COMMISSIONING OF BPM SYSTEM FOR TPS BOOSTER SYNCHROTRON

P. C. Chiu, K. H. Hu, C. H. Kuo, Y. S. Cheng, K. T. Hsu

NSRRC, Hsinchu 30076, Taiwan

Abstract

Booster synchrotron for the Taiwan photon source (TPS) project which is a 3 GeV synchrotron light source constructed at NSRRC had ramped beam to 3 GeV successfully in December 16 2014 and later the stored beam in the storage ring had achieved 5 mA in December 31. The BPM electronics Libera Brilliance+ [1-2] are adopted for booster and storage ring of TPS. The provided BPM data is useful for beam commissioning where it can be used to measure beam position, rough beam intensity along the longitudinal position and also for tune measurement. This report summarizes the efforts on BPM measurement and related diagnostic tools during TPS booster commissioning.

INTRODUCTION

The TPS is a state-of-the-art synchrotron radiation facility featuring ultra-high photon brightness with extremely low emittance [3]. Civil constructions had been completed in early 2013. The TPS accelerator complex consists of a 150 MeV S-band linac, linac to booster transfer line (LTB), 0.15–3 GeV booster synchrotron, booster to storage ring transfer line (BTS), and 3 GeV storage ring. The booster has 6 FODO cells which include 7 BD dipoles with 1.6 m long and 2 BH dipoles with 0.8 m long in each cell. Its circumference is 496.8 meters and it is concentric with the storage ring in the same tunnel. At September 2014, booster BPM commissioning had committed with beam commissioning. After some hardware improvement such as power supply tuning, chamber and magnet re-alignment, demagnetization of chamber, kicker and septum improving and etc., booster had achieved beam ramped to 3 GeV at December 16 2014. Diagnostic system played a helpful rule to provided beam profile and information during booster commissioning. This report will focus on the booster BPM related environment, functionalities and measurement.

BOOSTER BPM FUNCTIONALITIES AND COMMISSIONING

The TPS booster ring has six cells where each cell is equipped with 10 BPMs which can be used to measure beam position and rough beam intensity along the longitudinal position. Fig. 1 shows the mechanical drawing of booster BPM which shapes 35x20 mm elliptical and button diameter 10.7 mm. The calibration factor Kx and Ky is 8.25 and 9.66 mm respectively.

The conceptual functional block diagram of the BPM electronics is shown in Fig. 2. It will provide several data type for different application. ADC and TBT data is

acquired on demand by trigger; 10 Hz slow data is for DC average orbit and 10 kHz fast data could be applied for booster ramping orbit or fast orbit feedback application. It is also embedded with EPICS IOC for control, monitor and configuration. The timing AMC module would provide functionalities of synchronization, trigger, interlock and post-mortem. To support operation of the BPM electronics, functionalities like cold start, shutdown, housing, control system interface should meet the requirements. The delivered units also had been performed functionality and performance test to ensure compliance with this specification.
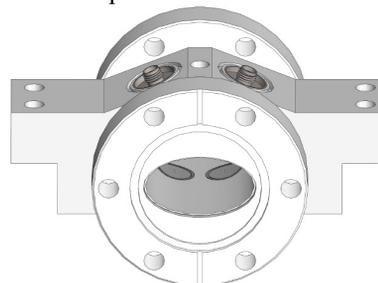

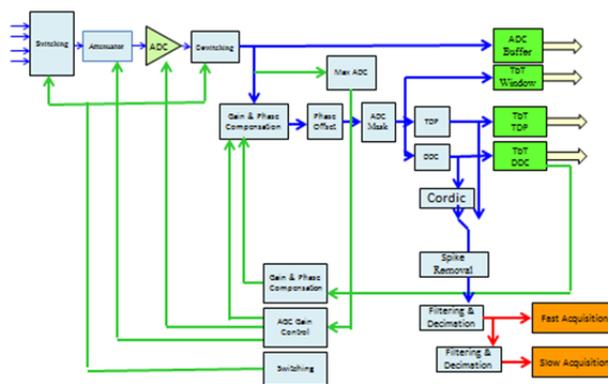Figure 1: Button-type BPM for TPS Booster.

Figure 2: BPM platform functional block diagram.

At early September, the first turn of the booster beam had achieved soon after correctors steering. There are only few buttons of BPM found to have contact problems quickly by observing ADC data with extremely low count compared to other buttons. The real BPM calibration factor was agreed with the designed values by measuring and comparing the optical function of machine model.

BOOSTER BPM MEASUREMENT

For TPS booster BPM, there are 60 sets of phase-trimmed 0.240” form polyethylene coaxial cables connected between the buttons and BPM electronics. The gain variation of BPM electronics is less than 5%. The equal length of all cable sets will contribute the same

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power consumptions and make possible to use the sum signal of BPM as an intensity indicator. The error would only come from position dependence of the beam. The BPM position and intensity data is useful for beam commissioning. In this section, different BPM data flow will be demonstrated for different applications.

ADC Raw Data

The ADC raw data is useful for checking the timing of the beam and beam property especially in the first turn. The phase delay due to time difference when beam travel pass the buttons along the ring could align by ADC clock offset. Fig. 3(a) shows that the first beam passing through the injection septum and kicker and arriving the 1st BPM of the booster ring when beam first steered pass through; (b) the beam circulates complete 5 turns in the booster after phase alignment.
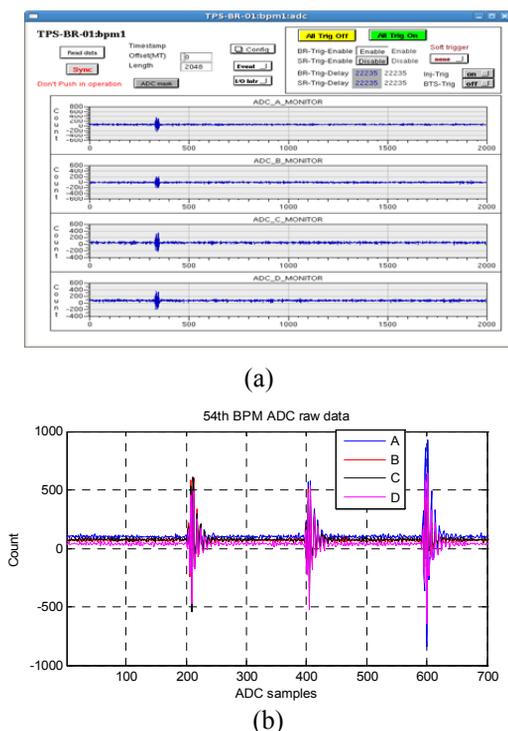
(a)

(b)

Figure 3: (a) The ADC data when beam passes through the 1st BPM of the booster synchrotron on the first day of Booster commissioning. (b) The ADC data as the beam had stored in the booster.

First-turn Application

BPM electronics provides single pass mode for calculating first turn trajectory from ADC data. However, vast beam losses and ADC DC offset up to 100 count will result in worsen signal to noise ratio and position calculation offset error. Therefore, a soft IOC would be applied to acquire more precise first turn trajectory from ADC raw minus DC offset. Fig. 4 shows the first turn orbit trajectory and sum along 60 BPMs. Horizontal trajectory shapes like dispersion function due to energy drift from Linac modulator.
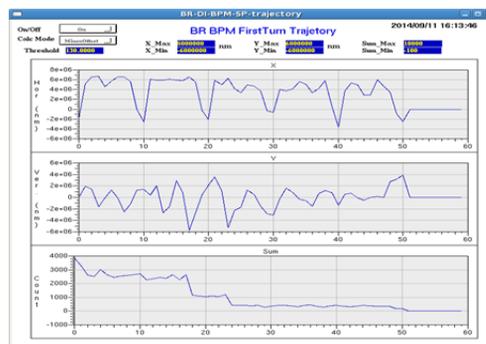
Figure 4: First turn horizontal, vertical trajectory and sum along 60 BPMs of booster. Horizontal trajectory shape like dispersion and it indicates the injection beam energy is higher that dipole current settings.

Turn by Turn Application

DDC (Digital Down Converter) and TDP (Time Domain Processing) Turn-by-turn data are both provided by BPM electronics and the resolution could achieve around 150 um at 0.5 mA. The BPM TBT data could be applied to extract tune such as Fig 5 shown the real-time injection tune as well as calculate optical function such as beta and dispersion more efficiently. To use TDP properly, phase offset should be adjusted by beam according ADC data and mask window also should be set correctly according bunch length. Compared to DDC, TDP could well resolve beam loss status and tune extraction due to clear and no smear TBT data as Fig. 6 which shows the spectrogram of DDC and TDP data respectively.
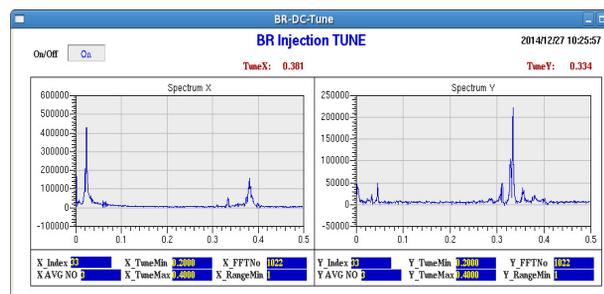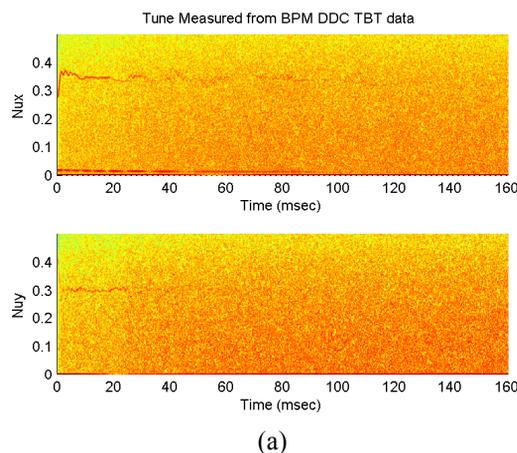
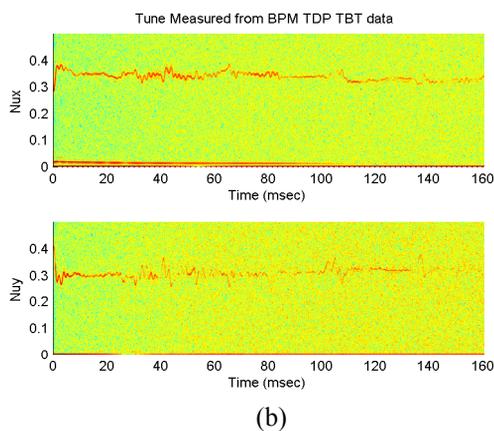Figure 5: Injection Tune extracted from BPM TBT data at injection time.

(a)

(b)

Figure 6: (a) Tune extracted from BPM DDC TBT data during booster ramping (b) Tune extracted from BPM TDP TBT data. TDP had better signal qualities than DDC due to its clear and no smear TBT data.

Slow & Fast Orbit Data

The BPM electronics also provide 10 Hz slow and 10 kHz fast position data to measure average stored beam orbit. The related applications including GUI and acquiring scripts are developed and provided for studying and helping commissioning as Fig. 7. Figure 8 shows the FA orbit variation for DC and AC mode respectively. The orbit correction according the data could help to improve injection efficiency.
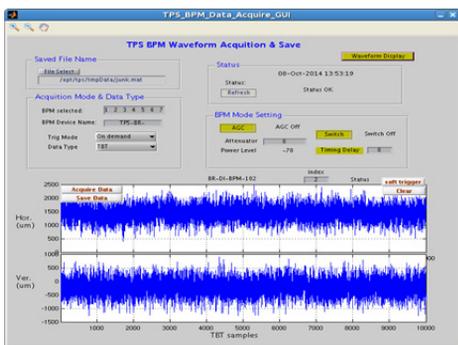

Figure 7: Acquisition tool for different data type of BPM.
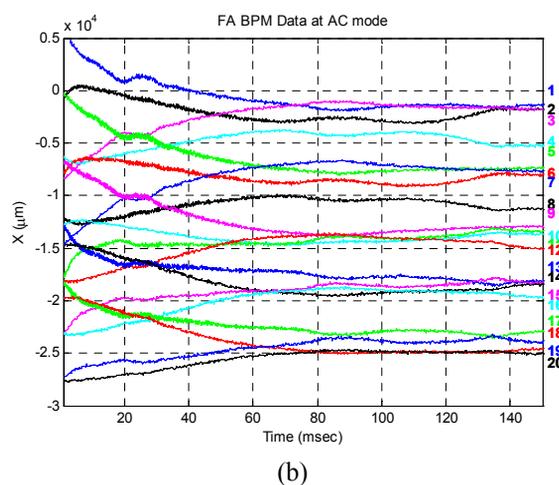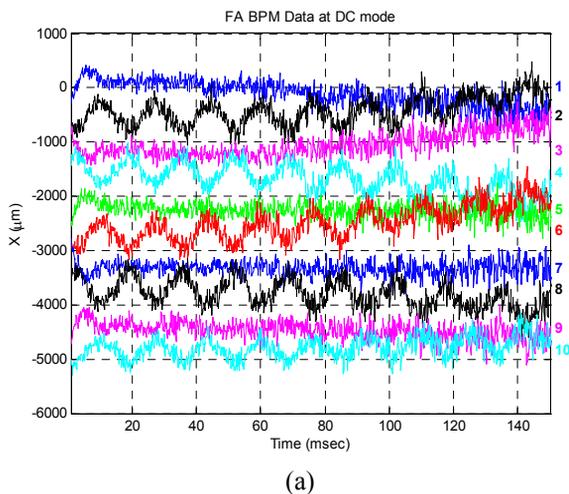

(a)

(b)

Figure 8: (a) DC mode Orbit. 60 Hz orbit perturbation is mainly from quadrupole power supply ripple. Horizontal Phase advance around adjacent BPMs is around π/4. Resolution of BPM is gradually deteriorated after 120 msec due to beam loss. (b) AC mode Orbit. Close orbit variation during ramping could be over 6 mm before tune and orbit correction and then reduced between 3 mm after tune correction.

CURRENT STATUS

Final BPM system test and beam commissioning of booster synchrotron had started at the same time in September 2014 and completed at December 2014. BPM functionalities and performance for the booster synchrotron has been exercised with beam during last several months. Supporting tools of software have been continuously revised and developed. Now the optimization of injection efficiency is still required further improvement [4]. The diagnostic tools especially BPM system provide quite a lot of information during commissioning as well as future optimization.

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