BEAM TESTS WITH LIBERA IN SINGLE PASS MODE

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Abstract

The single pass functionality available in the recent release of the Libera Brilliance software, takes particular interest when compared with the requirements of FEL machines, that need stable and precise control of the beam trajectory throughout Linacs and transfer lines in order to meet the stringent beam quality and transverse position constraints inside undulators.

Results from tests performed on Libera with beam from ELETTRA, SPARC and DAFNE operating in Sincrotrone Trieste and LNF Frascati are reported to characterize the resolution of single shot transverse beam position measurements.

INTRODUCTION

The Libera Brilliance detection electronics, developed by Instrumentation Technologies, implements the digital receiver technology to measure the beam position.

When used on a machine with stored beams, the narrow band signals from the pickups are downconverted to baseband with an undersampling technique for amplitude measurement.

Nevertheless one can perform accurate measurement of short single bunches signals, typical of transfer lines or Linacs, by working directly on the ADCs samples provided by the same boards used for the storage rings [1].

In the following chapter we report results of single pass tests obtained with beams from different accelerators, acquired as reported in Table 1.

Table 1: Beams parameters during measurements

	Bunch Charge	Acquisition Rate	FWHM Pulse Length
SPARC	0.08 nC	10 Hz	.5 ns
ELETTRA	.01÷1 nC	10 Hz	.2 ns
DAFNE	1 nC	2 Hz	.8 ns

SINGLE PASS DATA

Signals from beam position monitor (BPM) have been connected, through low attenuation coaxial cables, to Libera Brilliance.

Before sampling, the short single pulses are fed to the Libera RF front-end which includes passband filters of bandwidth larger than the accelerator revolution frequency and placed around a center frequency given by the RF frequency.

Raw data are collected from the four 16 bit ADCs buffer at a sampling frequency of ~116.8 MHz, which is customizable for each accelerator. To allow measurement on the stored beam it is usually chosen as a multiple of the revolution frequency. The buffer is 1024 samples long and acquisition can be started by an external trigger.

Beam Position Reconstruction

Stripline BPM have been used. The beam position is reconstructed from the amplitude difference of voltage signals from opposite pickups times the k sensitivity, according to:

$$x = k \cdot \frac{\Delta V}{\Sigma V}$$

Different BPM sensitivities k, dependent solely on the vacuum chamber geometry, must be taken into account when comparing results (Table 2).

Table 2: Pickup parameter

	BPM type	**chamber**	***k* [mm]**
DAFNE	Short circuited stripline	Circular	18.3 mm
ELETTRA	50 Ω matched stripline	Diamond shape	19.8 mm
SPARC	50 Ω matched stripline	Circular	10 mm

Libera release 2.00 provides a dedicate algorithm working over the raw buffer data and implemented directly onboard, to reconstruct the beam position

The amplitude from each electrode is assumed as the square root of the sum of the squared samples. Data used for this calculation are selected by setting an amplitude threshold on the waveform and taking into account only N points specified with the *pre-trigger* and *post-trigger* Libera parameters [2].

A further algorithm based on the Hilbert transform [3] has been applied offline to the sampled data. In this case the Hilbert transform has been used as amplitude envelope detector on the narrowband ADC samples.

The signal amplitude from each electrode has been extracted from the integral of the envelope amplitude.

RESOLUTION MEASUREMENTS

SPARC, the 150 MeV S-band photoinjector operating in Frascati (Italy) to produce high brightness electron beams for SASE-FEL experiments, has been equipped with stripline BPMs for trajectory measurement. Figure 1 shows a typical signal from a single stripline at the end of the coaxial cable and the sampled waveform available in the Libera ADC buffer.

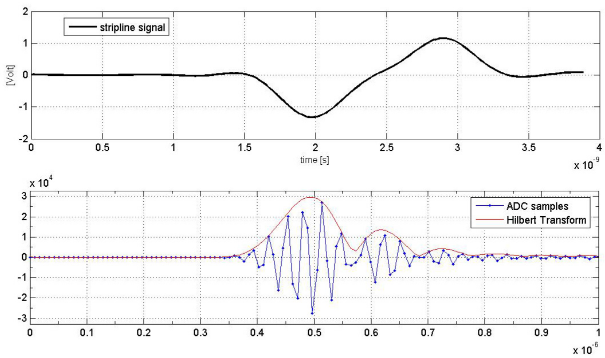

Figure 1: SPARC BPM signal (top) and Libera ADC sampled waveform (bottom), along with the computed Hilbert amplitude.

The data set acquired at SPARC is related to a bunch charge of ~80 pC. The results reported in Fig. 2 show the maximum of Libera ADCs counts for each acquisition on the left and the scatter plot of the beam positions on the right. The measured standard deviations of the (x,y) distributions are respectively 12.6 µm and 14.6 µm. However we cannot exclude a contribution to this values coming from actual beam jitter.

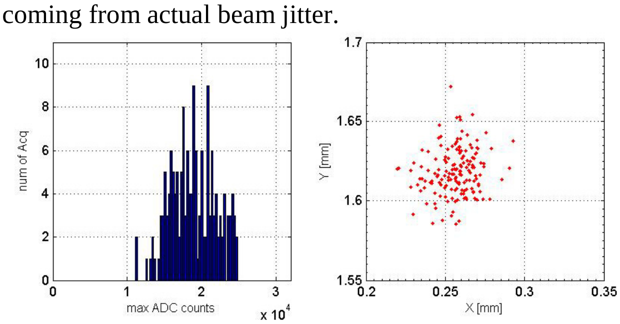

Figure 2: Histogram of maximum of ADC counts (left) and beam position (right) at a particular BPM at SPARC.

Measurements at the Elettra Synchrotron beam have been performed by sampling, at the location of a stripline BPM routinely used for tune measurements, non consecutives passages of a stable stored single bunch with a 10 Hz external trigger synchronous with the RF.

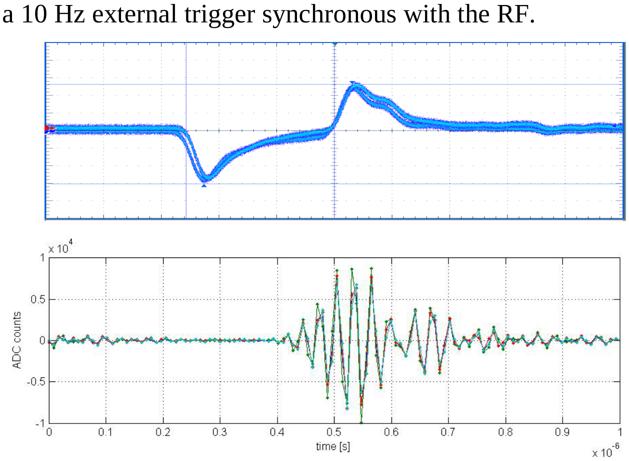

Figure 3: Stripline BPM signals at Elettra [400 mV/div vs 400 ps/div] (top) and Libera sampled data (bottom).

Several data sets of one hundred passages each, performed at different beam current, allowed to characterize the resolution vs. bunch charge. The results are reported in Fig. 4, where the beam position has been calculated using the two different algorithms described above.

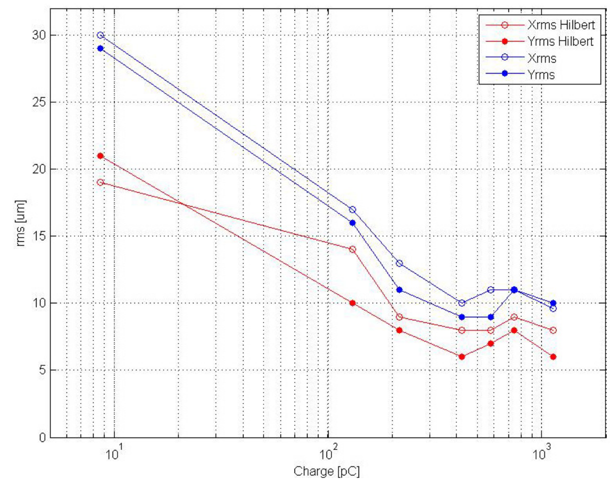

Figure 4: Measured resolution vs. bunch charge at Elettra.

The *Hilbert* method showed better accuracy in the reconstructed position without the needs to specify Libera parameters, at the price of an increased computing load after the acquisition.

A further set of measurements have been performed at a constant bunch current by equally splitting the signal from a single BPM electrode to the four Libera inputs, after the insertion of a variable attenuator.

With this setup, acquisitions for variable input levels have been collected by increasing the Libera sensitivity front-end with the programmable variable attenuators, in order to keep a stable signal level at the ADCs.

In Fig. 5 we report the measured resolution vs. the board sensitivity and the related linearity of the measured positions.

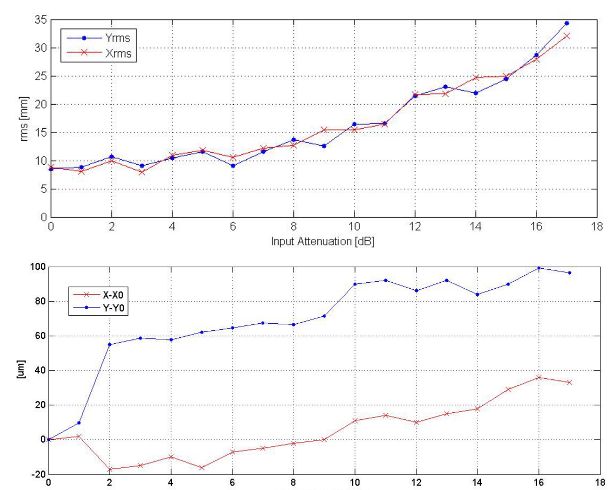

Figure 5: Position linearity (bottom) and resolution (top) vs. Libera input signal attenuation.

Measurements at DAFNE have been performed in the transfer lines used to connect the damping ring to the collider, with a bunch charge of ~1 nC.

Figure 6 (right) reports the histogram of the maximum ADC counts recorded for each acquisition, while Fig. 6 (left) shows beam positions for 100 consecutives pulses.

The (*x*,*y*) distribution is affected by the beam stability of the injection mostly horizontally, due to the operation of a pulsed bending magnet and kickers operating in the horizontal plane.

To evaluate the resolution in the presence of beam jitter, we used a least-square fit to evaluate a linear regression between the positions measured simultaneously at three BPMs over 100 consecutives beam pulses.

The standard deviation of the distribution of the residuals (i.e. the difference between the measured beam position and the predicted position as calculated from the fit equation) has been taken as an estimate of the resolution.

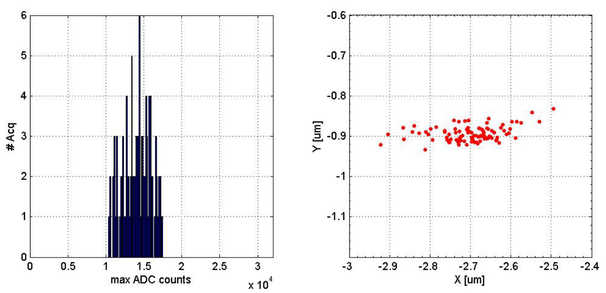

Figure 6: Histogram of maximum of ADC counts (left) and beam position (right) at a particular BPM in DAFNE.

Figure 7-8 show the vertical and horizontal position predicted with the best-fit linear combination of the other BPMs compared with the measured values.

The standard deviation of the residual distribution yielded a resolution of 9.7 µm for vertical position and 12.8 µm for radial position.

It must be noted that the measured resolutions should be related to the vacuum chamber aperture through the *k* constant of each BPM, for DAFNE the radius of the chamber is 37 mm.

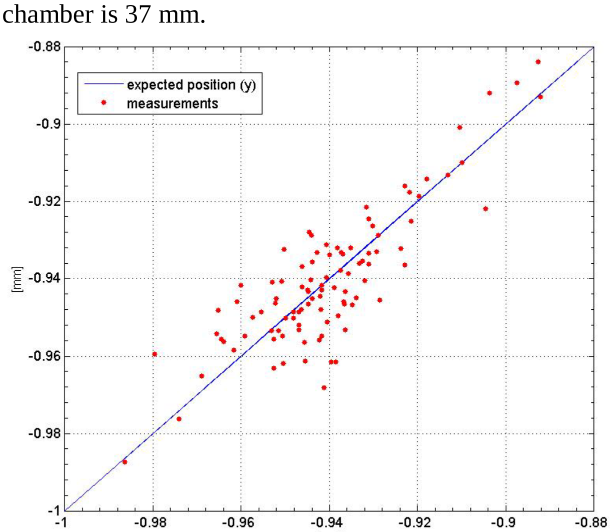

Figure 7: Expected vertical position vs. measured position for the BPSTT03 BPM in the DAFNE transfer line.

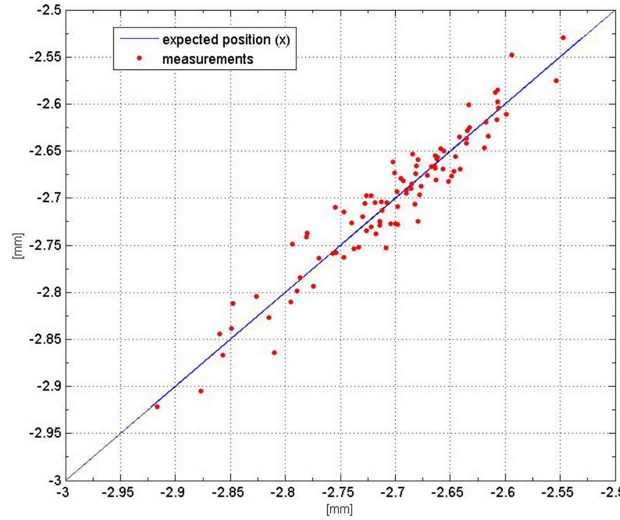

Figure 8: Expected horizontal position vs. measured position for the BPSTT03 BPM in the DAFNE transfer line.

CONCLUSIONS

Tests performed with real beam signals showed the feasibility of using Libera Brilliance for beam position measurements of single pass bunches. Very good results for RMS resolution have been reported.

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REFERENCES

[1] Instrumentation Technologies: “Libera Brilliance Single Pass Measurements”, (2009), http://www.i-tech.si

[2] Instrumentation Technologies, “Libera Brilliance: User Manual v2.00”, (2008), http://www.i-tech.si/

[3] Papoulis, A.: "The Fourier Integral and Its Applications", McGraw-Hill, (1962).