APPLICATION OF LIBERA BRILLIANCE SINGLE PASS AT NSRL LINAC BPM SYSTEM *

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Abstract

Libera Brilliance Single Pass is a digital beam position processor with capabilities of single pass position measurement. This device can be used on the stripline beam position monitor (BPM) of the linac and transfer lines on light sources as well as injector system for the FELs. The linac of Hefei light source (HLS) was equipped with 2 stripline beam position monitors, which will be increased to 20 BPMs after upgrading. The existing BPM electronics were the homemade electronics with logarithm detector. To enhance the functionality of the BPM system, the Libera Brilliance Single Pass is employed to replace the existing BPM electronics. The newly buying devices have made test of characterization. The mapping of stripline BPM is made on a workbench with Libera Brilliance Single Pass. The beam position is tested at linac using Libera Brilliance Single Pass. And the results of these measurement performed on Libera are reported to compared to measurements with the linac's existing BPM electronics.

INTRODUCTION

Starting mid of 2009 the HLS will be upgraded, the energy of the storage ring will remain 800MeV, the emittance will be decreased, and the energy of the linac will be improved from 200MeV to 800MeV. The electron beam position monitor that was installed before did not meet the resolution and stability requirements of the new linac. Therefore it was decided to equip the new HLS linac with a completely new BPM-system. 20 stripline beam position monitors will be used for measurement and control of the beam trajectory. Because the Libera Brilliance Single Pass has high performance [1, 2], the Libera Brilliance Single Pass will be used to replace the existing BPM electronics.

In order to show good performance in the future linac, Libera Brilliance Single Pass has to be carefully tested. In the following sections, the laboratory tests are performed, the mapping of stripline BPM is made, and several tests are made at HLS linac.

LABORATORY TEST OF LIBERA BRILLIANCE SINGLE PASS

The laboratory testing block diagram of Libera Brilliance Single Pass is shown in Fig.1. An arbitrary waveform generator produces two synchronous trigger signals with 50Hz repetition rate, one of them is fed into the Libera Brilliance Single Pass as an acquisition trigger signal while the other is fed into the pulse generator to generate pulses. The variable attenuator controls the amplitudes of the input signal to simulate different beam charges. And the pulses are fed into 4 channels of Libera Brilliance Single Pass through a 4 way power splitter.

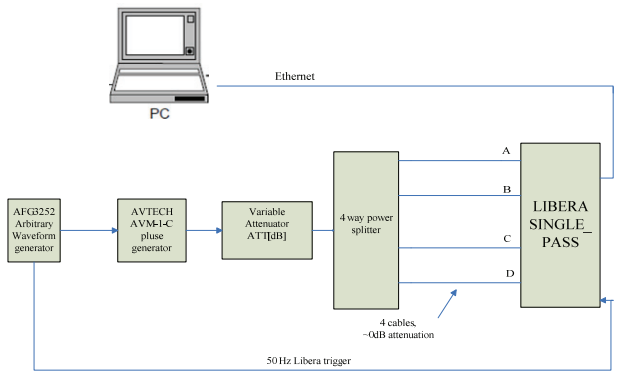

Figure 1: Laboratory test diagram of Libera Brilliance Single Pass

To simulate the stripline signal, the pulse generator generated a short pulse. There is a shot of pulse seen by oscilloscope shown in Fig. 2. The pulse width is 1.35ns, in order to simulate the new linac beam pulse which will be about 1ns width. And the repetition rate is 50Hz as triggered by the arbitrary waveform generator. The signal seen by Libera is practically the response of the 500MHz filter with the bandwidth of 10 MHz [1].

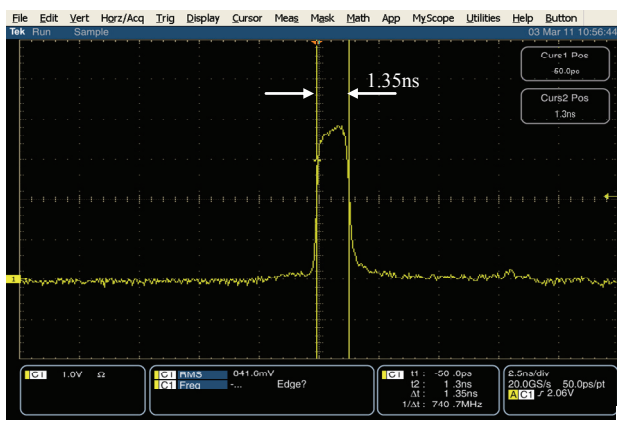

Figure 2: Simulated signal seen on an oscilloscope.

After receiving 4 channels of simulated signals, Libera Brilliance Single Pass begins to calculate the beam position. There are two position calculation methods in

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Libera Brilliance Single Pass [1], known as the Diagonal and Orthogonal pickup positioning. The laboratory test uses the Orthogonal pickup positioning, the same as it using in the upgrade HLS linac. The position is calculated using formulas for X, Y, and SUM (see Eq.1) [1]. In the experiment we consider the geometric coefficients of BPM: K_x=K_y=10mm.

$$\begin{cases} X = K_x \dfrac{V_A - V_C}{V_A + V_C} - X_{offset} = K_x P_x - X_{offset} \\ Y = K_y \dfrac{V_B - V_D}{V_B + V_D} - Y_{offset} = K_y P_x - Y_{offset} \\ \sum = K_\Sigma (V_A + V_B + V_C + V_D) - \sum_{offset} \end{cases} \quad (1)$$

There are 21 Libera Brilliance Single Pass that need to be tested in this experiment. The main goal of this test is to check if each Libera has reached the requirement of resolution at new HLS Linac. During the experiment, the 40dB variable attenuator controls the amplitude of the pulse. With each input signal Libera calculates the simulated beam position X, Y. The RMS of these position data are considered as the resolution at this specific input signal. The resolution at different signal with different charges can be simulated by changing the attenuate level of variable attenuator. Besides, the inside attenuator of Libera has to be carefully controlled in order to get better resolution. The result is shown in Fig.3.

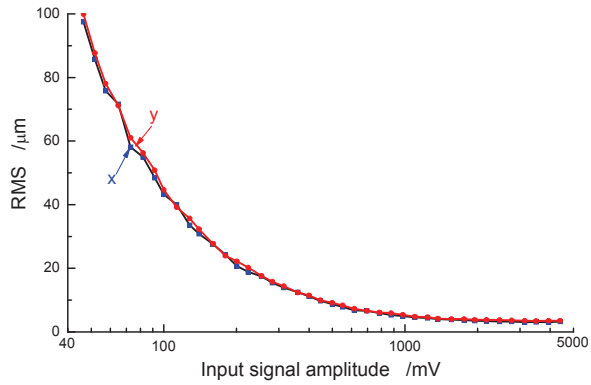


Figure 3: RMS results measured on Libera Brilliance Single Pass

Libera Brilliance Single Pass achieves less than 5μm position resolution at high bunch charges and still good position results at very low bunch charges. The using BPM electronics only get about 30~50μm position resolution during laboratory tests [3]. Several function of Libera has also been tested after resolution tests. Each Libera Brilliance Single Pass has shown good performance in these tests. The results indicate that the newly buying electronics are better than the previous ones.

CALIBRATION OF STRIP-LINE BPM WITH LIBERA BRILLIANCE SINGLE PASS

Because there are errors during machining process of BPM such as electrode parameters, we need to calibrate the BPM system before installing. The calibration data are fitted to an equation, and the equation will be used in next position calculation. Since the four stripline BPM has already installed at HLS linac, we use an eight stripline BPM to calibrate. The methods of calibration are the same.

The calibration system is made up of a movable antenna with a RF signal source to simulate the beam, a BPM moving bench with its control system, a Libera Brilliance Single Pass as its electrode signal acquisition system and analysis software [4].

Since Libra Brilliance Single Pass has an inside 500MHz filter in each channel, we feed-in the antenna with the high-frequency signal which has the frequency of 500MHz. Then we control the stepper motor to make the antenna moving near the center of the BPM within 6mm, and the move step is 0.5mm. We synchronous record the signals of each channel measured by Libera, and the results are shown in Fig.4.

We can see the position caculated by Libera is consistent with the real beam position in the central region. We fit the results with a polynomial shown as follows :

$$\begin{cases} x \approx -0.062 + 5.773P_x + 0.151P_y - 0.032P_xP_y \\ \quad +0.035P_x^2 + 0.018P_y^2 \\ y \approx -0.064 + 0.032P_x + 5.857P_y - 0.0064P_xP_y \\ \quad -0.025P_x^2 - 0.014P_y^2 \end{cases} \quad (2)$$

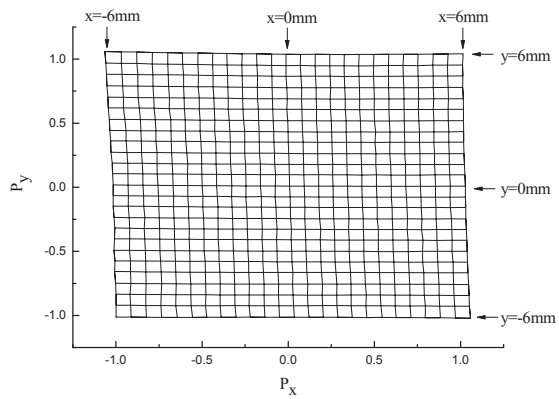


Figure 4: Mapping results of eight stripline BPM with Libera

REAL BEAM TEST AT HLS LINAC

In the HLS Linac, the frequency of micropulse is 2856MHz, the bunch width is 1μs, and the repetition rate is 1Hz. The existing BPM electronics are the homemade electronics with logarithm detector, the operating frequency is 2856MHz. We use Libera Brilliance Single Pass to replace it. There are two strip-lines BPM that equipped at HLS Linac. The experiment has been taken on one of them. To the BPM, its electrode opening angle is 60°, and its inner radius is 19mm [5]. With these

parameters we can calculate the geometric coefficients of stripline BPM using equation below:

$$K_x = K_y = \frac{\beta \cdot b}{4\sin(\beta/2)} \quad (3)$$

where b is the inner radius, β is the electrode opening angle.

According to formula (3), $K_x=K_y\approx 9.95$mm.

By setting Libera Brilliance Single Pass with parameters above, we made some tests during injection time at HLS Linac. The BPM electrode signals were directly feed into Libera. We get that the resolution of horizontal position is about 100μm, and vertical position is about 200μm.

The performance of Libera on real beam seems much worse than the laboratory tests. This reason is the frequency of micropulse at HLS Linac is 2856MHz, the width of micropulse is 1μs. When the main frequency of signals that fed into Libera was 2856MHz, but these signals were frist get through a 500MHz SAW filter before position calculating. So the signal levels seen by Libera were much lower than the BPM produced. And this directly led to worse resolutions of both X and Y position. To solve this problem, we added four mixer on each channel before Libera, see Fig.5. Signals picked up by BPM are fed into the mixer frist, and mixed with another 2356MHz signal produced by a signal generator. In order to avoid the overflow of signal level, four 16dB attenuators were equipped after mixer. During the experiment, the inside attenuators of Libera were set appropritely to get better resolutions. The results measured by Libera after improvement are shown is Fig.6.

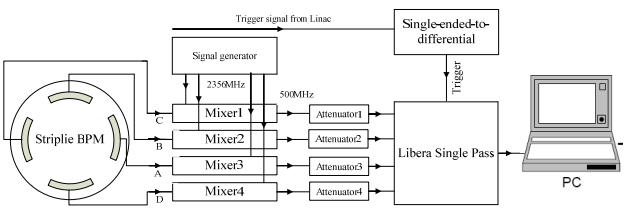
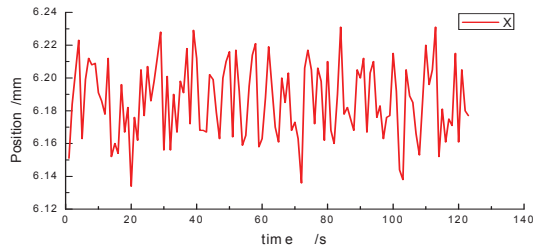
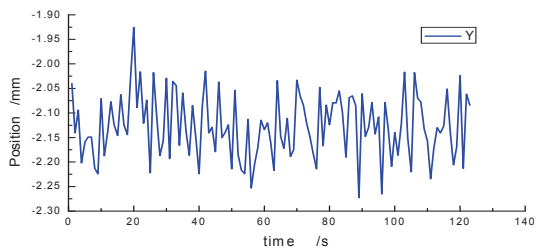


Figure 5: BPM measurement system using Libera Brilliance Single Pass with mixer added.

Accroding to the results we calculate the resolutions of both directions. The horizontal position resolution is about 20μm, while vertical position resolution is about 50μm. The former tests took in 2006 using homemade BPM electronics get the horizontal resolution of about 58μm and the vertical resolution of about 33μm [3]. The vertical position resolution is worse than before probably beacause the conditions of HLS Linac has changed. And the signals produced by BPM are probably influenced by the other signal of mixer.



(a) Horizontal



(b) Vertical

Figure 6: Position results on real beam with mixer added.

CONCLUSION

The Libera Brilliance Single Pass has shown good performance on both laboratory tests and real beam experiment on HLS Linac at present. These tests were mainly focus on position calculating by Libera. To get more characterization of Libera, several tests such as beam current measurement must be done in the future. Since Libera is designed for the upgrade Linac of HLS, we believe it will have better experssion in future work.

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