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APPLICATION OF LIBERA BRILLIANCE+ TO SPECIAL PURPOSE BPMS IN SuperKEKB

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Abstract

The KEKB accelerator at KEK is being upgraded to SuperKEKB, and will be starting operation in 2015. SuperKEKB will have 444 Beam Position Monitors (BPMs) in the positron ring (LER), and 466 in the electron ring (HER). Two BPMs in each ring will be newly introduced for measuring fast beam orbit oscillations, and another two BPMs in each ring will be introduced for the fast beam orbit interlock at SuperKEKB. The required resolution is below several μm for fast beam orbit oscillation monitoring, and the requirement for the response time is less than 100 μs for the fast beam orbit interlock. We plan to use the Libera Brilliance+ from Instrumentation Technologies as signal processors for these special purpose BPMs. This paper discusses the application of the Libera Brilliance+ to these special purpose BPMs.

INTRODUCTION

The electron-positron collider KEKB, which stopped its operation in 2010 after having achieved a world record luminosity of $2.11 \times 10^{34}\ cm^{-2}s^{-1}$, is being upgraded to SuperKEKB [1]. The commissioning of the accelerator is planned to start in 2015. To achieve the design luminosity of $8 \times 10^{35}\ cm^{-2}s^{-1}$, which is 40 times larger than that of KEKB, the beam current will be raised to 3.6 A in the positron ring (LER) and 2.6 A in the electron ring (HER) and the vertical beam size at the interaction point (IP) is reduced to 20 times smaller than that of KEKB. The beam energy is 4 GeV in LER and 7 GeV in HER.

About 900 Beam Position Monitors (BPMs), 444 in the LER and 466 in the HER, will be attached to quadruple magnets in SuperKEKB [2]. While the HER BPMs are almost reused as is from KEKB, those of the LER will be newly fabricated. A BPM typically has four button electrodes. Table 1 summarizes BPMs to be installed in SuperKEKB. A narrow band detector uses a super-heterodyne system and covers four BPMs in one unit. A turn-by-turn detector measures the orbit oscillation of a non-colliding pilot bunch to measure the optics during beam collision. An interaction region (IR) feedback monitor located near the IP measures beam position for the orbit feedback to maintain stable collision. A longitudinal phase monitor will be installed to adjust the injection phase of the beam.

In addition to the above BPMs, special purpose BPMs, such as a fast beam orbit oscillation monitor and a fast beam orbit interlock monitor, will be introduced in SuperKEKB. These monitors are described in this paper.

Table 1: BPMs in SuperKEKB

Detector type	**Resolution [μm]**	**Repetition [Hz]**	**Number of units**
Narrow band	2	0.25	244
Turn by turn	50 to 100	100 k	270
IR feedback	1	5 k	4
Fast oscillation	5	10 k to 100 k	4
Orbit interlock	100	100 k	4
Longitudinal phase	10	100 k	2

SPECIAL PURPOSE BPMS

Fast Beam Orbit Oscillation Monitor

Four monitors, two in the LER and two in the HER, will be installed near sextupole magnets around the IP which will be used for correcting chromaticity mainly produced in the IR quadrupole magnets. The vertical beta functions at the sextupoles are very large, typically about 2000 m, both in the LER and the HER. The purposes of installing the monitors are as follows:

- To estimate vertical oscillation at the IP.
  Since the vertical beam size at the IP in SuperKEKB is as small as 50 nm, even a small vertical offset of 15 nm between electron and positron beams at the IP will lead to luminosity loss of 6 % according to a simulation [3]. For example, the beam oscillation due to vibration of quadrupole magnets near the IP may cause such vertical offset at the IP [4]. Measurement of the oscillation will be useful for finding the cause of the luminosity loss, if any. Owing to the large vertical betatron function at the monitors, the required resolutions of the monitors to detect the oscillation of 0.1 r.m.s. vertical beam size at the IP are as large as 13 μm in the LER and 17 μm in the HER [5].
- To estimate vertical emittance growth due to the sextupole magnets.
  A vertical position offset at the sextupoles will cause vertical emittance or beam size growth, which leads to luminosity loss. An estimation shows that a vertical offset of 17 μm in the LER produces an emittance growth of 3.8 pm which is 1/3 of the tolerance level. The emittance growth in the HER is rather small, 1.8 pm even if the vertical offset is 30 μm [5].

The position resolution of the monitors of less than 5 μm is enough to satisfy the above requirements. The turn by turn

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measurement is desirable to detect fast oscillation. Slower measurement is sufficient for measuring the closed orbit or slow oscillation at the sextupoles.

Fast Beam Orbit Interlock Monitor

This monitor outputs a beam abort signal if the beam position exceeds a threshold level. If an aborted beam has a horizontal coherent betatron oscillation, the beam may hit outside the titanium abort window and destroy the joint between the chamber with the window and the next beam chamber [6]. An estimation shows that the oscillation amplitude should be less than 6 σ_x in the HER and 5 σ_x in the LER, respectively, which are converted into the horizontal amplitudes at the monitors of 1.5 mm in the LER and 2.2 mm in the HER, where σ_x is the horizontal beam size [6]. Further, the system will be useful for protecting accelerator components during the beam aborts because experience at KEKB showed that the beam oscillation was sometimes observed before the beam being aborted by the loss monitor interlock [7].

Four monitors, two in the LER and two in the HER, will be used for this purpose. The two monitors in each ring will be located at positions separated by a betatron phase of 90 degrees in order to cope with the situation where the betatron oscillation accidentally has a node at the monitors.

The specification for the interlock response time was set to 100 μs, i.e. 10 turns, by the commissioning group, though it is difficult to predict the shortest growth time of the oscillation, for example, by the damage of vacuum components.

The Libera Brilliance+ by Instrumentation Technologies [8] is a candidate for these special purpose monitors.

EVALUATION OF LIBERA BRILLIANCE+

Libera Brilliance+

A Libera Brilliance+ (LBP) is a signal processor for beam position measurement supplied by Instrumentation Technologies [8].

The LBP has four measurement modes: Raw ADC, Turn by Turn, Fast acquisition (FA) and Slow acquisition (SA), whose data repetition rates are 119 MHz, 100 kHz, 10 kHz and 10 Hz, respectively. The LBP has a function to output an interlock signal if the beam position exceeds a threshold level. The data repetition rate of position calculation for this orbit interlock is 10 kHz because the LBP uses FA mode for the orbit interlock. The LBP also has calibration functions such as Automatic Gain Control (AGC) with automatically controlled attenuators and Digital Signal Conditioning (DSC) to compensate gain and phase difference among four input channels.

Position Resolution Measurement

Figure 1 shows a block diagram for the measurement of position resolution. A signal generator (S.G.) generates a continuous sinusoidal wave (C.W.) at 508 MHz, which is divided into four signals, then supplied to the LBP's input channels, A, B, C and D . A C.W. of 508MHz generated by another S.G. is frequency-divided by 5120, then fed to an input of the Machine Clock as a revolution signal. The two S.G.s are synchronized with each other.

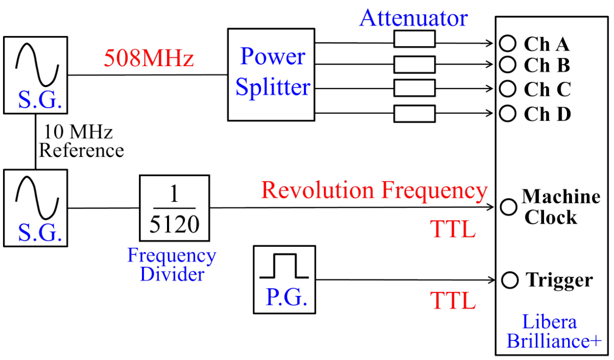

Figure 1: Block diagram of position resolution measurement. S.G. is a signal generator. P.G. is a pulse generator.

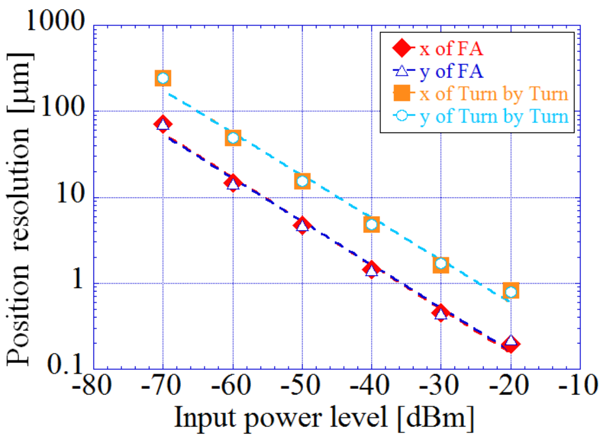

Figure 2: Position resolution as a function of input signal level. The upper traces are x and y resolutions in FA mode and lower traces are those in Turn by Turn mode. Kx and K_y are set to 33 mm.

The LBP calculates the vertical and horizontal positions according to the following formulas,

$$x = K_x \frac{(V_A + V_D) - (V_B + V_C)}{V_A + V_B + V_C + V_D} \quad (1)$$

$$y = K_y \frac{(V_A + V_B) - (V_C + V_D)}{V_A + V_B + V_C + V_D} \quad (2)$$

where V_A, V_B, V_C and V_D are the output voltages from four channels, the coefficients K_x and K_y the factors determined by the chamber radius and the diameter and configuration of the electrodes. K_x and K_y are about 33 mm in SuperKEKB.

Figure 2 shows the result of the position resolution measurement without AGC. The abscissa is the input power level to the LBP and the ordinate represents the r.m.s values of vertical and horizontal positions measured by FA and Turn by Turn modes. Since the estimated signal level at the input of the LBP at the design current is -5 dBm both in the LER and the HER, the position resolution of 1 μm and 4.2 μm will be achieved in FA and Turn by Turn modes, respectively, after adjusting the signal level by the internal attenuator using AGC. Even at 30 mA resolutions of 3 μm in FA and 10 μm in Turn by Turn modes are expected. Thus the requirement will be satisfied at fairly low beam current.

Interlock Response Time Measurement

The interlock response time of the LBP is estimated to be around 200 μs in the user manual of the LBP. In order to reduce the response time further an modification where the data acquisition mode for the orbit interlock was changed from FA (10 kHz) to Turn by Turn mode (100 kHz) was carried out by Instrumentation Technologies.

For the measurement of the interlock response, the setup of the resolution measurement was slightly modified as shown in Figure 3. The orbit interlock signal is connected to an oscilloscope through a pull up resistor. The S.G. originally connected to the Machine Clock was connected to channel D. The signal originally sent to the channel D was fed to the Machine Clock input after frequency-divided. The interlock was triggered by a manual button of a pulser which generates a pulse to switch off the signal of the S.G.. In this configuration a sudden large orbit shift was simulated because the voltage at the channel D was the only voltage which changed. Simultaneous measurement of the interlock signal and the S.G. signal by the oscilloscope gave the interlock response time.

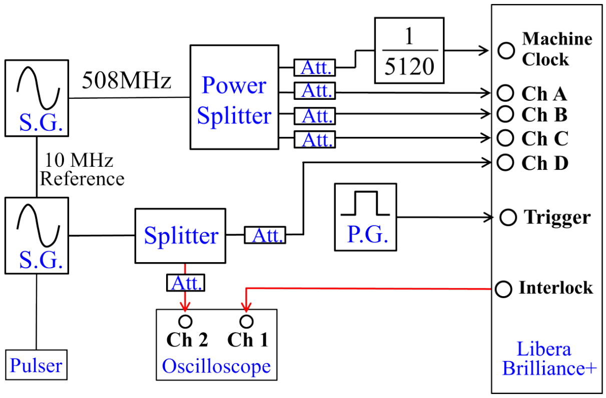

Figure 3: Block diagram of interlock response time measurement. Att. is an attenuator.

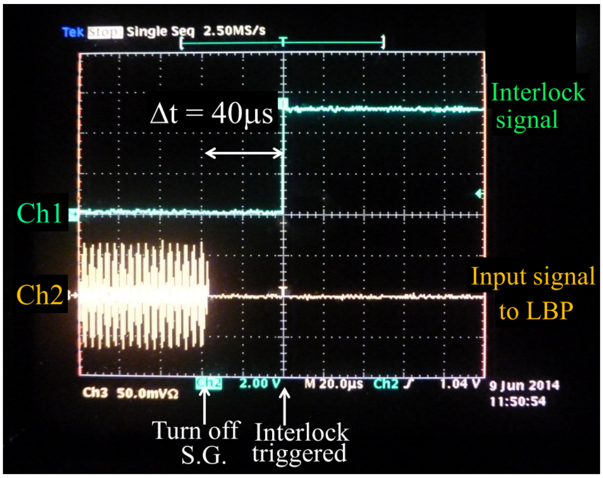

Figure 4: Measured interlock response time after the modification of Libera Brilliance+.

Figure 4 shows the measurement result of the interlock response time after the modification. The upper trace is the interlock signal from the LBP and the lower trace is the signal from the S.G.. Δt is the difference between the interlock signal and the time when the S.G. signal is turned off. The interlock response time is about 40μs (4 turns in the SuperKEKB). The position limit was set to ±10 mm in the measurement. If the limit was narrowed to ±0.1 mm the response time was about 20μs. The result meets the specification of the response time to be within 10 turns.

CONCLUSION

The performance of the Libera Brilliance+ was evaluated for the fast beam orbit oscillation monitors and the fast beam orbit interlock monitors in SuperKEKB rings. Since both the position resolution and the response time of the orbit interlock meets our specifications, we decided to introduce eight Libera Brilliance+ in the SuperKEKB rings. Remaining tasks are the software development and the decision of the operation policy of these monitors.

ACKNOWLEDGMENT

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