FIRST MEASUREMENTS OF A NEW BEAM POSITION PROCESSOR ON REAL BEAM AT TAIWAN LIGHT SOURCE

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Abstract

Libera Electron, Libera Brilliance and Libera Brilliance+ compose the electron beam position processors product family, which covers the needs of wide variety of the circular light source machines. 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 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). The test setup, measurements and results are discussed in the paper.

TEST SETUP

Taiwan Light Source operates with 499.654 MHz RF and harmonic number 200. The revolution frequency (Machine Clock) is 2.49827 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 TTL 3.3V and derived from the same source as for Libera Brilliance instruments in the storage ring. The installed unit is presented in Figure 1.

Figure 1: Connections.

Libera Brilliance+ processors were installed between 2 regularly operating Libera Brilliance units (#34 and #35), see Figure 2. The data was recorded from all four pickup positions. Comparison of input signal level reading, gain control and performance was done.

BPM calibration factors (or constant) were: Kx = 13 mm and Ky = 19 mm.

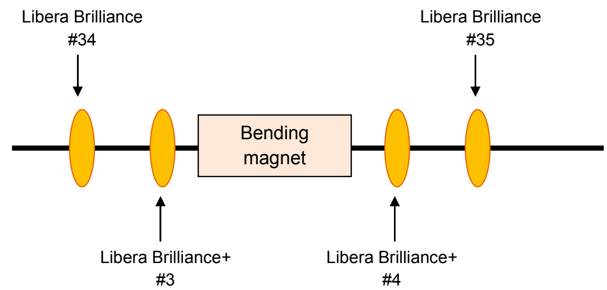

Figure 2: Position of BPMs.

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 AGC 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.

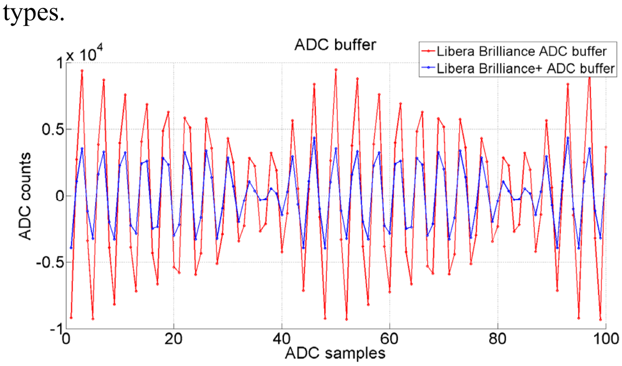

Figure 3: Raw amplitudes comparison.

For nicer comparison, gain was set manually to different values. The shape and maximum ADC count value in both instruments matched, see Figure 3.

MEASUREMENTS

Beside the general feature check, like synchronization, delay settings, gain control and sampling clock offset, the following measurements were done: excitation at betatron frequency, complete injection process and top-up injection recording and check of the new position calculation principle.

Injection Monitoring

The injection was running with 10 Hz rate. The process was monitored from the start (no current in the storage ring) with both processors in Libera Brilliance+. For detailed analysis, the FA and turn-by-turn data was recorded. The complete recording time was approximately 2 minutes, but the first ~30 seconds are presented in Figure 4.

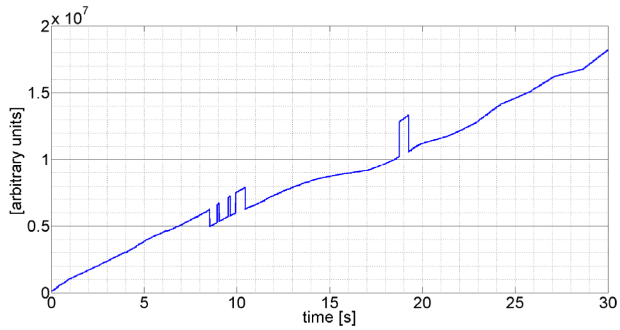

Figure 4: First 30 seconds of injection (SUM value).

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.

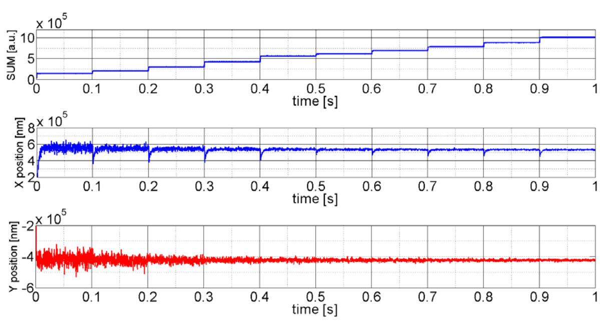

Figure 5: Position reading first 2 seconds of injection.

Detailed look to the first 2 seconds of the injection is presented in Figure 5. Spikes due to the injection were more intensive in the horizontal direction. Due to the very low input signal, attenuators were fully opened. Despite 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 6. The oscillations in vertical direction lasted approximately 2000 consecutive turns while in horizontal direction approximately 1000 turns. The peak-to-peak amplitudes were ~ 1 mm in horizontal and ~ 0.8 mm in vertical.

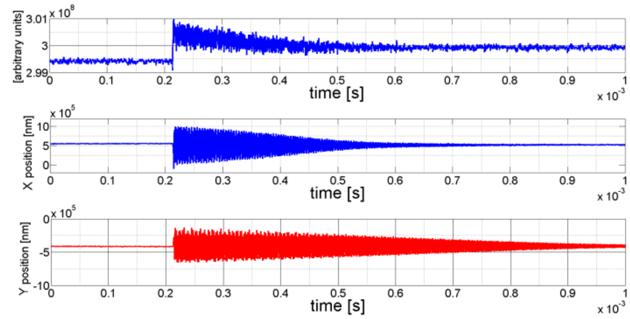

Figure 6: Injection as seen in the turn-by-turn data.

After reaching full current, the storage ring was operating in the top-up mode with 1-minute injections.

Excitation at Betatron Frequency

The excitation was done at betatron frequency in the vertical direction. Position and its frequency spectra were checked. The excitation was done with sweep of around 1 kHz. The betatron frequency for storage ring is around 459 kHz.

The long ADC buffers (1048576 ADC samples) were recorded from both processors, #3 and #4. Acquired ADC samples represented 22310 turns or ~8.9 ms, which provides the FFT resolution of 112 Hz.

The FFT of one out of the four amplitudes is presented in Figure 7. The main component was at 29.979292 MHz, which was aliased from the RF, 499.654 MHz. On both sides, side components were separated by exact revolution frequency (2.49827 MHz). Betatron frequency can be observed as a small spike, separated from the main component for exactly 459 kHz.

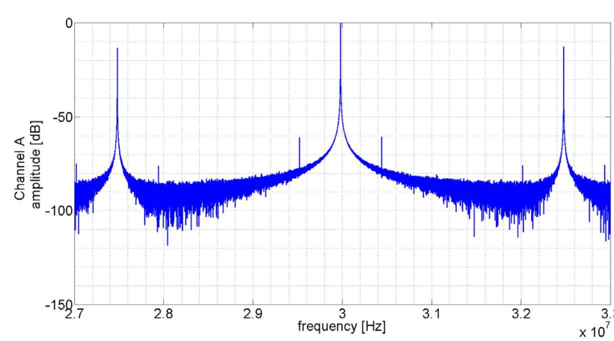

Figure 7: FFT of raw ADC data (channel A).

Since the excitation was a sweep of around 1 kHz, we were interested to see it in the spectra. The FFT of the vertical position of the turn-by-turn data is presented in Figure 8. 1048576 turns were recorded, representing ~419 ms in time domain. The FFT resolution for such buffer length is 2.38 Hz. The upper plot shows the full spectra which is clean, except of the betatron frequency component. The lower plot in Figure 8 is a zoomed view to the area around the sweep. The flat top is ~ 750 Hz wide, which was expected.

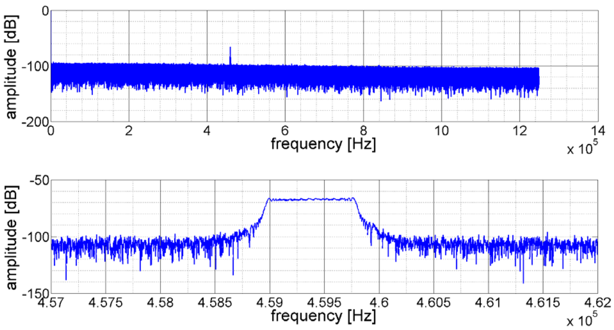

Figure 8: Excitation around betatron frequency.

Time Domain Processing

The goal of this measurement was to compare the acquired data, processed with classic DDC approach and newly introduced Time domain processing (TDP). Using TDP, one can define which ADC samples from 1 turn are taken into account to measure the position.

In our case, 1 turn was covered with 47 ADC samples (this number is called “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 (see Figure 9). This parameter defines, which ADC sample is taken into account for position calculation (1=use the ADC sample, 0=don't use, take “0”).

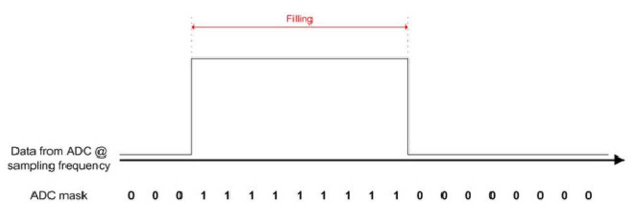

Figure 9: ADC mask.

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. The 10 kHz data sets were recorded between two consequent injections.

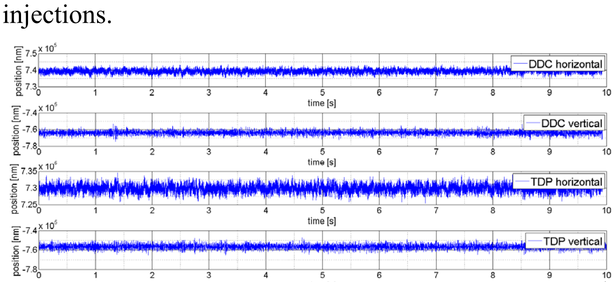

Figure 10: Performance comparison: DDC vs TDP.

The calculation was set to DDC and then to TDP mode. RMS values are presented in Table 1 with actual position recording in Figure 10.

Table 1: Performance Comparison: DDC vs TDP.

Position	**DDC**	**TDP**
Horizontal	1.2 µm RMS	1.1 µm RMS
Vertical	2.2 µm RMS	2.3 µm RMS

The bandwidth of the 10 kHz data stream is 2 kHz. Measured values in Table 1 were expected to be lower but are still reasonable. The BPM calibration factor (or constant), used for the calculation of vertical position is relatively high (19 mm, to be compared with default 10 mm), contributing to higher RMS value. Other contribution could be from the vibration of the vacuum chamber since the BPMs were not fixed on the stable fixture.

CONCLUSION

The tested unit was a basic 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 freedom in the acquisition settings. The beta version of the software was recognized to be very user-friendly covering the user’s demands. The continuous 2.5 days testing revealed no major deficiencies.

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.

The next step is proving the instrument’s 0,1 um/1°C longterm stability in a classic temperature controlled environment.