PRELIMINARY BPM ELECTRONIC TESTING FOR THE TAIWAN PHOTON SOURCE PROJECT

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Abstract

The preliminary BPM electronics are developing for Taiwan Photon Source (TPS), a 3 GeV synchrotron light source being in construction at NSRRC. This new BPM electronics with integrated FPGA-based hardware is testing in the TLS (Taiwan Light Source) with real beam at first and will be adopted in the TPS. The test of electronics prototype and related property will be reported in this report.

INTRODUCTION

The new TPS BPM electrical system is based on Libera serial technique. From Libera Electron, Brilliance to Brilliance+ compose the electron beam position processors product family, which covers the needs of wide variety of the circular light source machines [1,2]. The instruments deliver unprecedented possibilities for either building powerful single station solutions or architecting complex feedback systems. Compared to its predecessors (Libera Electron and Libera Briliance), the latest member of the family Libera Brilliance+ allows even more extensive machine physics studies to be conducted due to large data buffers and the new true turn-by-turn position calculation. It offers a large playground for custom- written applications with VirtexTM 5, Virtex 6 (grouping data, orbit feedback control) and COM Express Basic module with Intel Atom N270 (x86) inside. First field tests of the new product were performed on real beam at Taiwan Light Source (TLS).

BENCH MEASUREMENT

The platform installation and setup is shown in the Fig. 1. Rohde & Schwarz signal generator SMG which could adjust input power level source to the 4-channel power splitter and connect to BPM modules to verify its performance. Tempearure detectors are installed to measure the elctronics ambient temperature variation. RF gate will be included as well for filling pattern depedency test in the future. The testing environment are all setup with EPICS compatible which was employed as TPS control system.

Figure 1: Libera Brillance+ installation in the TLS.

Figure 2 shows the histogram of the bench measurement after 3 days record at 0.1 Hz. Horizontal position stability is around RMS 0.126 um while vertical around RMS 0.137 um

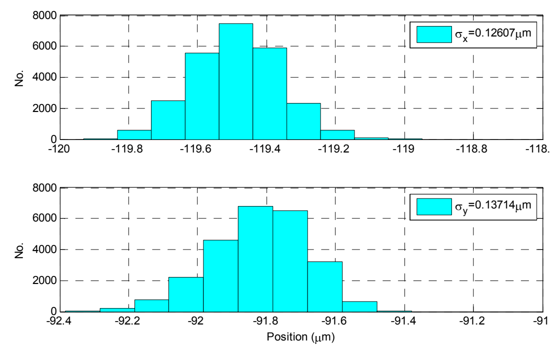

Figure 2: Histogram during 3 days at 0.1 Hz stability test.

The short-term testing is shown in the Fig. 3. The stability for horizontal and vertical FA Data is ~ 0.127 um for σ x, ~0.125 um for y.

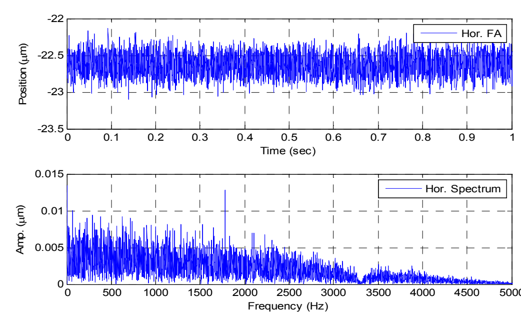

Figure 3: Horizontal FA data of time series and spectrum. There is a notch frequency near 3.3 kHz to compensate channel switch noise.

The temperature dependence testing is shown in the Fig. 4. The time delay between temperature sensors and ADC output is around 20~30 seconds.

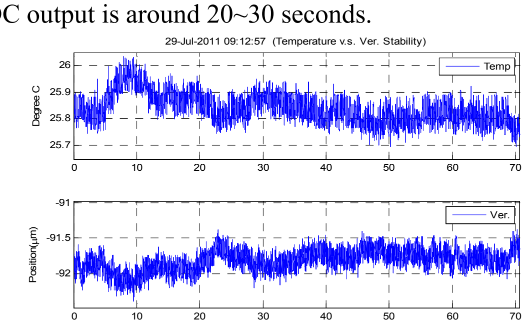

Figure 4: Temperature dependency test. The test site temperature is controlled within 0.2 °C during 72 hours.

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REAL BEAM MEASUREMENT

Taiwan Light Source operates with 499.654 MHz RF and harmonic number 200. The revolution frequency (Machine Clock) is 2.4983 MHz. First tests were done during machine start (injection), most of the tests were done during user mode (top-up operation). Libera Brilliance+ instrument was configured with 2 beam position processors in a single chassis and a timing module. Machine Clock and Trigger signals were LVTTL level and derived from the same source as for Libera Brilliance instruments in the storage ring.

Libera Brilliance+ processors were installed between 2 regularly operating Libera Brilliance units.

Beam Current (Signal Intensity) Dependence

The dynamic range of the A/D converters and the programmable attenuators was the same on both instrument types. The attenuators' value is driven by the gain control feature, which can work in automatic or manual mode. The input for Automatic Gain Control (AGC) is the maximum ADC count value (MaxADC), which is updated continuously. The A*GC* speed was set to 1 Hz in Libera Brilliance while it is adjustable in Libera Brilliance+. It was set to 10 Hz, which is a default speed. The brief setup check was done with comparison of the raw amplitudes in the ADC buffer on both instrument types.

At the Figure 5 and 6, the AGC is off, and two modes of programmable attenuators at 0 dBm and -30 dBm are tested for current dependency. Figure 6 shows current position dependency when beam current accumulated from 0mA ~ 5 mA. ADC input power level is set to -30 dBm. At this mode, the resolution of -70 dBm signal could achieve 1 um and position variation less than 1 um as well. Figure 6 shows another current position dependency when beam current accumulated from 5 mA ~ 360 mA. ADC input power level is set to 0 dBm. At this mode, the resolution of -50 dBm signal could achieve 1 um; position variation less than 1 um.

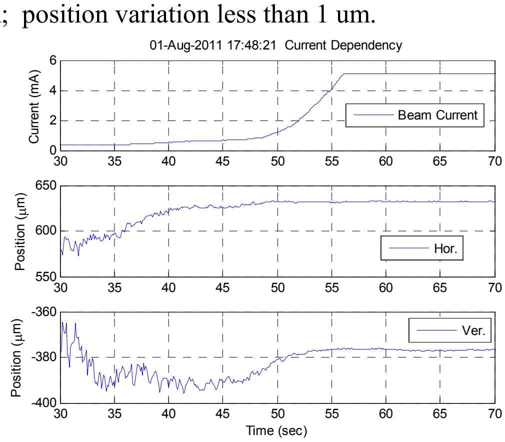

Figure 5: SA data for real beam. Current from 0 mA to 5 mA. Input power level of the Libera Briliance+ is set at -30 dBm.

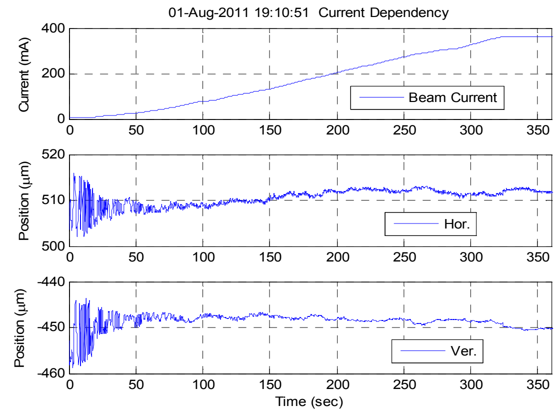

Figure 6: SA data for real beam. Current from 5 mA to 360 mA. Input power level of the Libera Briliance+ is set at 0 dBm.

Synchronization, delay settings and sampling clock offset are tested. Measurements of excitation at betatron frequency, complete injection process and top-up injection recording and check of the new position calculation principle are examined as well.

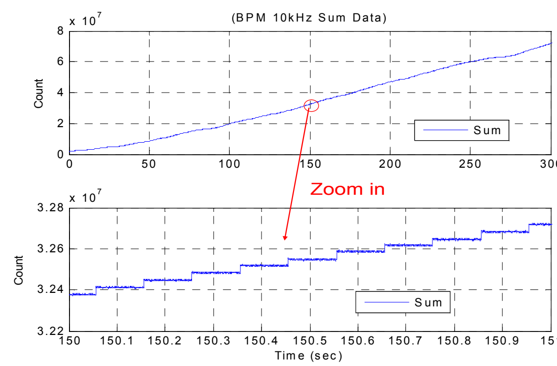

Figure 7: FA Sum data during injection.

Figures 7 and 8 shows BPM sum and position signal at 10 kHz respectively during injection. For some injection shoots, particles occasionally fail to be accumulated has been discovered before and also observed by the instrument. This FA data could be quite useful diagnostic tools to look into transient beam motion.

During the acquisition, the Automatic gain control was enabled while the Digital Signal Conditioning (DSC) was disabled. Jumps of the SUM value came from the change in attenuators (storage ring current was increasing injection by injection). The Automatic Gain Control was working correctly. To avoid multiple attenuator changes, further optimization of the gain scheme and refresh rate will be done. The first second of the injection detail is presented in Figure 8. Spikes due to the injection were more intensive in the horizontal direction. Due to the very low input signal, attenuators were fully opened. Despite of such conditions, the mean position was very stable as the linearity of the RF chains is excellent. For even more detailed look at the single injection shot, turn-by-turn data was used, 1 ms window is presented in Figure 9. The oscillations in vertical direction lasted approximately

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2400 consecutive turns while in horizontal direction approximately 2000 turns. The peak-to-peak amplitudes were ~ 1 mm in horizontal and ~ 0.8 mm in vertical.

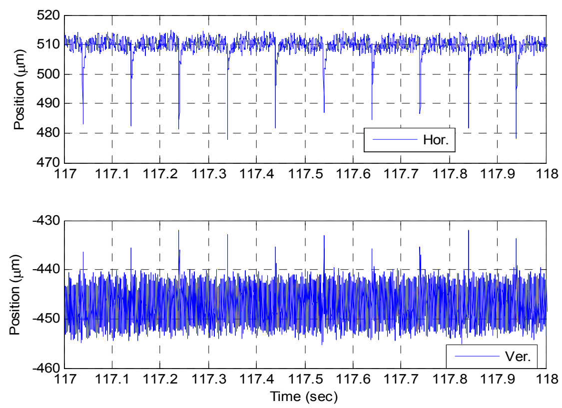

Figure 8: Orbit excursion due to septum & kicker field leakage during injection.

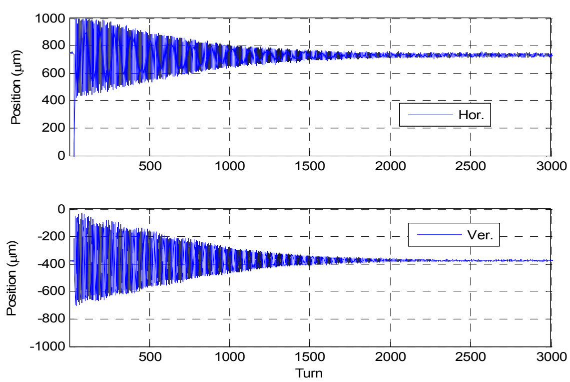

Figure 9: Turn by turn data. Betatron oscillation excited by injection.

Time Domain Processing

There are two approaches to process from ADC data to turn-by-turn data. One is classic DDC approach; another is time domain processing (TDP). Using TDP, one can define which ADC samples are taken into account to measure the position. In our case, 1 turn was covered with ADC samples decimation. In case of small partial fill (single bunch or 20% for example), the instrument does not see the input as a continuous wave but as fractions. The shape and length of the response depends on the fill and can be shorter than 47 ADC samples. The position calculation can be optimized for specific fill pattern. To adjust the calculation window, one can use the newly introduced “ADC mask” feature. This parameter defines which ADC sample is taken into account for position calculation (1=use the ADC sample, 0=don't use). The TDP provides the data to the circular buffer at exact revolution frequency and can be also used as source for fast 10 kHz and slow 10 Hz data streams. During the test, the filling pattern was almost CW so all ADC samples in one turn were taken into account. Figure 10 show the real beam testing result to compare DDC and TDP approaches to process FA data respectively. Difference seems not apparently. Various filling pattern and introduced ADC mask will be applied to further study for the proper configuration at different operation mode in the future.

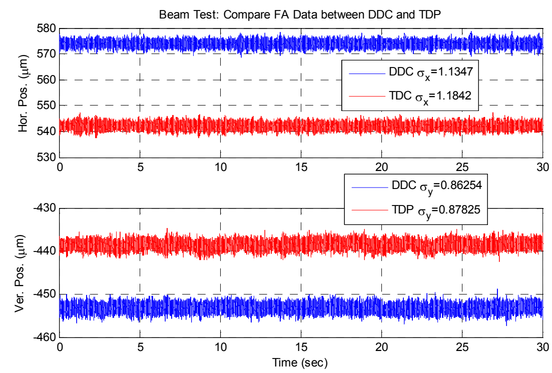

Figure 10: DDC and TDP FA data comparison of horizontal and vertical position for beam test. Kx and Ky are both set 10mm. Horizontal RMS of TDP 1.18 um is a little higher than DDC RMS 1.13 um. Vertical RMS 0.89 um of TDP is also higher than DDC RMS 0.86 um. The cause could be inferred from turn by turn data where TDP data with higher amplitude variation.

CONCLUSION

The tested unit is one Libera Brilliance+ unit from the limited first production series with the beta software version. The unit was working smoothly after resolving the initial real time clock battery consumption issue. The data was recorded by the EPICS server (with the known limitations in the buffer length), and also using libera-ireg tool, which offers more flexibility in the acquisition settings. The beta version of the software was recognized to be very user-friendly covering the user’s demands. Measured turn-by-turn and FA resolutions on the beam were expected and are further being improved. The resolution on the test bench with well phase matched cables was around 0.1 μm RMS on FA data and around 1 μm RMS on turn-by-turn data, both at -20 dBm input signal level and at 2.5 MHz revolution frequency. Long-term stability in a temperature controlled environment is proceeding.

REFERENCE

[1] http://www.i-tech.si .
[2] P. Leban et al., “First Measurement of a New Beam Position Processor on Real Beam at Taiwan Light Source”, Proceedings of PAC 2011.

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