TESTING OF NEW HADRON BEAM PHASE AND POSITION MONITOR AT CIEMAT LABORATORY

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Abstract

Libera Single Pass H is the new instrumentation intended for phase, position and charge monitoring in hadron and heavy ion LINACs and transfer lines. Initial measurements and verification of the instrumentation performance were conducted in the laboratory at Instrumentation Technologies. Characterization measurements of the real BPM prototype were later carried out at CIEMAT wire test bench [2] in Madrid. The measurements were performed with the 175 MHz bunched beam-like signal connected to the wire.

Different measurements were performed on the test bench; first by moving the wire over larger displacements and checking the position sensitivity and resolution and later by changing the signal phase and performing the phase shift measurement.

This article discusses the new electronics, the tests carried out in the test bench and the performance obtained.

INTRODUCTION

Libera Single Pass H system is a beam position and phase signal processing system, developed especially for the needs of the heavy particles linear accelerators.

Each particle-bunch induces a pulse signal on the sensor electrodes. With processing the signals on the four electrodes it is possible to calculate the beam transversal position and longitudinal phase. Libera Single Pass H features accurate position and phase measurement capabilities. The accurate phase measurement is important in the heavy, non-relativistic particles accelerators as it identifies the beam arrival time, which can be used for cavity tuning operations.

Libera Single Pass H enables processing of CW and pulsed beams and calculates a sequence of position and phase data at a decimated data stream [1]. Furthermore, the system enables acquisition of raw samples at full sampling rate. Together with the implemented fast communication protocols, it represents a reliable and deterministic building block for fast feedback building or feed forward loops.

Libera Single Pass H system is based on uTCA modular technologies with IPMI platform management. The system is therefore developed on multiple AMC modules. Each module covers different functionalities.

User can access functions implemented in Libera Single Pass H unit through a control system interface, named Measurement and Control Interface. This interface is developed in order to be easily integrated into the accelerator's control system software.

MEASUREMENT PRINCIPLE

The aim of a single pass position measurement is to resolve the beam transverse position and phase from the information extrapolated from the very short pulses. There are several different kinds of sensors that are used in these machines (button pick-ups, striplines, ...). The sequence of the pickup pulses can be decomposed in the sum of frequency components which can be individually taken in account for the phase and position measurements. Alternatively, depending on the machine, more frequency components can be used for the data processing what contributes to better performances.

The phase relation between the bunch signal and the master oscillator signal is used for the time of arrival measurements. The beam RF signals are first processed by means of analogue signal processing, then the amplitude and phase information is extracted from the digitized signals. The position and phase data is available in a stream that can be used for monitoring and furthermore building the feed forward and fast feedback loops. Main Libera Single Pass H characteristics and typical performances are presented in the Tables 1 and 2.

Table 1: Libera Single Pass H characteristics

Parameter	Value
Number of input channels (measuring)	20 (4 per module + reference channel)
ADC resolution	16 bits
Max. ADC sampling clock frequency	up to 130 MHz
Memory size per module	up to 8 Gbits

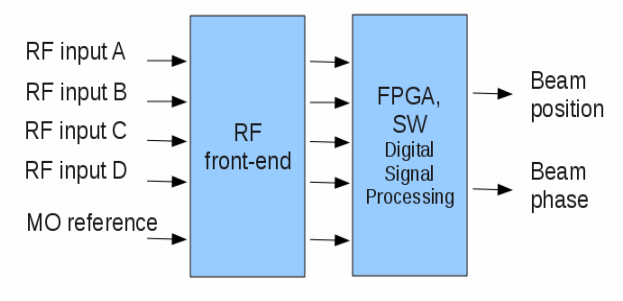
Table 2: Performance Specifications (Sensitivity coefficients kx = ky = 10 mm, data rate = 1 MHz)

Signal Level [dBFS]	Measured Signal Peak Voltage [mV]	Typical Position RMS [um]	Typical Phase RMS [°]
0	4000	3	0.01
-20	400	3	0.01
-40	40	15	0.05
-60	4	150	0.025

There are two main data paths available in Libera Single Pass H: The raw data acquisition and the single pass data acquisition. The raw data acquisition is

organized in a vector of 5 signals that represent the ADC samples on the four electrodes and a reference signal. The single pass data stream contains already processed data and represents four amplitudes, sum signal, phase information and position information. Simple block diagram of the Libera Single Pass H unit is presented on the Figure 1.

Figure 1: Libera Single Pass H block diagram



MEASUREMENTS

The following measurements were done under laboratory conditions. Firstly, the instrument evaluation was done in-house on the testing setup with the RF generator, and splitter. After the successful in-house testing, characterization measurements of the same electronics were carried out at the CIEMAT lab. The measurements were performed on a CIEMAT wire test bench with the 175 MHz / 25 dBm signal input connected to the wire. It has to be stressed out, that the insertion loss of the test bench was around 50 dB so the intensity of the signal connected the Libera Single Pass H inputs was around 180 mV. The Libera Single Pass H system was set-up for the measurements of the second harmonic frequency component (350 MHz). The sensitivity coefficients of the test bench sensor were k=12.8 mm.

Figure 2: Test Bench and Testing Setup at CIEMAT

Testing of position accuracy

Different measurements were performed on the test bench, firstly by moving the wire over larger displacements and checking the position. From each 120 us long macro acquisition the positions and phase result was extracted. Figure 3 and Figure 4 shows concatenated macro acquisition information. In such a way the repeatability of the Libera Single Pass H was measured.

Figure 3: Wire movement measurement. Concatenated results for the displacements over a larger scale (X = +1 mm, -1 mm, +2 mm; Y = 0 mm). Four amplitudes and X, Y positions are plotted.

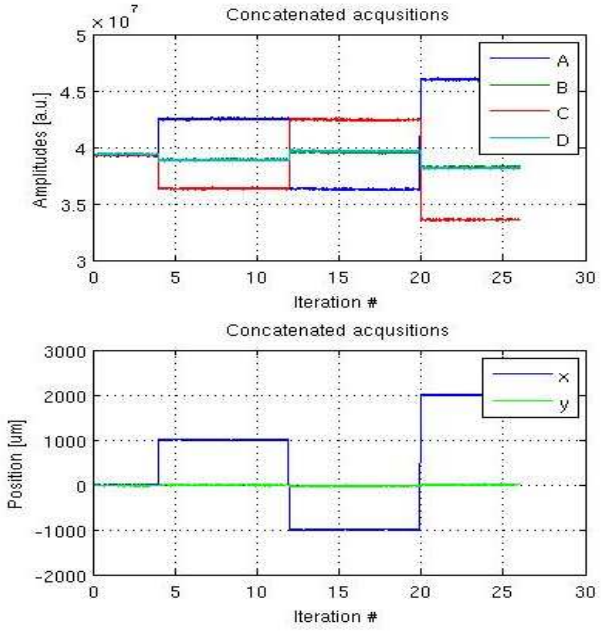
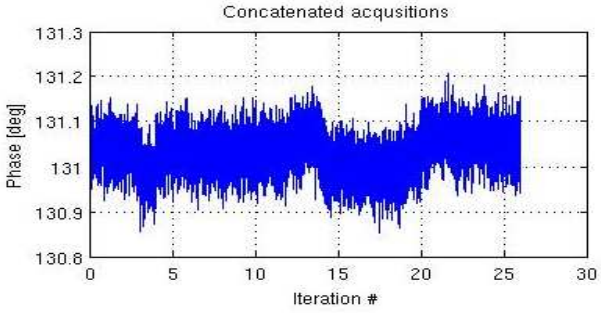


Figure 4: Negligible impact of the off-centred beam on the phase measurement



The results prove that the impact on the phase measurement of an off-centred beam within the measured range may be neglected.

Furthermore the wire was moved in continuous steps of 5 micrometers in X direction, to prove and compare the performance of the Libera Single Pass H system with the real wire movements in the test bench. Figures 5 and 6 show the X position measurement performed during the displacements within 60 seconds – one data point per second. The phase resolution of this measurement was noted to be 0,0259 deg.

Figure 5: Wire movement – by 5 um steps in X-direction. Seven steps are seen in position measurement

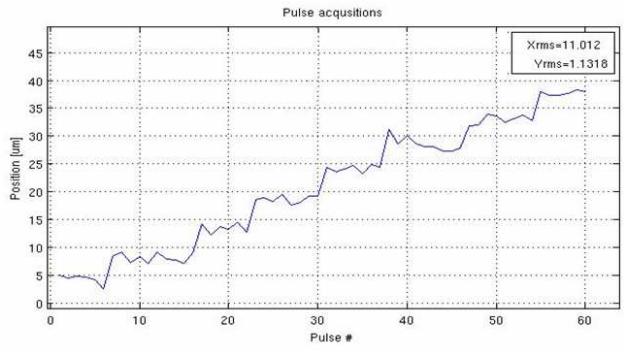
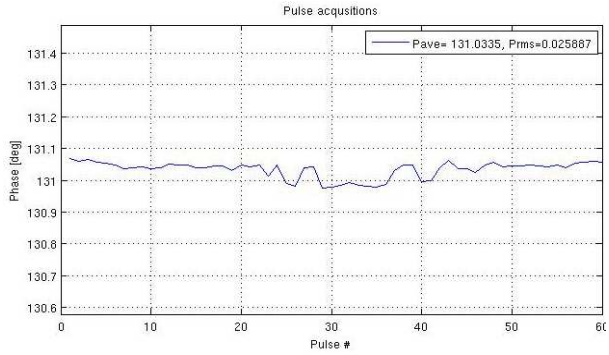


Figure 6: Impact of the off-centred beam on the phase measurement



Acquisition of consecutive macro pulse structures

In this measurement input signal was in the form of macro pulses. The signal acquisition by Libera Single Pass H was triggered by an external synchronized trigger. Ten consecutive pulses were acquired, each over 120 microseconds (Figure 7). The Libera Single Pass H system conducted measurements with submicron resolution for X and Y position and phase resolution of 0,0074 deg.

Figure 7: Consecutive macro pulse acquisition – position measurement

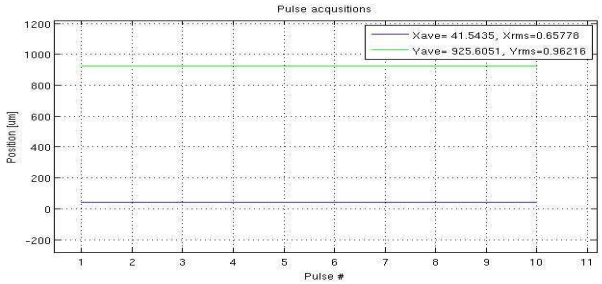
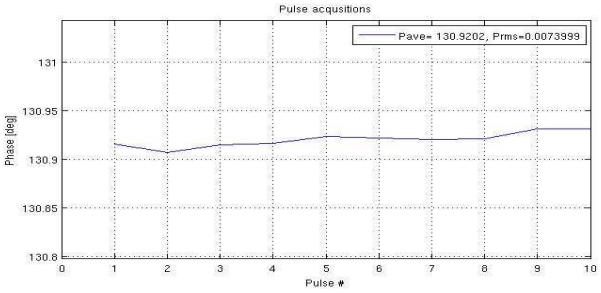


Figure 8: Consecutive macro pulse acquisition – phase measurement



Testing of phase accuracy

The phase shifting measurement was done with inserting the phase delay bullets into the RF chain and running two acquisitions. This is not the most elegant solution, because in this way we interfere in the measuring setup and the phase shift is not accurate. The phase shifting measurement was later repeated and confirmed with the dedicated phase shifting device.

Table 3: Libera Single Pass H phase shifting test

No. of phase delay bullets	Measurement 1 [deg]	Measurement 2 [deg]
0	131.089	131.097
1	122.190	122.201
2	114.350	114.380
1	122.540	122.620
0	130.410	130.710

CONCLUSION

The first Libera Single Pass units have been tested with a pulsed signal source at Instrumentation Technologies and on a test bench at CIEMAT. The tests gave clean and expected results with an excellent phase and position accuracy resolution on both longer concatenated acquisition and within individual bunch trains.

We would like to emphasize successful collaboration between users (CIEMAT) and manufacturers of the instrument (Instrumentation Technologies).

REFERENCES

[1] Instrumentation Technologies, Libera Single Pass H User Manual v1.00, Solkan, December 2010

[2] I. Podadera at al., Developments for IFMIF/EVEDA LIPAc Beam Position Monitors: the sensors at the MEBT and the wire test bench, these proceedings.