LIBERA BRILLIANCE SINGLE PASS POSITION MEASUREMENTS

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Abstract

Libera Brilliance is a standard device for beam position monitoring on circular synchrotron light sources. Initially, the idea of optimizing its signal processing for the single bunch measurement came from the users community. This was afterwards followed by the idea of using it on transfer lines on the same 3rd generation light sources as well as on injector system for the FELs. The device can be used on pickup buttons and on striplines. The single pass functionality is contained in newest Libera Brilliance software Release 2.0, however, a new Libera Brilliance Single Pass Release 2.0 with various functionalities will be issued. Minor hardware changes were implemented to optimize the measurements. The measurement principles and first measurements with results are presented.

INTRODUCTION

The aim of a single pass position measurement, for example in a FEL, is to resolve the bunch position from the information extrapolated from the very short pulses produced by a single bunch that is crossing the beam position monitor (BPM). There are several different kinds of BPMs that are used in these machines (button pick-ups, striplines, cavity BPMs, …). Each of these BPMs involves different kinds of signal typologies. Libera Brilliance is able to process the signals produced by first two of the above mentioned BPMs since there is a bandwidth matching between processing unit and the signal frequencies.

The Libera unit elaboration and implementation of adapted calculation algorithm was done at Instrumentation Technologies. Tests on real beam were subsequently carried out at Synchrotron Trieste and at SPARC (INFN, Frascati).

SIGNAL PROCESSING

Four identical signal processing chains on Libera Brilliance Single Pass are composed of analog signal processing, digitalization on fast ADCs and the digital signal processing, see Figure 1. Variable attenuator can be set between 0 and 31 dB in discrete steps of 1 dB.

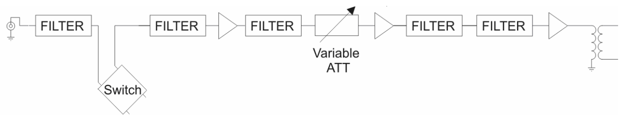

Figure 1: Schematics of Analog Signal Processing Chain

Complete digital signal processing is currently implemented onboard a SBC – Single Board Computer in Linux operating system. Some functions will be ported to FPGA in near future.

Position Calculation Algorithm

On the Figure 2, there is a typical Libera response to single bunch signal, ADC raw data is shown. The signal is lengthened to approx. 250 ns due to relatively narrow (10 MHz width at 500 MHz) passband filters on the analog board. The window for position calculation is defined with three parameters, see Figure 2:

- Threshold level (in ADC counts)
- Pre-trigger samples (in ADC samples)
- Post-trigger samples (in ADC samples)

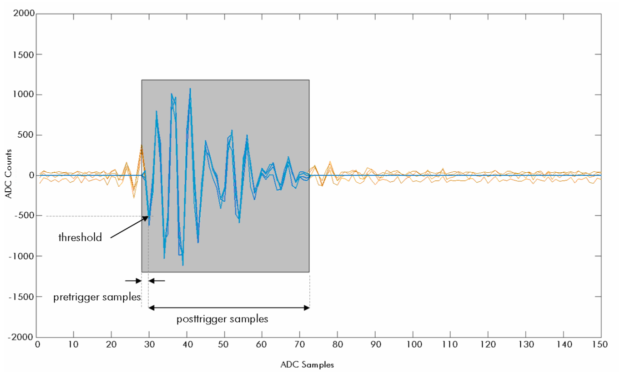

Figure 2: Parameter Definition for Single Pass Position Calculation

Threshold is the base for calculation. Before bunch arrival, only noise is acquired. With threshold setting, the limit is set, above which we consider the signal as useful. To take into account only useful part of acquired buffer, pre-trigger and post-trigger samples are set. These two parameters can be freely set in predefined ranges. Samples, which are taken into account, are simply squared and summed, then the square root is applied over the sum (see Eq. 1).

$$V_A = \sqrt{\sum_{PRETRIG.}^{POSTTR.} A^2} \qquad (1)$$

The result is proportional to the amplitude. After calculating all 4 amplitudes, position is calculated using formulas for X, Y and SUM calculation (see Eq. 2, 3).

$$X = K_X \frac{((V_A + V_D) - (V_B + V_C))}{\sum} - X_{OFFSET} \qquad (2)$$

$$Y = K_Y \frac{((V_A + V_B) - (V_C + V_D))}{\sum} - Y_{OFFSET} \qquad (3)$$

Alternatively, it is possible to perform position calculation at orthogonal BPMs, in this case the calculation formula changes (see Eq. 4, 5).

$$X = K_X \frac{(V_A - V_C)}{(V_A + V_C)} - X_{OFFSET} \tag{4}$$

$$Y = K_Y \frac{(V_B - V_D)}{(V_B + V_D)} - Y_{OFFSET} \tag{5}$$

It is important to mention that algorithm checks if at least one channel's max ADC count (A, B, D, C) is higher than threshold. For threshold position, first channel which rises over the threshold is taken into account.

The current maximum trigger frequency for position calculation (i.e. max. bunch repetition rate) is 100 Hz. This frequency will be increased in near future.

LABORATORY TESTS

After initial tests of the first hardware modifications in the laboratory, first beam tests were performed at the Synchrotron Trieste in Aug. 2008. Many laboratory and real beam tests followed.

Stripline Signal Simulation

A very common pickup is the stripline BPM which was simulated in laboratory for single pass tests. This device, when excited by the beam produces two narrow pulses of opposite polarity. The delay between the pulses is defined by the stripline length and determines the frequency components of the signal.

Such signal has a rich spectrum that can easily be measured and processed by the Libera system, even if the stripline signal has a main frequency higher than a GHz.

The feasibility of measuring such signals was proven by means of extensive laboratory measurements and simulations. On Figure 3, there is shown an oscilloscope screen shot of a simulated pulse as seen after 15 dB attenuator. The pulse was generated with short pulse generator with 50 Hz pulse repetition rate.

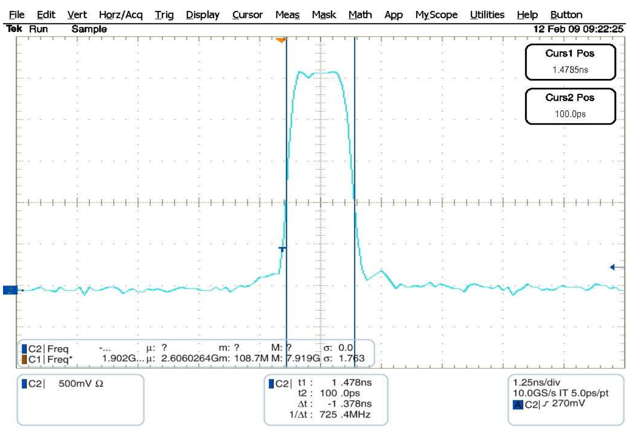

Figure 3: Simulated Signal Seen Through 15 dB Attenuator

The signal seen by Libera is practically the response of the 500 MHz SAW filter, see Figure 4.

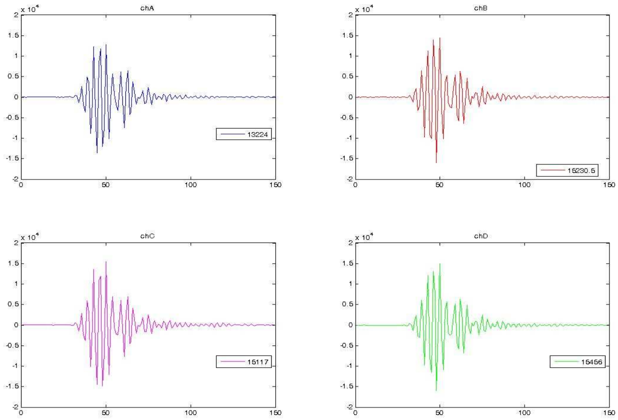

Figure 4: Signal Seen by Libera Brilliance Single Pass

Temperature Stability

Various temperature stability tests were performed. The aim of the following measurement was to test the position stability of the Libera Brilliance in the temperature range between 20°C to 30°C. The tests were performed in stabilized temperature chamber with 15 minutes time intervals and 0.5°C temperature steps, see Figure 5. The measurements were performed with accelerator geometric coefficients Kx and Ky set to 10mm. The standard deviation and mean value of the position was: Xrms=3.9509 um, Yrms=3.7738 um, Xmean=130.4766 um, Ymean=-95.2049 um, see Figures 5, 6.

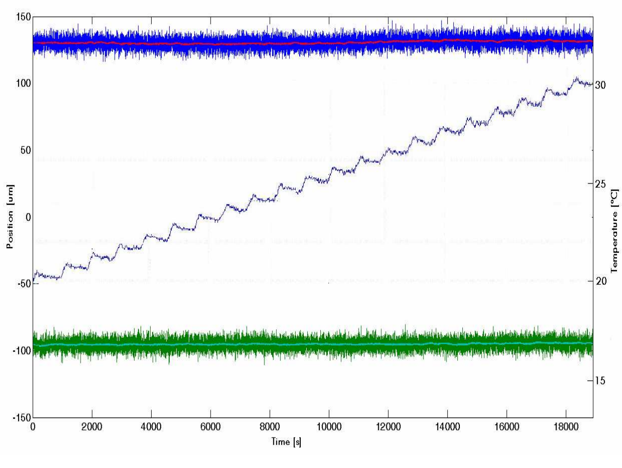

Figure 5: X and Y position (Red and Light Blue are Averaged Values) during temperature stability test

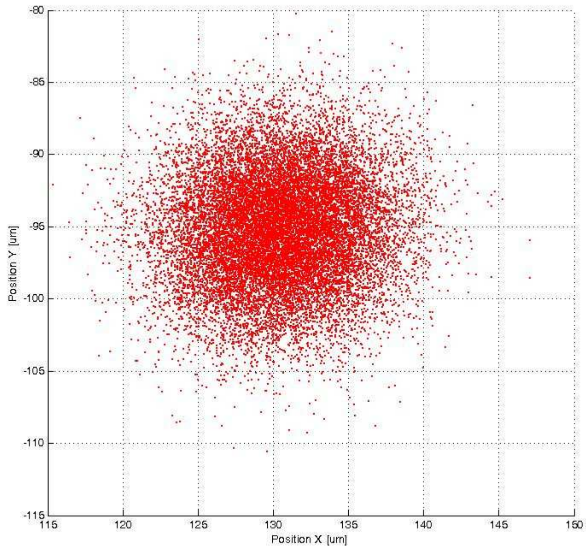

Figure 6: X and Y position

Some more long term stability tests at stabilized temperatures around 25°C were performed. The temperature dependent position drifts were negligible.

Libera Brilliance Single Pass showed excellent temperature dependence stability and very good RMS results on the long term tests.

Resolution and Charge Dependence

The goal of the Libera Brilliance Single Pass is to achieve under 5um position resolution at high bunch charges and still good position results at very low bunch charges in ranges of 10pC, see Figure 7.

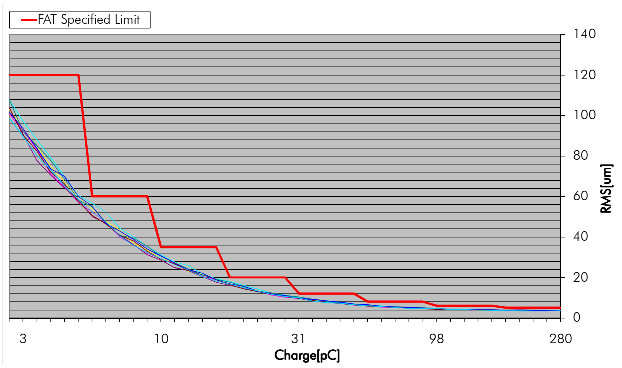

Figure 7: RMS Results Measured on Four Libera Brilliance Single Pass Units. FAT Limits are depicted with Blue Line.

With the help of users (Sincrotrone Trieste, Sparc at INFN), we effectively reproduced laboratory results on the real beam.

Operation charges on real beam are usually above 1nC, which contributes to higher signal level, better stability and directly also better position RMS values. The position RMS values for higher charges were estimated on values around 3um. The confrontation of signal levels for lower charges is presented in Table 1.

Table 1: Confrontation of Signal Levels

Estim.Charge [pC]	Measured Peak[mV]	Libera Level Setting	ADC Counts (± 1000)	Required RMS
280	4400	-10	15000	**5**
98	1560	-19	15000	**6**
31	500	-29	15000	**12**
10	160	-31	7000	**35**

SUMMARY AFTER THE MEASUREMENTS

The idea of modifying standard Libera Brilliance for single bunch measurements has been confirmed in practice as a very efficient way to obtain true and pure single bunch measurements. This is an example of how the digital system can be successfully tailored to a special task just by a change in software with only minor hardware changes. The test results gave very clean and expected results. We would like to emphasize successful collaboration between users (Synchrotron Trieste, INFN) and manufacturers of the instrument (Instrumentation Technologies).

Further Developments

To cover even more complex modes of operation, the list of improvements has been made already. All the new functionalities will be issued as Libera Brilliance Single Pass 2.00 software release. The project has been already started and will be concluded in autumn 2009.

Main new features will be:

- Increased triggering frequency
- Synchronization of group of units on trigger.
- Gain scanning.
- Interlock.
- Digital Signal Processing ported to FPGA.
- Gigabit Ethernet datastream with two available data formats. Standard data format will include only processed data, while extended data format will include processed data and a batch of raw data. Intended for fast forward purposes.

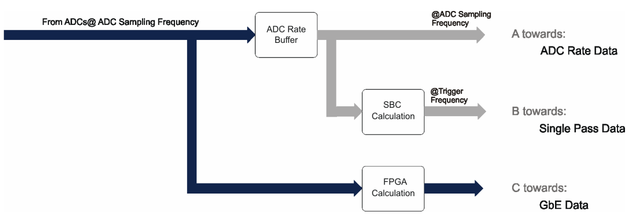

Figure 8: Data paths

REFERENCES

[1] Borut Baricevic, "Single pass measurements with Libera", White paper (2007)