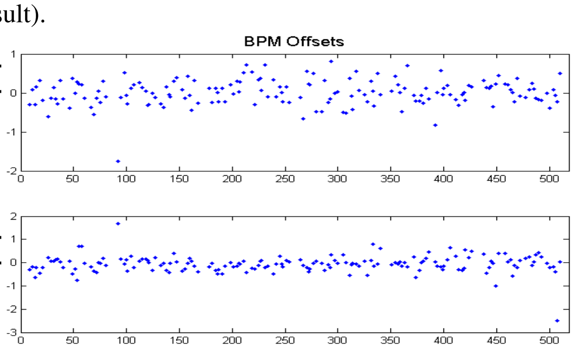

Figure 6: Results of BBA measurement.

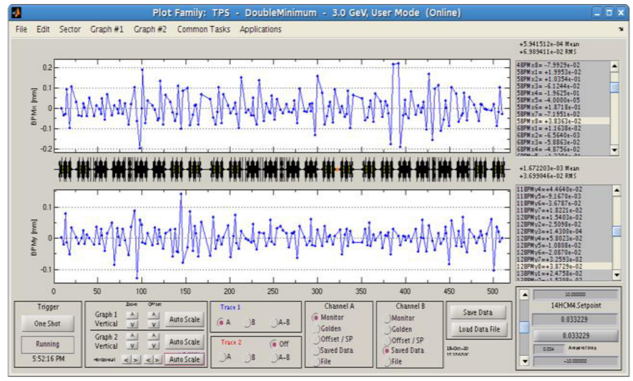

Figure 7: Residual orbit deviation after BBA and orbit correction.

To provide a stable and high quality light source for the beamline users, we perform the procedure of the optics correction monthly. The requirement of the rms beta beatings in both planes is less than 1 %. The rms beta beatings after optics correction in both planes are always less than 0.5 % in the past year as shown in Fig. 8. The rms values of the quadrupole strength variation after optics correction in 2018 are kept within a small range as shown in Fig. 9.

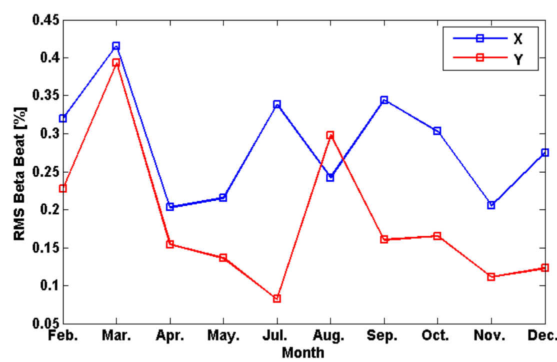

Figure 8: Beta beat after optics correction.

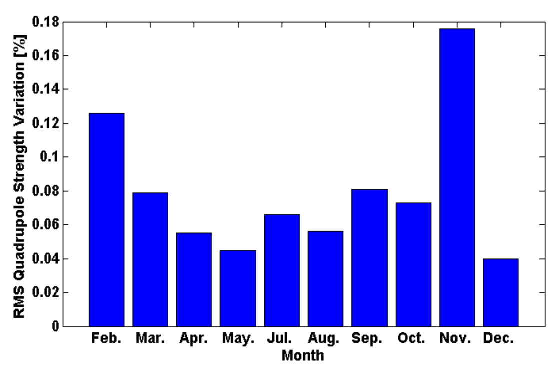

Figure 9: Quadrupole strength variation.

The betatron tune is an important beam parameter which would influence the injection efficiency and the beam lifetime. Figure 10 shows the differences with the working tune after optics correction. The tune differences are always less than 0.004 in 2018.

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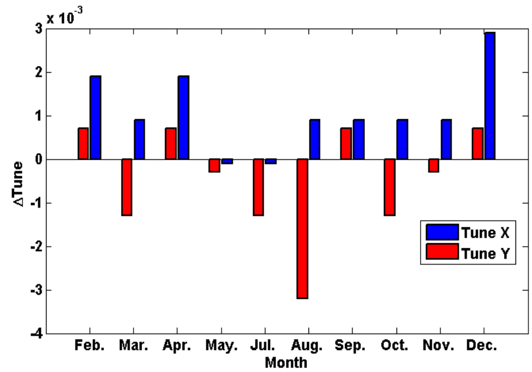

Figure 10: Betatron tune differences after optics correction.

Due to the optics calibration every month, we kept the beam parameters the same in the past year. The beam size was almost the same with or without coupling correction. As shown in Fig. 11, the vertical beam size was reduced from 15.87 um to 15.46 um after coupling correction. In the same way, the horizontal beam size was reduced from 48.60 um to 48.21 um. The difference in both planes was less than 0.5 um.

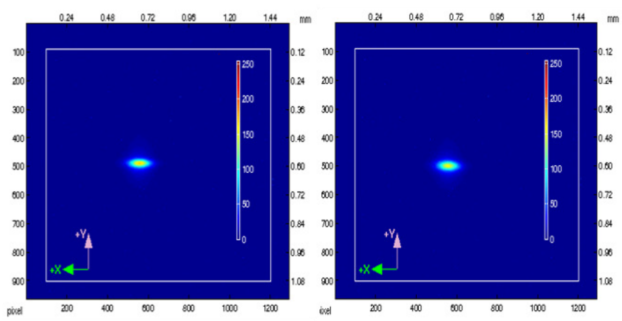
Figure 11: Beam profile before coupling correction (left) and after correction (right).

The BBA measurements are also very important for the routine operations. After the short or long shutdown, we perform the BBA measurement to make sure the BPM offsets are corrected. Because the wrong BPM offsets would influence the user orbit. In the past year, most BPM offsets are less than 1 mm except one faulty BPM in the vertical plane as shown in Fig. 12.

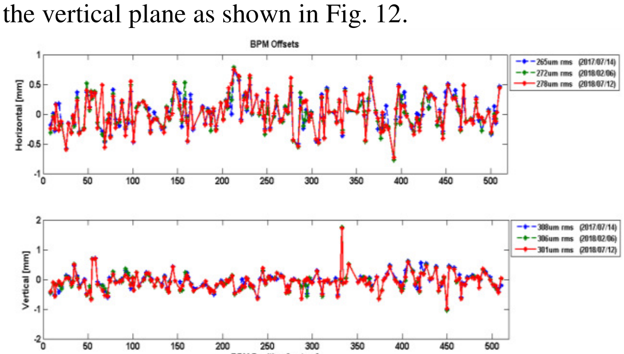

Figure 12: Results of BBA measurement.

In order to simplify the complicated LOCO procedures, we developed a LOCO automation GUI as shown in Fig. 13. The GUI combined the measurements of the LOCO input data (including the dispersion, orbit response matrix and BPM standard deviation) and LOCO calculation in one figure. The users just click the "Measure" button to activate the procedures and then click the "Correct" button to do the optics correction for the real machine. It helps us to speed up the procedures and save time.

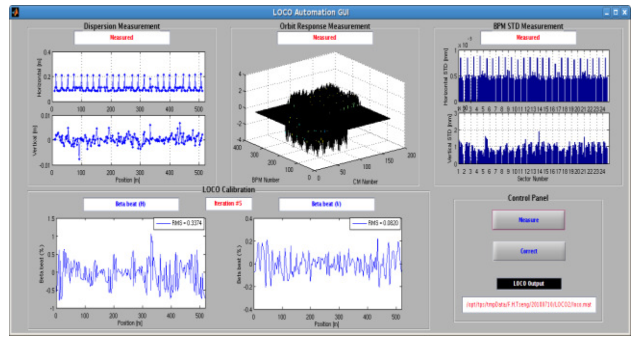

Figure 13: GUI window of LOCO automation.

SUMMARY

LOCO is a very powerful tool for the TPS commissioning and routine operations. The TPS performance is much improved after optics corrections. Due to the routine optics calibration, we could provide a reliable and high performance light source for the beamline users.

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