

BEAM MOTION AND PHOTON FLUX DIPS DURING INJECTION AT THE TAIWAN PHOTON SOURCE

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Abstract

The Taiwan photon source (TPS) is a 3 GeV synchrotron light source now in routine operation at the NSRRC. At the beginning of beam commissioning, significant photon flux dips could be observed at injection due to a blow-up of the beam size. To eliminate this transient effect, all four kickers were rematched. The leakage field was shielded and the induced current loops at vacuum chambers in the injection area were also eliminated. These efforts reduced the horizontal betatron oscillations and orbit distortions to around one-tenth. In order to decrease the recovery time of photon dips during injection, the operational chromaticity was reduced to improve incoherent effects. After all those improvements, the photon flux dips during injection dropped to 30 % and the recovery time to less than 1 msec.

INTRODUCTION

The Taiwan Photon Source (TPS) is a third-generation light source to provide a highly brilliant beam with top-up injection at the NSRRC [1]. It consists of a 150 MeV linac, a 150 MeV to 3 GeV booster ring (BR) and a 3 GeV storage ring (SR). The BR and SR share the same tunnel. Two half-sine wave septa in the booster to storage (BTS) transfer line need to deflect the beam around 120 mrad within a limited space, shown in Fig. 1. The design field are 0.63 T and 0.56 T to bend the beam for 3.6 o and 3.18o for the up- and down-stream septa, respectively. Four kickers (K1-K4) are installed in the first straight section [2] with kick angles of around 4.5 mrad with a pulse current of 2200 A [3].

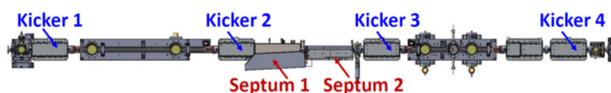


Figure 1: Layout of the injection section.

BEAM MOTION AT INJECTION DURING BEAM COMMISSIONING

During beam commissioning, the beam orbit showed large betatron oscillations in the turn-by-turn (TBT) data, i.e. (± 3 mm in the horizontal and ± 0.15 mm in vertical plane) during the injection, as shown in Fig. 2. These beam oscillations can be observed only when kickers and septa or only the four kickers are fired. No oscillation can be observed when only the two septa are fired, because the septa pulse width (~ 370 μ sec) is too long to excite betatron oscillations [4]. The orbit distortions, as the septa are fired, come from stray fields [5], i.e. eddy currents and leakage fields of the septa. The betatron oscillations caused by the

four kickers come from the mismatch of the four kickers, which can be improved by re-matching the kickers. The betatron oscillations are higher when all four kickers and both septa were fired compared to only four kickers alone because the beam is moved closer to the septa and gets an extra kick due to stray fields in the off-axis injection. The extra kick strength increases as the beam is moved closer to the septa. Therefore, the leakage fields coming from the septa should be shielded to minimize such oscillations.

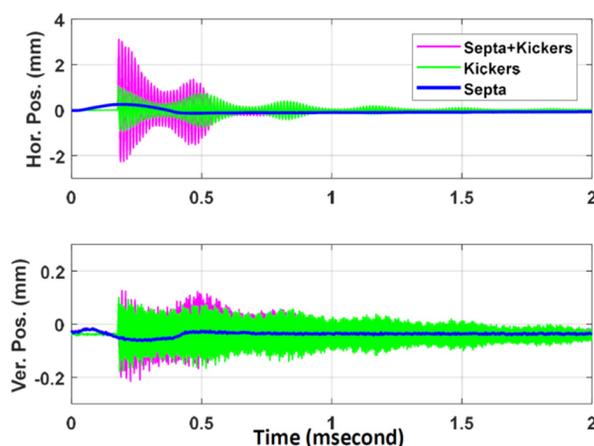


Figure 2: Turn-by-turn data of horizontal and vertical beam positions in BPM021 as two septa and four kickers or four kickers or two septa are fired separately.

STRAY FIELD REDUCTION AND KICKERS MATCHING

The first step to reduce the beam motion during injection is to rematch the four kickers and shield the leakage fields for the kickers and septa to the beam with mu-metal. From the 10 kHz data in Fig. 3(a), the horizontal beam motion at BPM021 becomes smaller but do not meet our expectation. Measuring the induced currents around the vacuum chamber in the injection area, values as high as ~ 750 A were detected. This current depends on where the current probe is set. This means large currents flow in the vacuum chamber around the intersection of the BTS and storage ring which disturb the beam significantly. Therefore, the BTS is isolated from the storage ring and the grounding of the BTS is improved to reduce the induced current from the septa to the beam, as the red line shows in Fig. 3 (a).

There is one positive and one negative peak in the 10 kHz data, one peak occurring around 0.3 ms and the other around 0.7 ms. The first peak mainly comes from leakage fields and induced currents in the injection area. The second peak comes from eddy currents. Plotting the orbit distortions at 0.3 ms and 0.7 ms as shown in Fig. 4, we

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observe that the beam distortions occur at 0.3 ms and become much smaller after shielding the leakage fields and isolating the BTS current loops. However, the reduction of orbit distortions at 0.7 ms is more limited because the eddy currents in the vacuum chamber cannot be completely avoided.

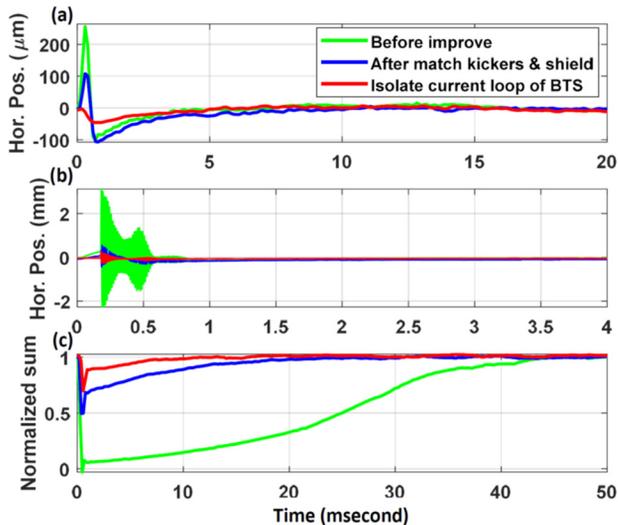


Figure 3: (a) Data at 10 kHz rate, (b) turn-by-turn data of the horizontal beam positions at BPM021 and (c) counts of the four pin-diode sum signals from the QBPM2 in beamline 05A during injection before improvements or matching the four kicker & shielding the stray fields and after isolating current loops in the BTS separately.

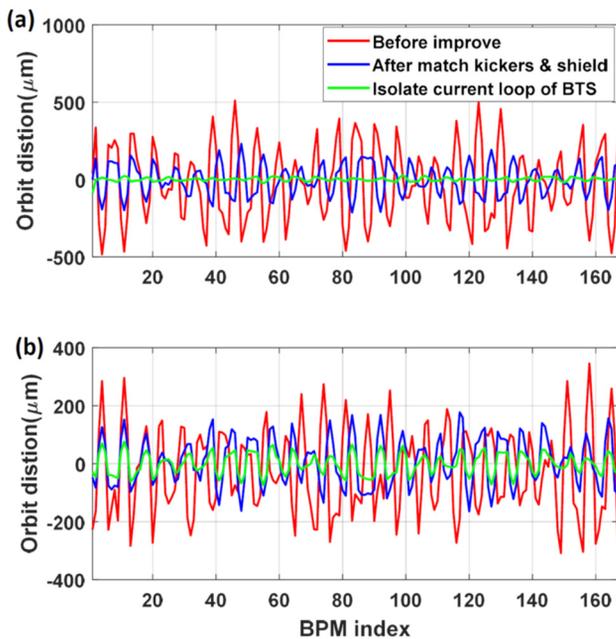


Figure 4: Beam orbit distortion in each BPM at (a) 0.4 ms and (b) 0.7 ms.

In the TBT data shown in Fig. 3 (b), the betatron motion decreases significantly after matching all four kickers and shielding the leakage field. The betatron motion becomes negligible after 1 ms. On the other hand, observing the photon flux dips, in the quadrant photon beam position monitor (QBPM) [6] in beamline 05A (shown in Fig. 3 (c)),

the recovery time is as long as 10 ms when the betatron oscillations have completely damped out. That is because the electric BPMs can only detect the centroid beam motion but it cannot detect incoherent motion due to energy spread [7, 8]. In this case, the chromaticity (ξ) set to $\xi_x = 4$ and $\xi_y = 2$ and not only the coherent beam motion but also the incoherent motion make the photon beam size larger. There are beam limiting masks and a double crystal monochromator before the QBPM causing the photon flux dips in the QBPM during injection. Although the stray field reduction and kicker matching can decrease the magnitude of the photon dips during injection, the most effective method to decrease the recovery time is a reduction of the chromaticities which will be discussed in a later section.

FULL-SINE SEPTUM

The pulsed high magnetic field strengths produce eddy currents in the vacuum chambers and distorts the beam orbit in the storage ring for a few mseconds. Modifying the power supply of the pulser [9] to produce a bipolar full-sine current exciting the magnet, as shown in Fig. 5, can compensate this effect. Resistive losses in the drive circuit limits the negative strength being only 75 % of the positive strength.

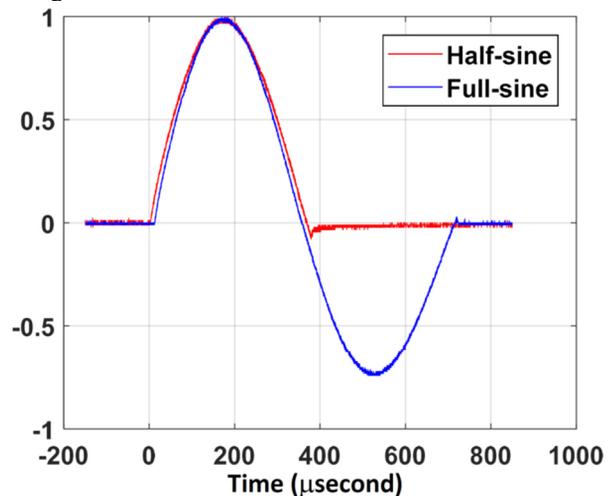


Figure 5: Waveform of a half-sine and a full-sine current pulse.

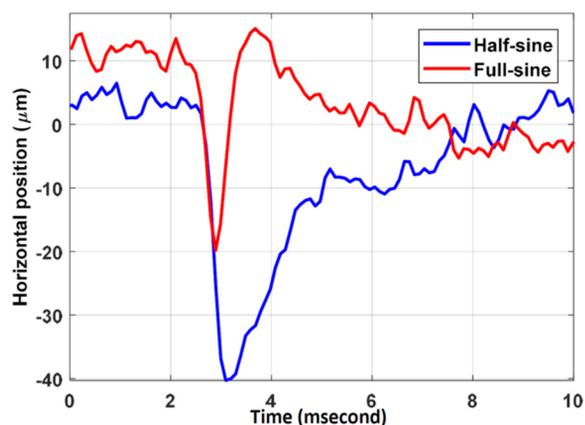


Figure 6: Horizontal beam distortion in the BPM021 for full-sine/half-sine septa excitation.

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Because the eddy current effect of the first septum to the stored beam is almost negligible due to the distance between the first septum and SR, only the pulse power supply of the second septum is modified to produce full-sine current. Comparing the horizontal beam distortion for the second full-sine/ half-sine septa excitation in Fig. 6, we find the magnitude of the horizontal beam distortion and recovery time is smaller for a full-sine excitation.

CHROMATICITY EFFECT

When the four kickers are fired, the unmatched kickers produce betatron oscillations and the septa leakage fields will enhance those oscillations. Because the four kickers and pulser power supplies are not identical, it is unrealistic to completely remove betatron oscillation. Therefore, the reduction of the chromaticities to reduce the effects of incoherent beam motion appears to become an effective method. It is because the lower chromatic tune spread at low chromaticities causes minimal coherent beam motion and the bunch-by-bunch feedback system has the capability to depress the remaining betatron motion.

The harmonic number of the TPS storage is 864. When 700 bunches are filled with a total current of 500 mA in multi-bunch mode, the bunch current is around 0.7 mA. At the start of routine operation, the chromaticity was set at $\xi_x = 4$ and $\xi_y = 2$. There was still room to optimize the lattice for operation at lower chromaticities to lower the injection transient time. After reducing the operational chromaticities to $\xi_x = 0.5$ and $\xi_y = 0.5$, the recovery time of the photon flux dips became smaller than 1 ms as shown in Fig. 7.

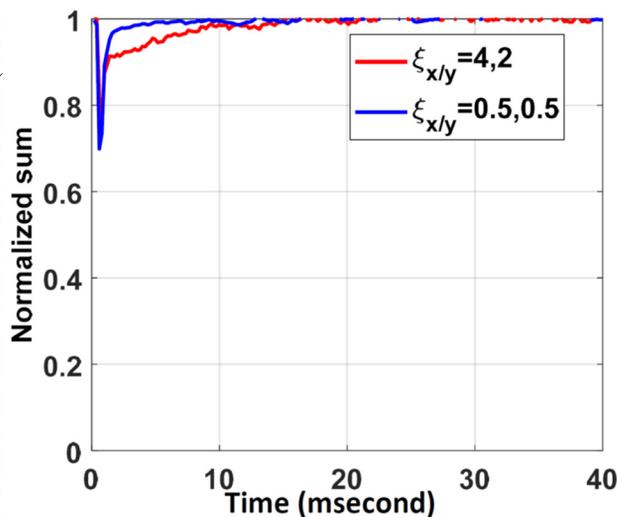


Figure 7: Counts of the four pin-diode sum signal from the QBPM2 in beamline 05A during injection with chromaticities $\xi_{x/y} = 4/2$ and $0.5/0.5$.

CONCLUSIONS

To eliminate beam distortions caused by injection transients, many studies and improvements have been made since start of beam commissioning when the horizontal/vertical betatron oscillations were around ± 3

mm/ ± 0.15 mm and the photon flux dips were nearly 100% during injection. There are two orbit distortion peaks during and after the septa are fired. One comes from the leakage field and induced currents and the other comes from eddy currents. After shielding the leakage field and matching all four kickers, the betatron oscillations became much smaller but there were still beam orbit distortions when the septa were fired. These orbit distortions come from induced currents in the vacuum chambers around the injection area, which were eliminated by isolating the current loops. In order to reduce the beam distortions caused by eddy currents, the pulse waveform of the second septum was also modified from a half-sine to a full-sine.

When the TPS is operated at high chromaticities, incoherent beam motion makes the recovery time of the photon flux dips much larger in time for betatron oscillations. In order to decrease the incoherent effect, the both chromaticities ($\xi_{x/y}$) were decreased from 4/2 to 0.5/0.5 and the recovery time of the photon flux dips become shorter than 1 ms.

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