INJECTION EFFICIENCY DIAGNOSTIC AT TAIWAN LIGHT SOURCE STORAGE RING

P.C. Chiu, C.H. Kuo, K. H. Hu, Jenny Chen, Y. K. Chen, K.T. Hsu
NSRRC, Hsinchu 30076, Taiwan

Abstract

TLS is now running at 360 mA top-up mode. In the normal situation, it takes few minutes for injection from zero current to 360 mA. When the machine condition is drifted or parameter settings are reset improperly, however, injection efficiency sometimes become worsen and it is necessary to adjust some machine parameters such as quadrupole strength, transport line correctors or booster dipole to improve efficiency. In the present, the injection efficiency is roughly based on the charge loss from the booster to storage ring. To determine the more precise efficiency from different transmission paths, some diagnostic tools are developed. A single pass BPM was tested and installed in the first BPM of the transport line. Moreover, BPM sum reading of the storage ring is also developed to provide 10 kHz waveform display every one second. Operators could utilize it to estimate efficiency more precise, quickly and easier.

INTRODUCTION

TLS had changed from decay mode to top-up mode in 2005. In order to help the operation of constant current, the optics of booster to storage ring transport line had been readjusted and the injection scheme was also reviewed [1]. However, in the top-up mode, maintaining stable storage ring current has become important for users' experiments. This stability should need both stable booster current and injection efficiency. In general, the overall injection efficiency from booster to storage ring was around 41.6% [2] while it deviated from time to time for different conditions. In this paper, some new diagnostic tools to observe storage ring and transport line current intensity will be introduced and the procedure to estimate the injection efficiency will also presented. Moreover, the possible causes which effect on efficiency will also be investigated.

SINGLE PASS BPM TO MEASURE TRANSPORT LINE BEAM POSITION AND INTESNSITY

TLS booster to storage transport line has 7 orthogonal BPMs which could be used to measure beam position and intensity. The commercial instrumentation Brilliance Single Pass [3] provides a standard solution which has useful functions of threshold and pretrigger & posttrigger such that it could calculate the button data more precise. It also supports EPICS environment and provides various data flow for multiple purposes. One unit of Libera Brilliance Single Pass was installed at the first BPM of the booster to storage ring transport line of the TLS for evaluation purpose. Figure 1 shows one button ADC raw data when injected beam passes by, the valid portion of the data is extracted according to three parameters THREHOLD, PRETRIGGER and POSTTRIGGER to calculate position X, Y and intensity SUM. The beam extracted from the booster synchrotron is about 200 pC in change distributed in 50 nsec bunch train (~ 25 bunches).

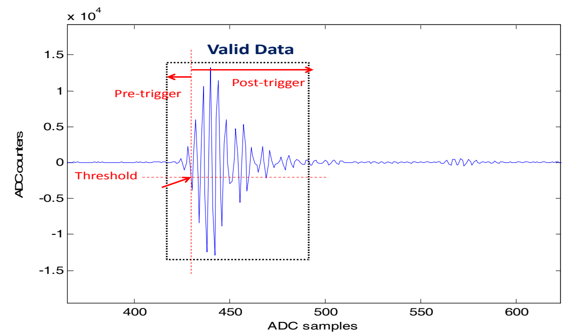


Figure 1: Three parameters defined to calculate position.

BPM SUM AS AN INDICATOR OF STORAGE BEAM CURRENT

DCCT provides high accurate current readout of the storage ring while 10 Hz readings could not clarify some fast transient phenomenon. Therefore, a diagnostic tool which is embedded with EPICS IOC and based on BPM sum reading is developed to provide 10 kHz waveform display every one second. However, it should be very careful that using BPM sum as an indicator of beam current intensity should consider the effect of position dependency. The eddy current caused by field leakage of kicker and septum will result in orbit distortion up to hundreds of micron [4] and could deteriorate the precise of sum reading. R1BPM3 with lower βx and βy is thus chosen for BPM sum readout. Figure 2 shows its 10 kHz sum data where it is clear that septum effect completely disappears and kicker effect is hardly observed either.

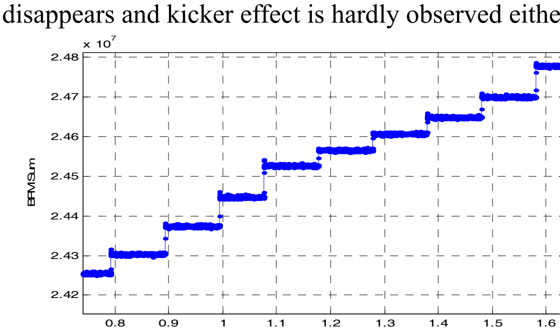


Figure 2: R1BPM3 10 kHz sum readout.

INJECTION OBSERVATION

360 mA Beam Store Injection

In this report, the injection efficiency would be determined by the current transformer of the booster, the first BPM sum signal and the ICT which is installed in the middle transport line, and the storage ring DCCT. Figure 3 shows an example of these charges during injection. It takes around 5 minutes of this injection when storage ring current is accumulated from zero to 360 mA. The average injection efficiency actually is around 18.3% in this injection process. The booster charges gradually increased while the storage ring charges didn't. It seemed that machine condition varied (see BTS horizontal position also gradually drifted). It is expected that more diagnostic tools developed to help to clarify the unclear process.

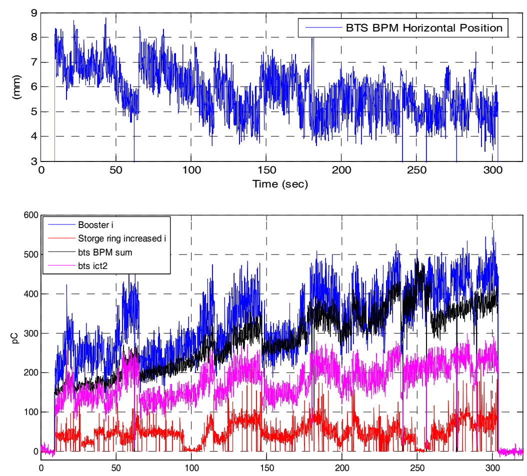


Figure 3: Booster, BTS BPM sum and hor. position and DCCT and Storage ring increased charges.

Top-up Mode Injection

In TLS top-up mode operation, the injection cycling is 10 Hz and the injection time is 1.8 sec in every minute. The injection shoot number is depended on the storage ring current which could not over 362 mA limit. Figure 4 shows an example that the electrons passing the booster, transport line and storage ring during top-up where the charge number decrease one by one due to loss. From the figure, it can be observed that injected charge number is much related with booster current. Otherwise, the booster charges weren't injected into the transport line in the last time injection. The phenomenon almost be appeared at each injection and inferred due to pulse magnet timing.

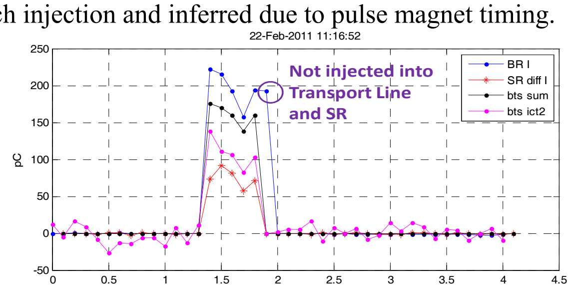


Figure 4: Booster, Transport line BPM sum and DCCT and Storage ring charges during top-up injection.

In the other hand, another pulse magnet trigger problem was also observed by the storage ring BPM sum 10 kHz data. Figure 5 showed that the orbit was disturbed before 100 msec of injection start where BPM sum value was increasing at the same injection time as Figure 4. It was inferred by comparing to Figure 4 and Figure 5 that at the first time pulse magnet was fired while booster had no current such that the orbit was disturbed but no current increase at the storage ring.

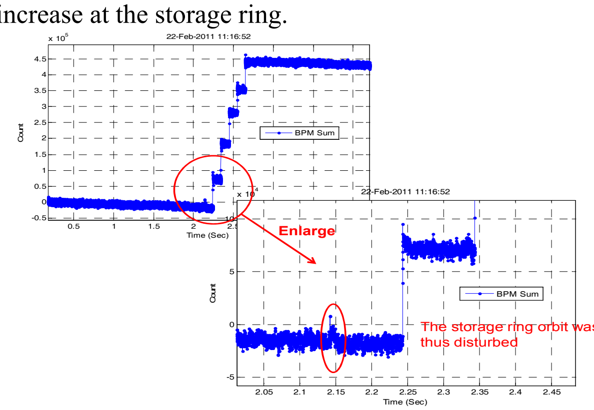


Figure 5: R1BPM3 10 kHz sum readout. The red circle of the below picture remarks that booster has no current but pulse magnet still fired caused the orbit disturbed.

SEVERAL POSSIBLE PARAMETERS TO EFFECT ON EFFICIENCY

Energy variation could be observed by horizontal position change at high dispersion location. The TLS had quite stable energy output but sometimes it still could be discovered how the energy variation effect on the injection efficiency. As Figure 6 shown, during the 4th injection the charges were hardly captured and accumulated at the storage ring for its possible energy mismatch causes the 2/3 charges loss at the first entrance of the transport line and the rest 1/3 charges completely loss at the end.

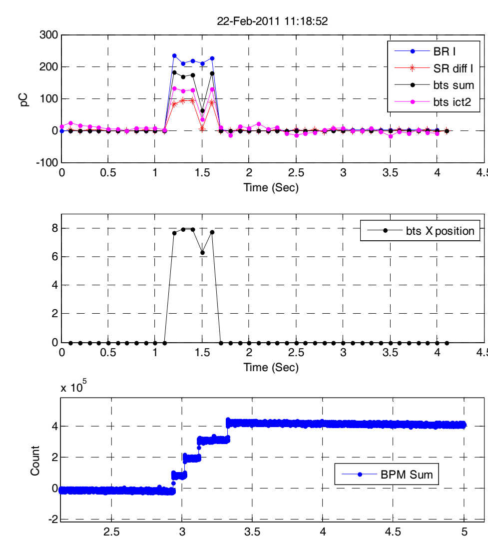


Figure 6: Energy vibration effects on efficiency.

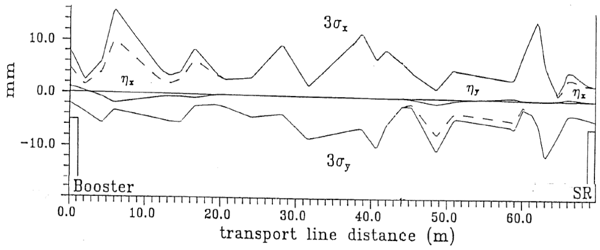
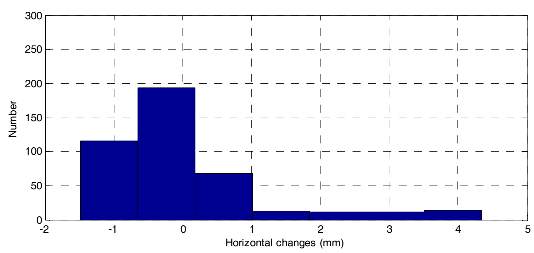
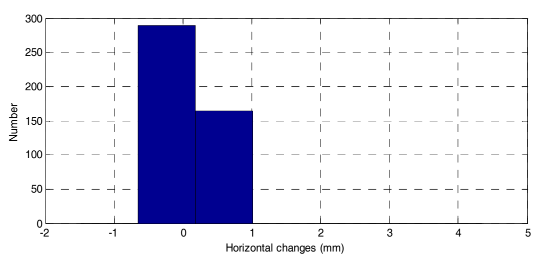


Figure 7: Optical function of Booster to the Storage Ring Transport Line.

To investigate the energy vibration effects on injection, we choose two locations of transport line with the respective high and low dispersion as Figure 7 and look at the position stability at every shoot of injection. Figure 8 shows the histograms of the BPM1 and BPM4 horizontal position change during 3 hours. Since horizontal variation (σ 1.25 mm) is respectively larger than low dispersion BPM4' horizontal changes (σ 0.30 mm), it can be inferred that it should be probably resulted from energy vibration. The position deviation over 2 mm will significantly deteriorate injection efficiency as Figure 6 and roughly takes 8% partition of injection.



(a)



(b)

Figure 8: (a) LTB BPM1 (high dispersion) horizontal position change. (b) LTB BPM4 (low dispersion) horizontal position change.

Septum charging voltage and trim quadrupole strength are the other two factors which are used to optimize injection efficiency. Figure 9 and Figure 10 show these two factors changes effect on injection efficiency respectively between different transmissions. In these tests, it can be observed that these two factors have major influences on the end transport line to the storage ring while less impact on the other transmission path. The acceptable settings are allowed quite big range. However, if the threshold is across, the efficiency drops dramatically.

Actually, there are too many factors which would affect on injection efficiency. The above listed parameters are only the selected parameters we are studying. The TLS injection efficiency is not so well while the lack of diagnostic tools lead it difficult to find out the exactly influential cause to improve efficiency. The future expansion is expected to really help to resolve problems.

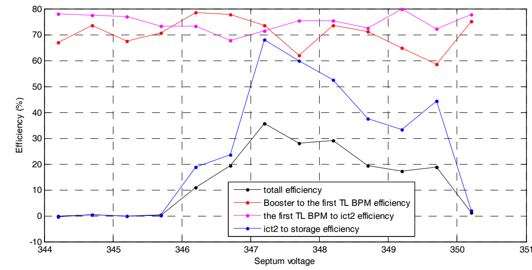


Figure 9: Septum charging voltage effects on efficiency.

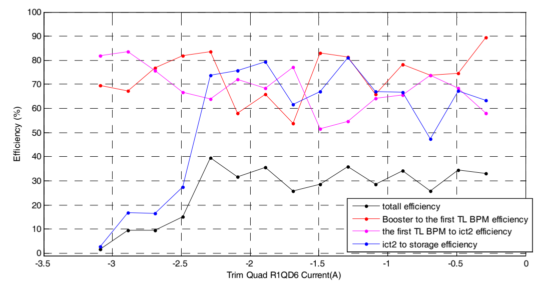


Figure 10: Trim quadrupole R1QDT16 effects on efficiency.

SUMMARY

The injection efficiency from the booster to the storage ring could be tuned and optimized up to 42% while it had often been lower than 20% when the machine condition is drifted or parameter settings are reset improperly. It is expected that more diagnostic tools could be developed to determine the precise efficiency and help to improve the injection efficiency. Otherwise, the pulse magnet timing problem mentioned at the report would also be further studied.

REFERENCES

[1] Min-Huey Wang, et al., "Revision of Booster to Storage Ring Transport Line Design and Injection Scheme for Top-up Operation at NSRRC", Proceedings of PAC 2005, Knoxville, Tennessee.
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