First beam tests with Libera Brilliance+ at Taiwan Light Source

White paper

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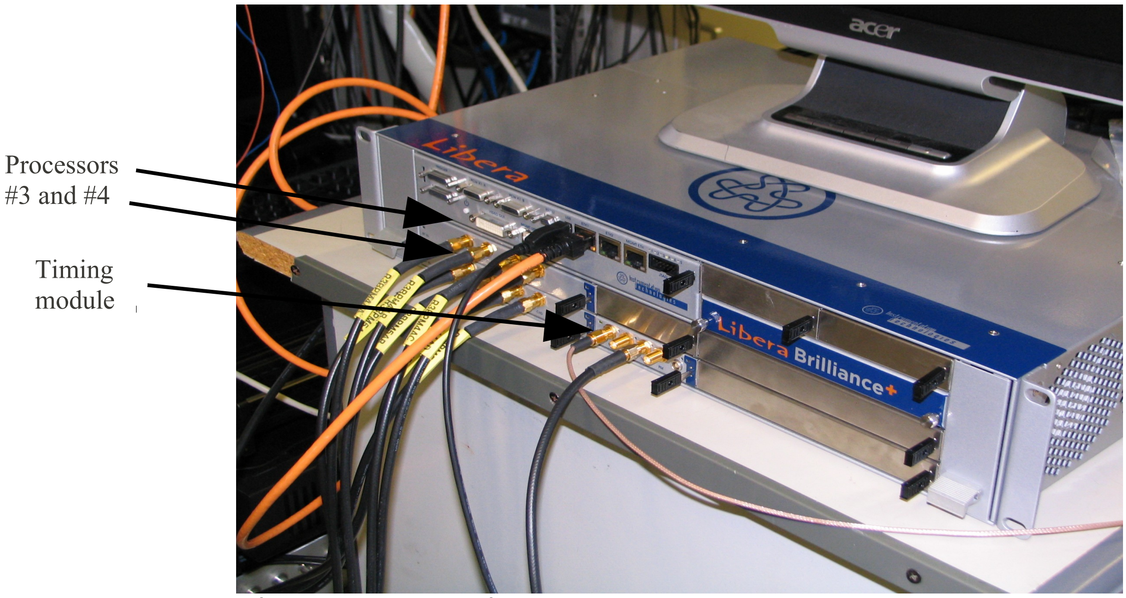
1. Introduction

Libera Brilliance+ is a new beam position processor, developed by Instrumentation Technologies. Functionalities are based on its predecessor, Libera Brilliance. Hardware platform has been upgraded and can now utilize up to 4 processor modules, timing distribution module and optional fast orbit feedback (FOFB) module. The unit's dimension is a standard 19” 2U. Software runs on a standard Linux Ubuntu distribution. The application, libera-ebpm, implements base functionalities, allowing complete evaluation of the unit though. Full set of features will be available in mid 2011.
First beam tests of Libera Brilliance+ were done at Taiwan Light Source storage ring, which is fully equipped with Libera Brilliance instruments.

2. 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+ unit was configured with 2 processors in a single chassis and a timing module. Machine Clock and Trigger signals were TTL 3.3V high-Z and derived from the same source as for Libera Brilliance units.



Picture 1: Connections

Libera Brilliance+ (processor #3 and #4) were installed between 2 Libera Brilliance units (#34 and #35). Data was recorded from all and compared when necessary.
In this paper, processors in Libera Brilliance+ were named as #3 and #4 (positions in the chassis).

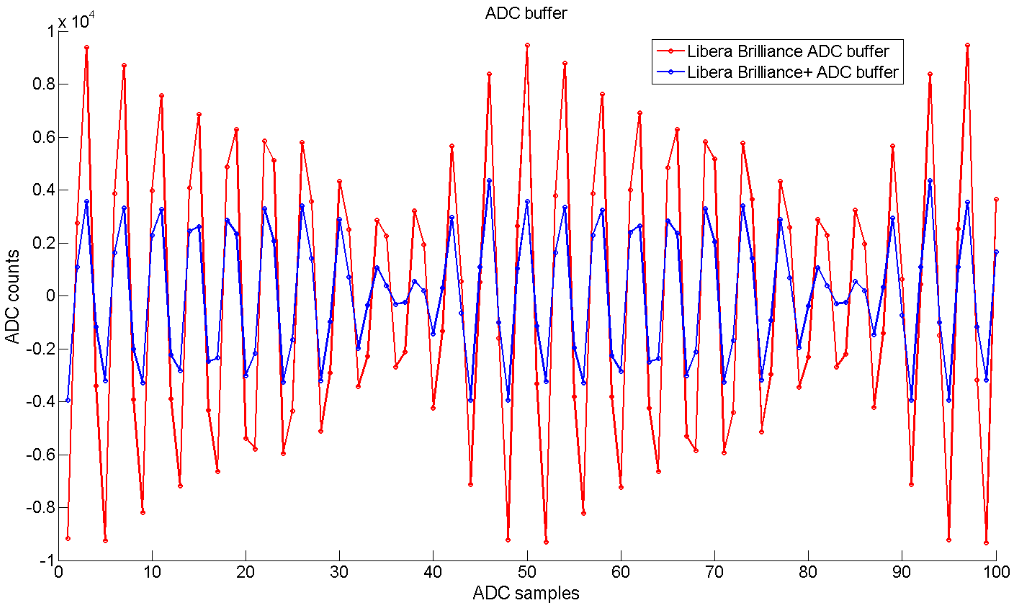
3. Results

3.1. General setup and check

Geometry coefficients were set to the same value as in Libera Brilliance units. Corresponding values are:
Kx = 13 mm
Ky = 19 mm

Offsets (X and Y) were not set for Libera Brilliance+, consequently absolute readings were not correlated with adjacent Libera Brilliance units.

The raw ADC data was checked and compared to Libera Brilliance readings. As it is seen from Picture 2, the signal level was lower at Libera Brilliance+. This was due to different attenuation setting (Level, Power_level).



Picture 2: ADC buffer comparison

When comparing the maximum ADC value (MaxADC parameter in both units), it is well related at the same Level / Power_level setting. The MaxADC value was more constant (less peak-to-peak) in Libera Brilliance than in Libera Brilliance+. The reason is the detection principle, which was simplified in the base software of Libera Brilliance+.

3.2. Automatic Gain Control

The Automatic Gain Control (AGC) functionality was tested during the top-up operation at stable conditions.

The Level setting (Libera Brilliance) vs Power_level (Libera Brilliance+) with corresponding MaxADC values were in the same range.

The AGC speed in Libera Brilliance+ was set to 10 Hz (0.1 s) therefore the Power_level parameter was set 10 times faster than in Libera Brilliance case.

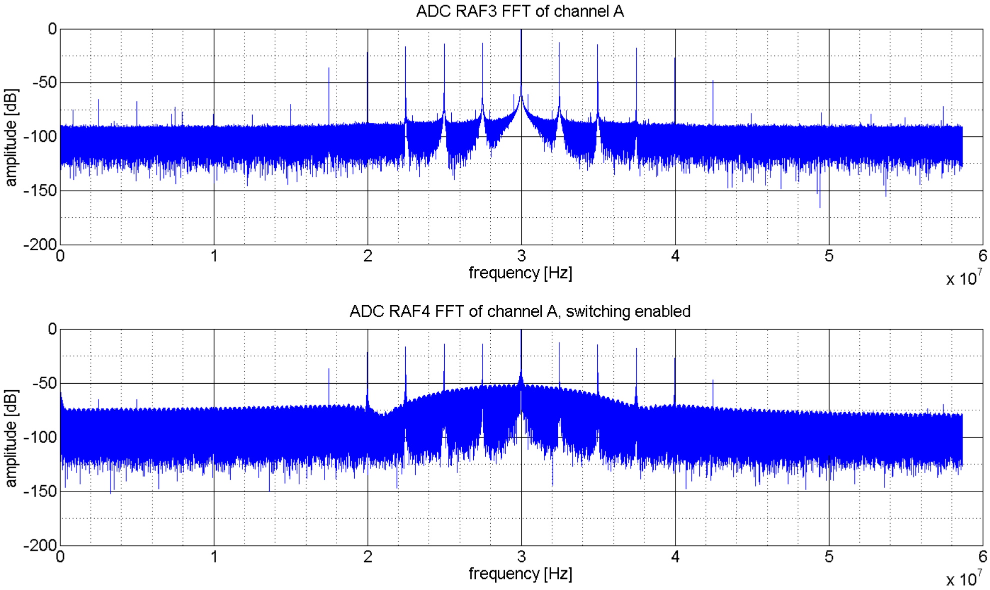
3.3. Excitation at betatron frequency

The excitation was done at betatron frequency in the vertical direction. Position and frequency spectrum was checked. The excitation was done with sweep of around 1 kHz.

The long ADC buffer (1048576 ADC samples) was recorded from both processors, #3 and #4, which allows the FFT resolution of 112 Hz.
1 M ADC samples represent 22310 turns or ~8.9 ms. The total ADC buffer length is 4 M ADC samples. Compared to Libera Brilliance (1 k samples), this is a vast improvement.

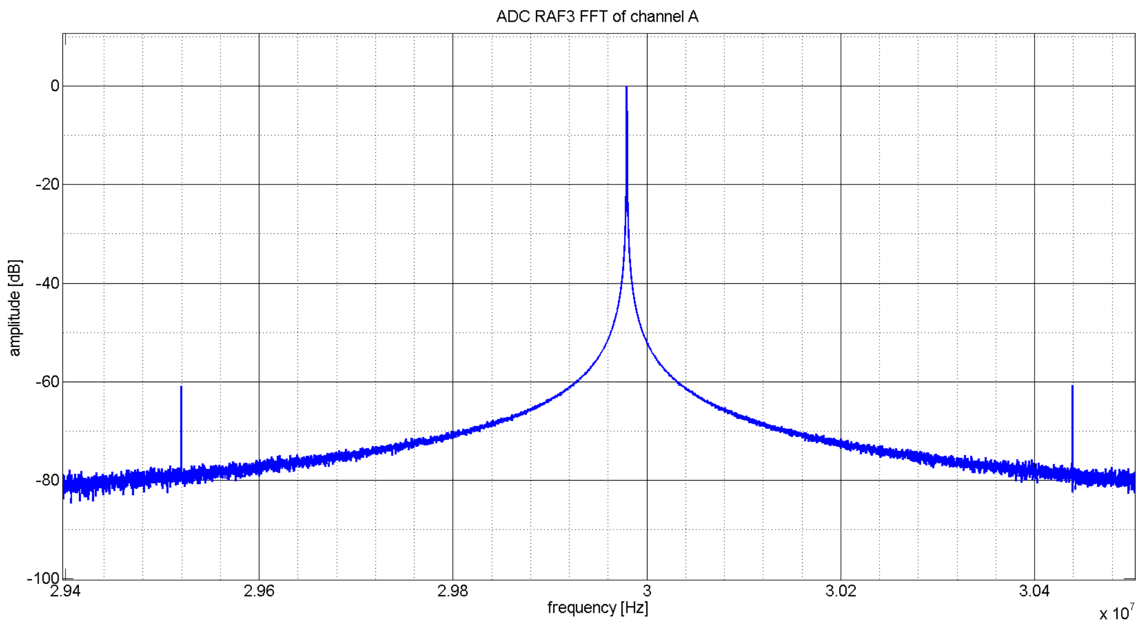
Processor #3 did not have Switching enabled. The FFT is presented in the upper plot of Picture 3. All known components are nicely seen: the NCO frequency (29.979292 MHz), Machine Clock (2.49827 MHz) and betatron frequency (~459 kHz).

Processor #4 was running DSC which is seen also from the lower plot of Picture 3. Normally, when using ADC raw data, the Switching shall not be used.



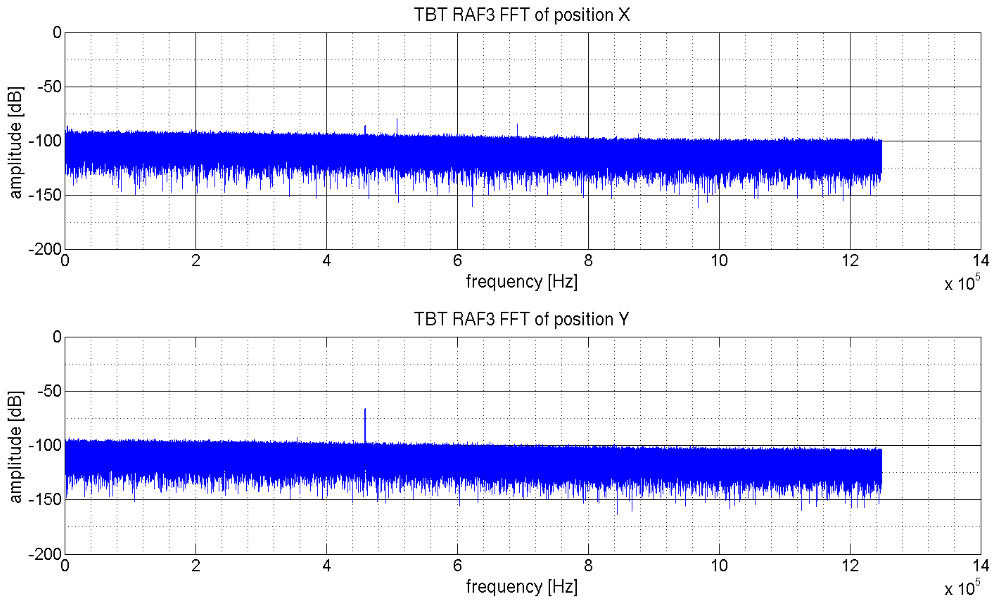
Picture 3: FFT of the ADC data

Zoom at the spectrum is presented in Picture 4. Spectrum is clear and betatron frequency is nicely seen.



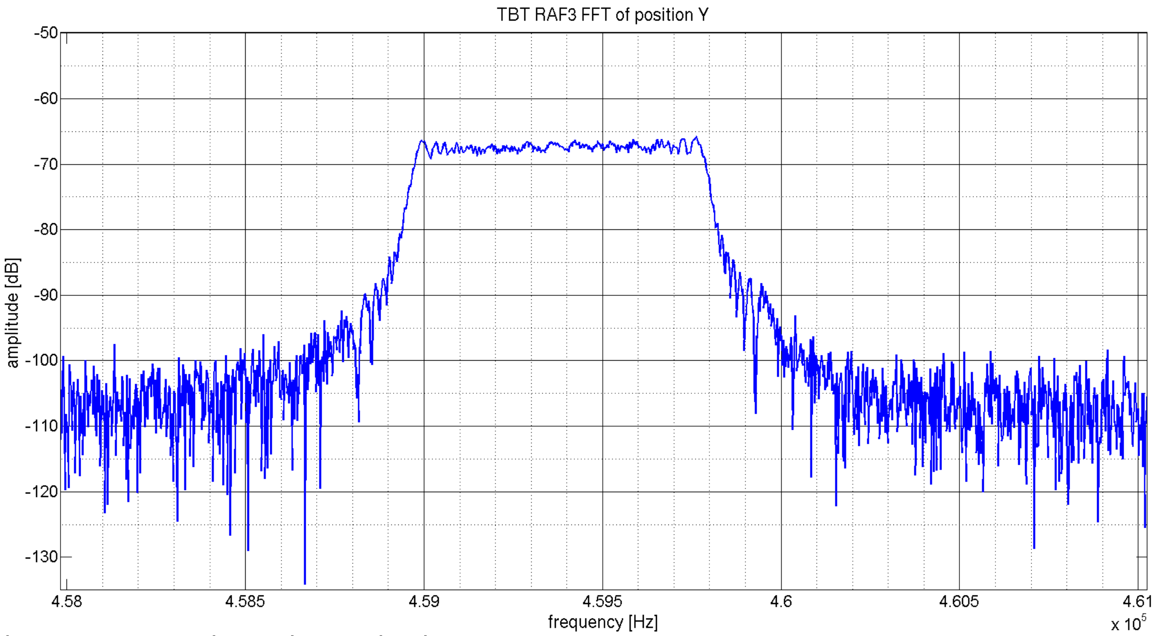
Picture 4: FFT of ADC data, zoom to betatron frequency

The FFT was done also on the Turn-by-turn data. It is presented in Picture 5. As it was expected, the excitation is seen mostly in the vertical direction.
For this test, 1048576 turns were recorded, which represents ~419 ms. The FFT resolution is 2.38 Hz.



Picture 5: FFT of the turn-by-turn data, processor #3

The excitation was done with sweep of ~1 kHz. Zoomed spectrum is presented in the Picture 6.



Picture 6: Zoom-in to the excitation sweep

3.4. Injection

Injection is done at 10 Hz rate. It was monitored with both processors in Libera Brilliance+. For analysis, the FA and turn-by-turn data was recorded.

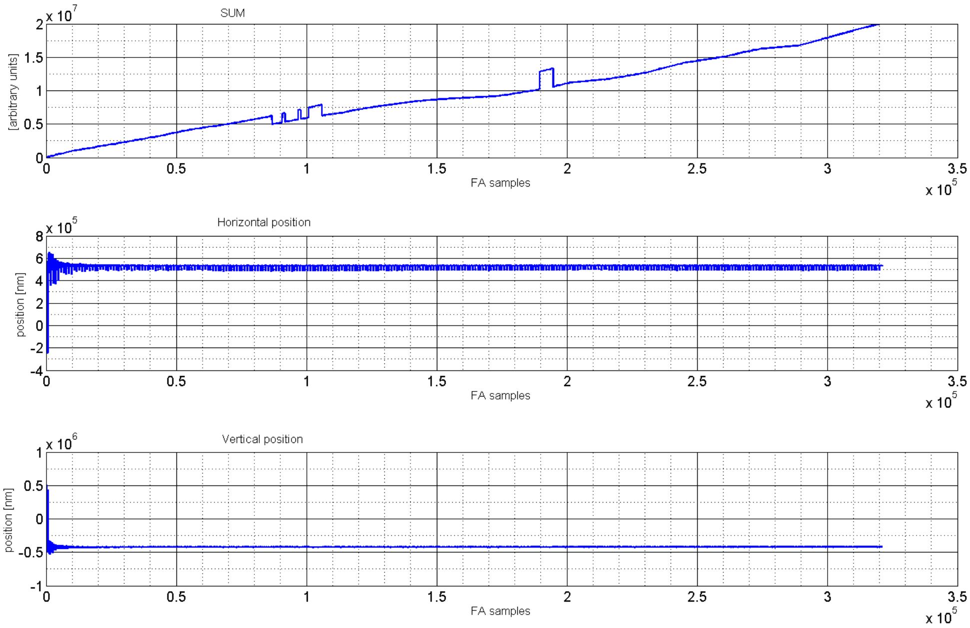
It was possible to record the injection from the start (with no current in the storage ring). Libera Brilliance+ offers FA data acquisition through the libera-ireg or EPICS. The complete recording time was approximately 2 minutes, but the data of ~30 seconds is presented in this chapter.

During the acquisition, the Automatic gain control was enabled and was working at 10 Hz rate. The Digital Signal Conditioning was disabled.

FA data is presented in the Picture 7. The upper plot presents the SUM value, which can be correlated to the storage ring current, middle and lower plot present horizontal and vertical directions.

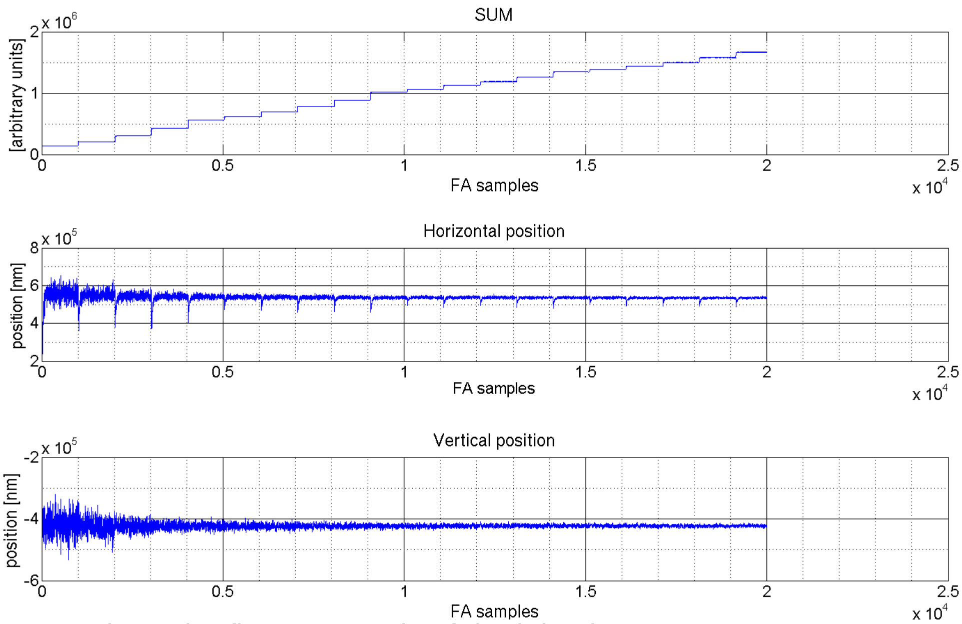
Some jumps are seen in the SUM value. They come from the change in attenuators (storage ring current was increasing injection by injection). The Automatic Gain Control was working correctly, only the hysteresis was not optimized yet.

Spikes due to the injection were more intensive in the horizontal direction. The mean position was very stable, the linearity was excellent.



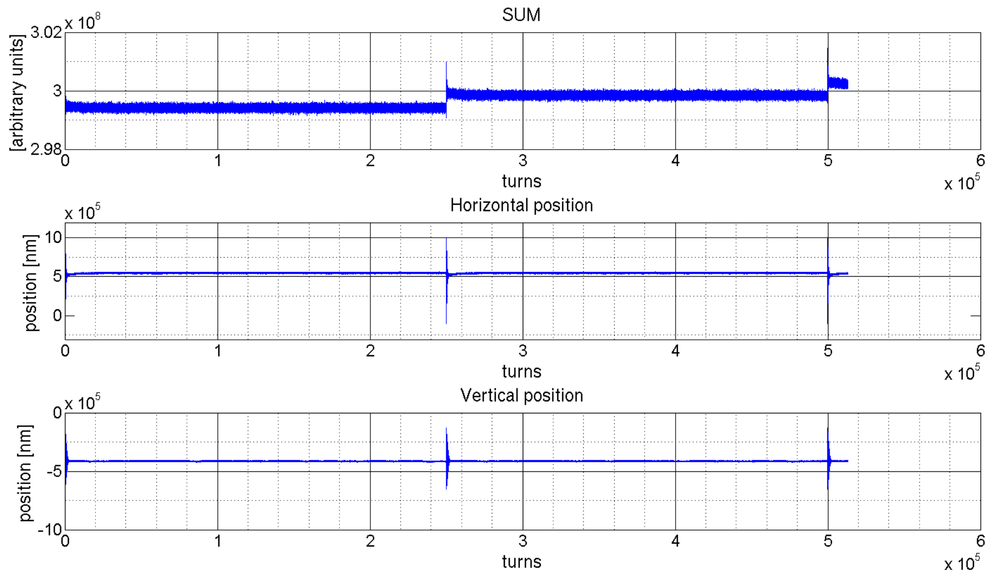
Picture 7: Injection, recorded with FA data

In Picture 8, the first 2 seconds of the injection is presented (zoom-in of Picture 7). Acquisition started a few seconds before the first injection.
The increase of the SUM is not constant from injection to injection. This does not depend on the Libera Brilliance+ but external factors. As it is seen from middle and lower plot, position is stabilized after few injections, the RMS is reasonable after ~1 second.



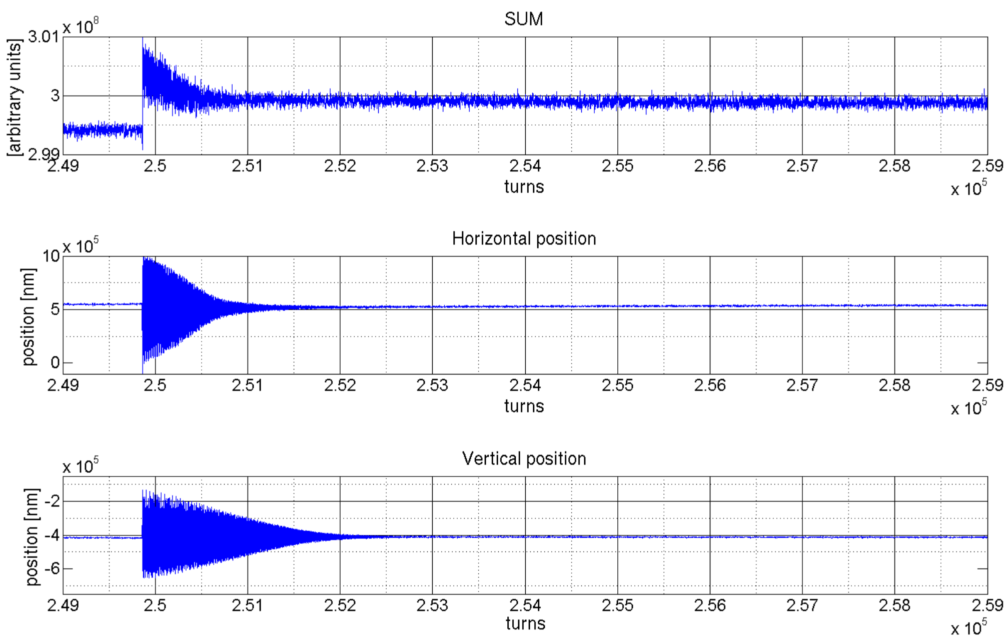
Picture 8: Zoom-in to the first 2 seconds of the injection

The benefit coming from Libera Brilliance+ is that the FA data is available through the control system, which offers the user a full range of data paths at different bandwidths. For more detailed look at the single injection, the acquisition of turn-by-turn data was done on-trigger. Data in Picture 9 represents 3 consecutive injections, as they were seen in the turn-by-turn data buffer.



Picture 9: 3 consecutive injections, as seen in the turn-by-turn data

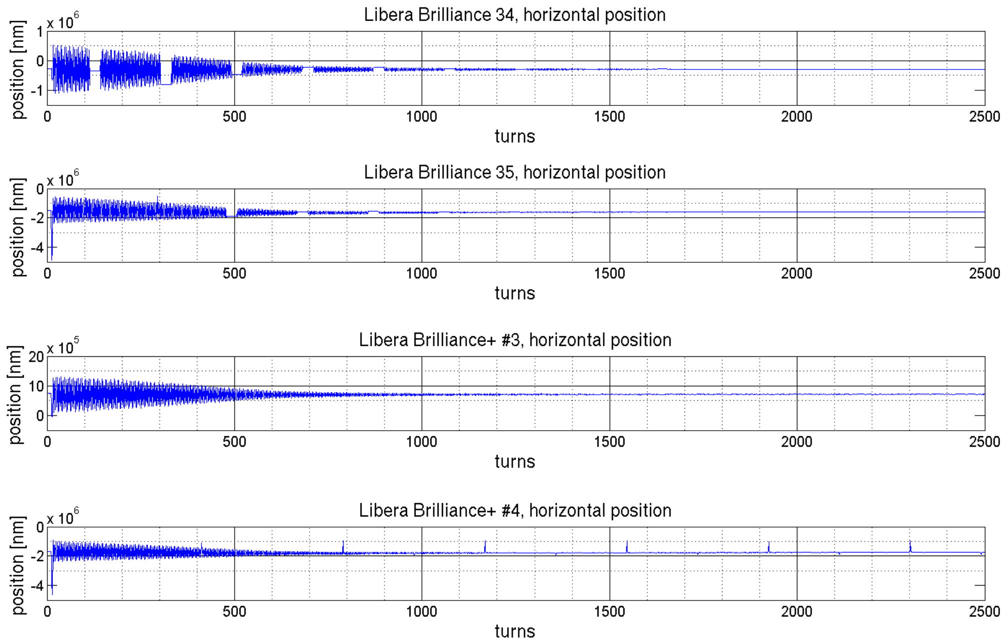
For more detailed look of one injection, the data was zoomed-in in Picture 10. The upper plot shows the increase in the SUM value, the middle and lower plot show horizontal and vertical positions. It is seen that the oscillations due to one injection, last approximately 1000 turns in horizontal and 2000 turns in vertical direction. The peak-to-peak values are ~1 mm both.



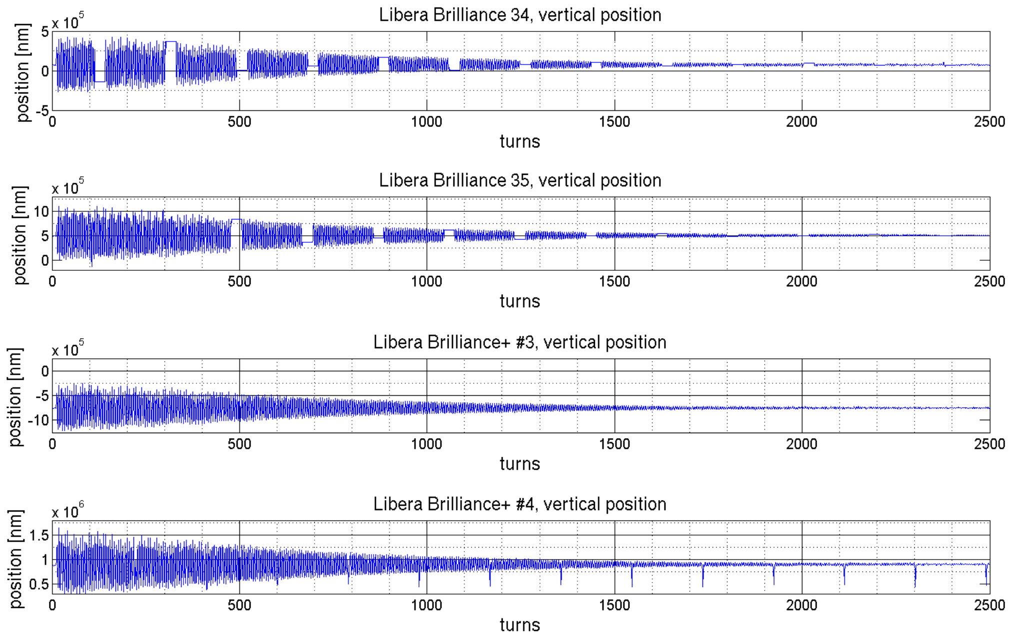
Picture 10: Zoom-in to 1 injection

3.5. Top-up mode

Libera Brilliance+ was tested in top-up mode. Injection was done every 60 seconds. Most acquisitions were done on-trigger. Turn-by-turn data was acquired and compared to Libera Brilliance units. Furthermore, the DSC and SpikeRemoval functionalities were used.



Picture 11: Top-up injection, horizontal direction



Picture 12: Top-up injection, vertical direction

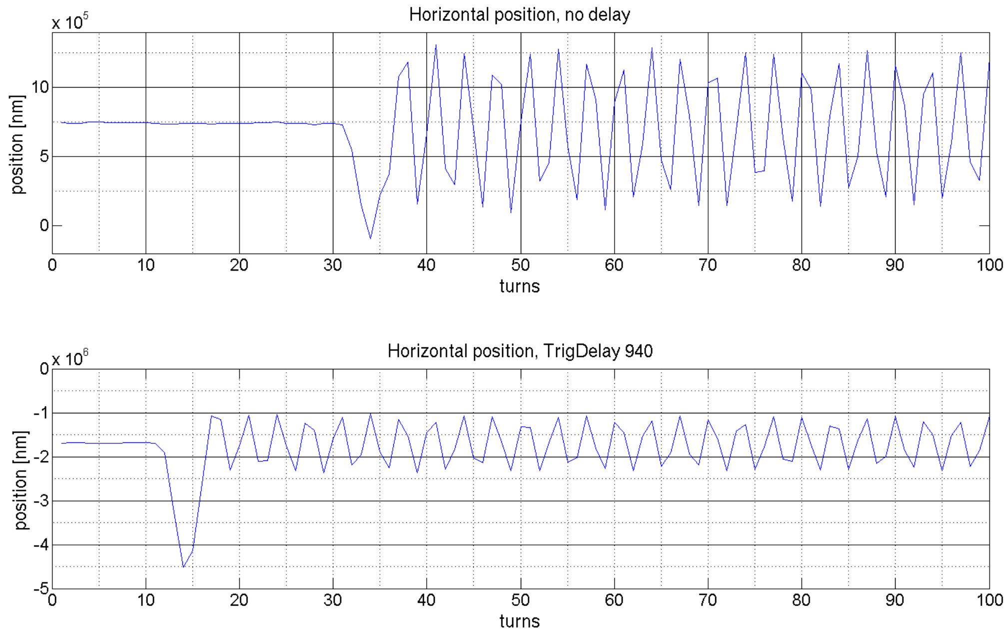
Picture 11 and Picture 12 show the top-up injection as it was seen at neighbour Libera Brilliance units (34 and 35) and Libera Brilliance+ unit (#3 and #4). Libera Brilliance units were working in the FOFB therefore their settings could not be changed. They were working with DSC and SpikeRemoval enabled, Offstune set to 100.
In both Libera Brilliance plots, there are straight lines seen in the data. These lines are replacing the spikes, which come from calibration (Switching).

Libera Brilliance+ #3 did not have switching enabled therefore the data is clean. #4 had switching enabled but no SpikeRemoval.

The peak-to-peak values in horizontal position were slightly lower in Libera Brilliance+, peak-to-peak values in vertical position were slighty lower in Libera Brilliance units.

3.6. MToffset and TrigDelay tests

The starting point for this test was the acquisition on-trigger of the turn-by-turn data. Processor #4 was configured with TrigDelay of 940 (which is 20 turns). It was expected that the signal on processor #3 was detected 20 turns faster than on processor #4.



Picture 13: Trigger Delay parameter check

The result is presented in Picture 13. The upper plot shows processor #3, the lower plot shows processor #4.

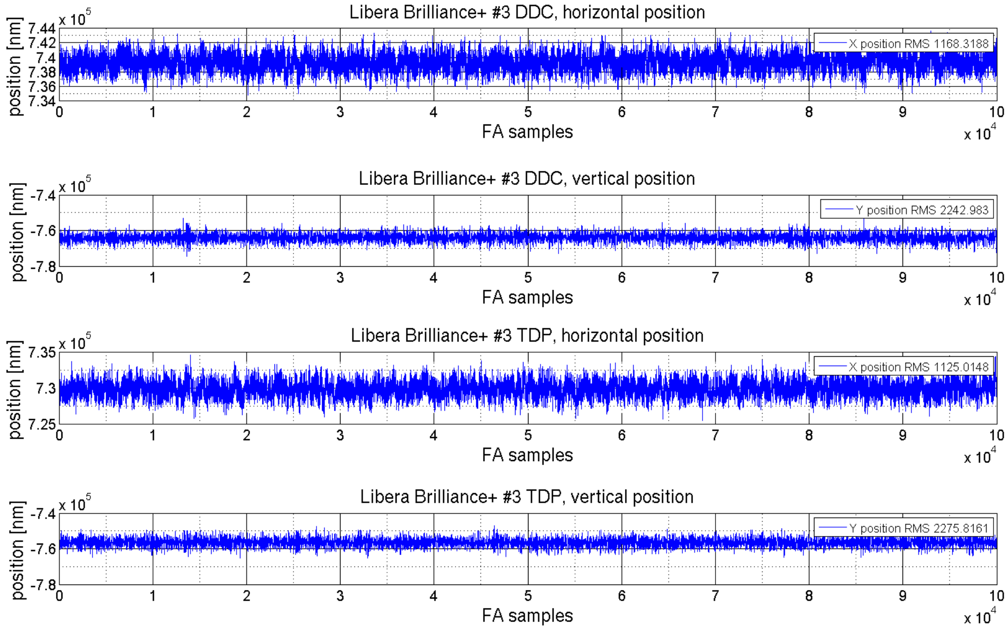
While comparing the data with neighbour Libera Brilliance units, the delay of 8 µs was seen (Libera Brilliance+ detected the signal faster comparing to Libera Brilliance). This may be the consequence of the cabling setup (Libera Brilliance uses differential LEMO with single-to-differential converter, Libera Brilliance+ uses direct single-ended signal through SMA connector).

3.7. DDC vs TDP processing

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

In Taiwan Light Source case, 1 turn is covered with 47 ADC samples (this number is called “decimation”). In case of small partial fill (single bunch or 20% for example), the filter response does not cover all 47 ADC samples but less.
To adjust the number of samples, one can use the newely introduced “ADC mask”. This is the register, which contains simple information (1=use the ADC sample, 0=don't use the ADC sample) for these 47 ADC samples in a single turn.

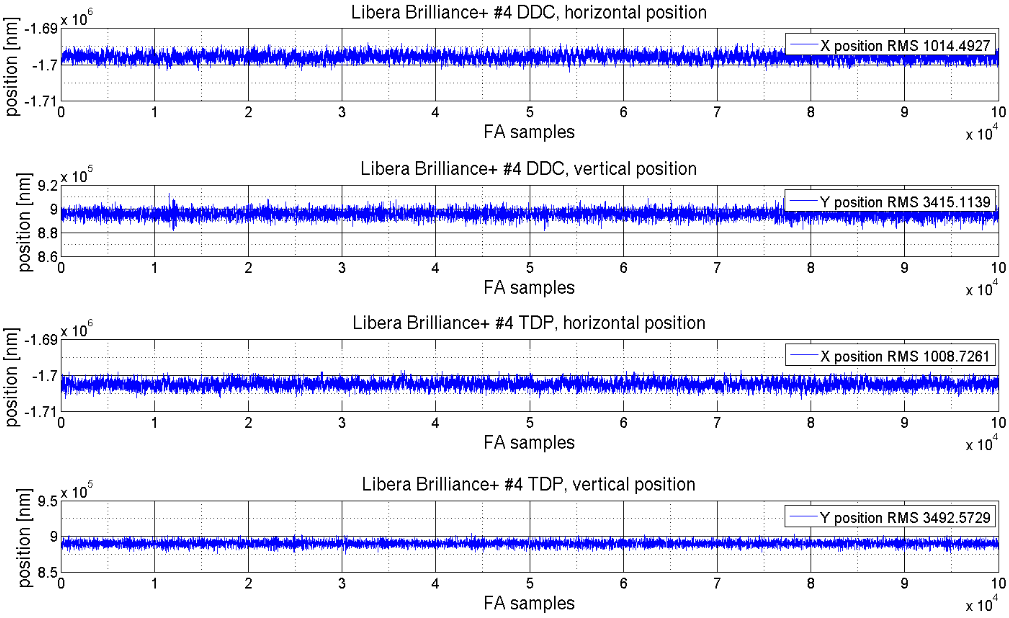
Both processing approaches are delivering the turn-by-turn data at accelerator's revolution frequency. They both can also be the source of the FA and SA streams.



Picture 14: Comparison of different TBT data source for FA stream, processor #3

The RMS on both FA streams and both positions were in the same range, which was also expected.
However, there was no chance to test different filling pattern in order to set the ADC mask to a different value. In all cases, the ADC mask was set to cover all 47 ADC samples in a turn.

The results from both processors are presented in Picture 14 and Picture 15.



Picture 15: Comparison of different TBT data source for FA stream, processor #4

4. Improvements compared to Libera Brilliance

The platform upgrade was a major task during development of Libera Brilliance+. The software platform is running on a powerful PC (Intel Atom, Intel Core2Duo) and is generic for similar instruments (like Libera Single Pass H, Libera Single Pass E).
The application (libera-ebpm) is specific for measuring the electron beam position in general.

All the base functionalities, which are implemented in the base version (current software), do cover most of the functionalities of Libera Brilliance. As said, full set of features will be available in the mid 2011.

The user, already familiar with Libera Brilliance, can work with the new instrument practically without any difficulties. EPICS server is installed by default and is well supported with the documentation which allows fast reconfiguration, if needed.
Graphical User Interface comes with the unit in two versions: a) the EDM source code, which needs the compilation and b) the Virtual Machine (VM) image, which only needs the Virtualbox environment. Second option, VM image, was used at Taiwan Light Source and was set-up practically in 5 minutes.

The diagnostic options have been vastly improved due to memory, which is now available on the new hardware platform.

ADC raw data	8 Msamples (64 MB)
Turn-by-turn DDC data	2 Msamples (64 MB)
Turn-by-turn TDP data	4 Msamples (64 MB)

Having so long ADC buffer, it is possible to perform detailed off-line analysis like injection studies, FFT analysis, First-turn analysis.
The newly introduced Turn-by-turn TDP may become very useful at users with partial filling pattern. Instead of using specially designed MAF filters for Libera Brilliance, only the ADC mask needs to be adapted.

The Digital Signal Conditioning has now more degrees of freedom. It is possible to fully control the learning/applying coefficients as well as control the switching. The DSC coefficients are available to the user and are accessible through libera-ireg (Libera software) and EPICS interface. User has the option to monitor, log and save the coefficients. The option to loading the coefficients has been taken into account and may become available in the next software releases.

Health monitoring has rich options compared to Libera Brilliance. There are 6 fans and myriad of temperature and voltage sensors on modules in the chassis. They all can be monitored and logged for building up the health history and later analysis if needed.

One of the most important functionalities of a new Libera Brilliance+ instrument is the synchronization between Libera Electron, Libera Brilliance and Libera Photon instruments. The synchronization is still based on the machine clock reference and done on common external trigger on all instruments.
The source of the sampling clock remains the VCXO, with software controlled PLL. The PLL coefficients are available (for now) in the base version of Libera Brilliance+. Same as for all other health, signal and parameter buffers and values, the PLL coefficients can be monitored runtime.

Performance wise, the direct and relevant comparison between Libera Brilliance and Libera Brilliance+ units was done with RF generators only. Libera Brilliance units in the Taiwan Light Source are installed in a temperature controlled racks with airflow, but Libera Brilliance+ was located in the table in front (during the tests). Therefore, comparing the longterm drift (especially when talking about tenth of microns) was not relevant.

5. Conclusion

After some initial booting problem (battery consumption), the unit was working normally. Beside EPICS, data was recorded also by using libera-ireg, which offers a bit more freedom in acquisition settings. There were no application problems, except some known EPICS server limitations (long buffer acquisitions on Trigger).

The next steps are evaluating the unit's longterm performance in a stable (real life) environment, recording more data at different filling patterns and getting more experience with real life usage (EPICS server, any possible software hickups, etc).

The basic version of the software was recognized to be very useful and covers most demands. There were also no major bugs observed when testing the unit for continuous 2,5 days.