BUNCH TRACING BY BUNCH BY BUNCH MEASUREMENT SYSTEM IN HLS*

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Abstract

In this paper, we introduce a bunch tracing system which is based on a bunch-by-bunch (BxB) measurement system in Hefei Light Source (HLS), and present the analysis of the experiment results. Using an in-phase gate signal and a double balance mixer to control an external trigger of ADC, we test the reliability of the BxB system. By this system, we can trace all marked bunches in a set time slot or in manual burst mode. We can record all bunches' data during the injection, ramping, wiggler excitation and normal operation, and provide a powerful facility for machine study.

INTRODUCTION

The National Synchrotron Radiation Laboratory (NSRL) electron storage ring, with a circumference of 66 meters, operates with 45 bunches in 204.035MHz RF (Radio Frequency), and contains 31 BPMs (Beam Position Monitor). Each BPM has a four-button type pick-ups mounted in a skew of 45o. A 200MeV injection beam from linac and transport line ramps to 800MeV and operates at 200-300mA in the HLS storage ring. A multi-cycle multi-turn injection system is used for current accumulation. A wiggler is available in the HLS.

The BxB measurement system is dedicated to observe the beam instability and works as a part of the transverse BxB feedback system in HLS[1]. Fig. 1 shows an overview of the BxB transverse feedback system of HLS, the shadow part is for one BPM detection system.

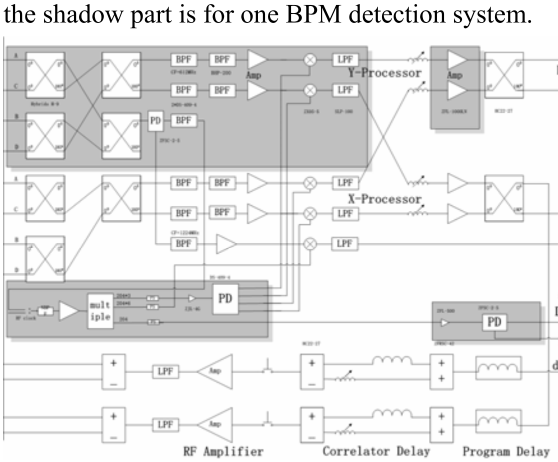

Figure 1: An overview of the transverse feedback system.

The HLS BxB transverse measurement system works at 612MHz (3* fRF), with 100MHz bandwidth. A high speed 12-bit digitizer, up to 400 MSPS (Million Samples Per Second) and simultaneous in two channels [2], is installed in a PXI (PCI eXtensions for Instrumentation) desktop. An in-phase FRF signal is used as the external clock of the ADC (Analog-to-Digital Converter), and an in-phase Revolution Frequency signal (4.533MHz) is connected with the External Trigger of the ADC.

RELIABILITY TEST OF THE BXB MEASUREMENT SYSTEM

Before the measurement of the beam signal, a signal simulation experiment was designed to test the reliability of the system. An overview of the test system is shown in Fig. 2.

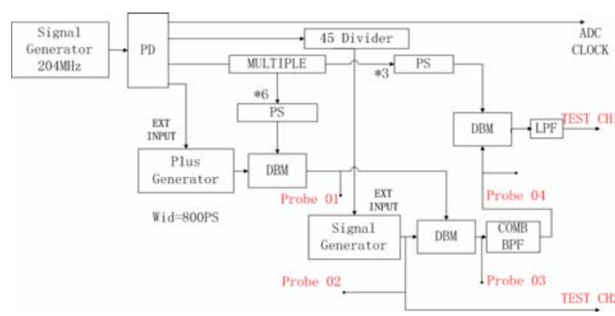

Figure 2: An overview of the reliability test system.

Controlled by a gate signal about 800ps width, a 6* f_{RF} signal becomes a pulse signal after passing the double balance mixer (Fig. 3). This signal works as a carrier wave of the Amplitude Modulation (AM), and an in-phase triangle or sine wave (Fig. 4) works as a modulation signal of the AM. The modulated pulse is treated as the beam signal, (Fig. 3). The beam signal after the comb filter is shown in (Fig. 4).

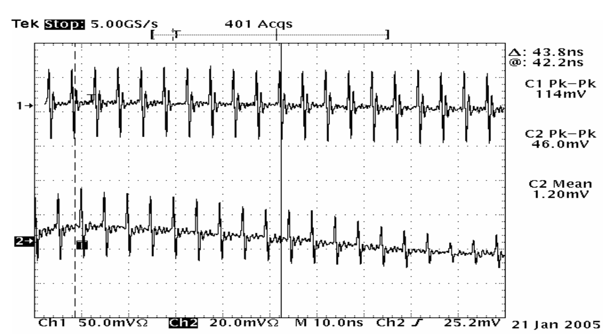

Figure 3: Pulse signal and modulated pulse signal.

*Supported by National Natural Science Project (10175063).
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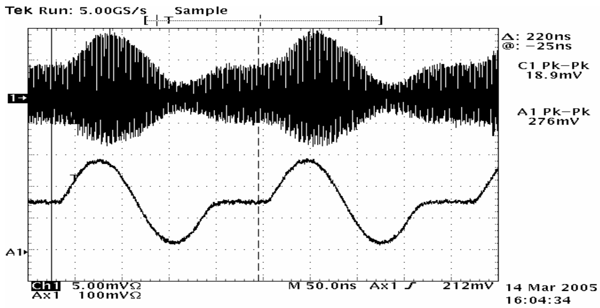

Figure 4: Modulation signal and simulation beam signal.

Figure 5 compares the original modulation signal and the modulated pulse signal processed by the BxB measurement system. These waveforms are detected by ADC, with 4.2M samples. The average of the Mean Square Error (MSE) (see Eq. 1) of the 45 simulation bunches' normalization amplitude is 1.49%.

$$MSE = \frac{1}{n}\sum_{i=0}^{n-1}(x_i - y_i)^2 \qquad (1)$$

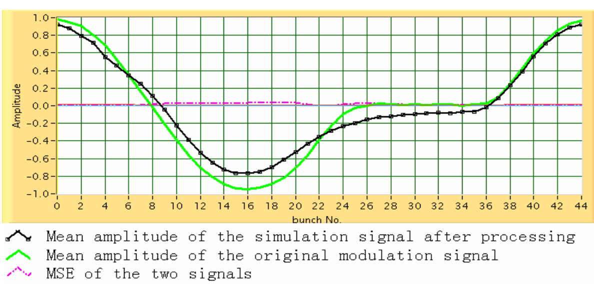

Figure 5: Simulation beam signal detected by ADC.

The test of the BxB measurement system by the simulation signal shows a good result of this high speed AD system. It is necessary before the experiment in the storage ring.

EXPERIMENTS AND ANALYSES

Restricted by the on broad memory of the digitizer, we couldn't acquire more than 4,194,192 samples in each record. With an external trigger of Revolution Frequency, we can trace each bunch during a long period. The marker of the bunch was given in the first data record, and then we can track one or several bunch in the following records. In this way, the information of each bunch, such as x, y and sum signal, could be saved during the injection, ramping, wiggler charging normal operation and wiggler discharging. The status of each record of the following experiments is shown in Table 1.

Table 1: Detail of the record.

Record No.	Status
001~046	Injection
047~123	Ramping
124~160	Decreasing FRF from 204.0554MHz to 204.016MHz
161~200	Correcting Closed Orbit
201-267	Wiggler Charging (WC)
268~305	Adding skew-quadrupole
306~400	Open for users

Tune Test

Tune shift in the both X and Y direction is measured in the HLS, the y-direction is shown in Fig. 6. Each point in the figure is calculated by 2048 samples of Bunch No.13 in each record by FFT (Fast Fourier Transform) Algorithm. During the injection, tune y is decreased; the peaks in No.12 and No.28 correspond to the beam lost during the injection.

During the process of wiggler charging, from record No. 201 to 267, the effect of magnetic field causes the increase of tune y. There is a detectable beta oscillation in the y-direction without kicker just after adding skew-quadrupole. Tune shift from record No. 306 to No. 400 is about 0.0014.

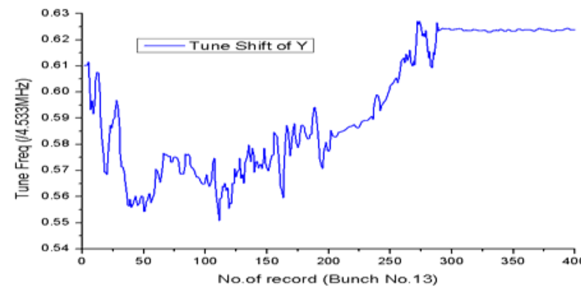

Figure 6: Tune shift in the Y-direction.

Mode Test

Mode test [3, 4] is also carried out by the data we acquired. All the samples of each record are used to undergo the FFT analyse. The corresponded amplitudes of the mode frequency are selected for the Fig. 7 and Fig.8. The phenomena of Fig. 7 and Fig. 8 are summed up in Table. 2.

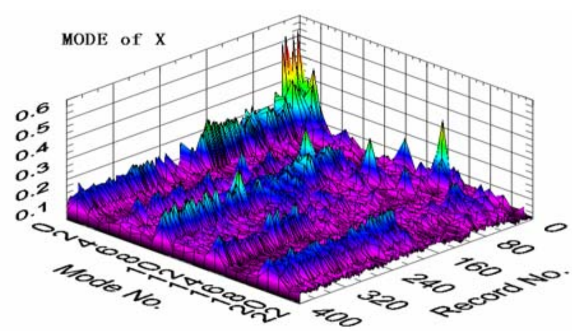

Figure 7: Mode display in X-direction.

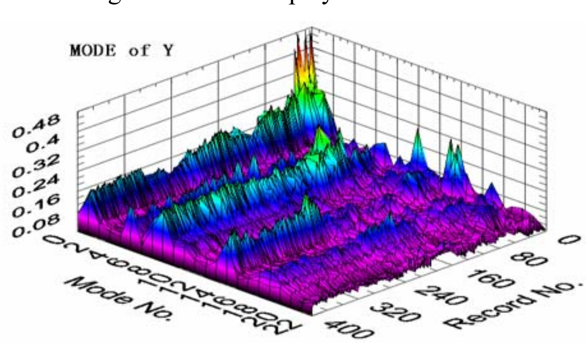

Figure 8: Mode display in Y-direction.

Table 2: Analyse of the mode display.

Mode No.	Phenomena	Direction
0	Only high in injection	X and Y
1	Going down in adding wiggler	X
5	Going up in changing F_{RF}	X
8(Y)/9(X)	Always high	Y / X
14	High in injection and WC	X and Y
18(Y)/19 (X)	Going up when correcting the closed orbit	Y / X

Position and Amplitude Test

Fig. 9 shows the average of the beam position in the Y-direction (see Eq. 2). The position changes a lot in the ramping and the decreasing of FRF.

$$\overline{y}_{r,b} = \frac{1}{n}\sum_{i=1}^{n} y_{r,b,i} \quad (2)$$

n = 2048 (in this case, Sampling length of each bunch)
r = 1, 2, 3 … 400, (Record No.)
b = 0, 1, 2 … 44, (Bunch No.)

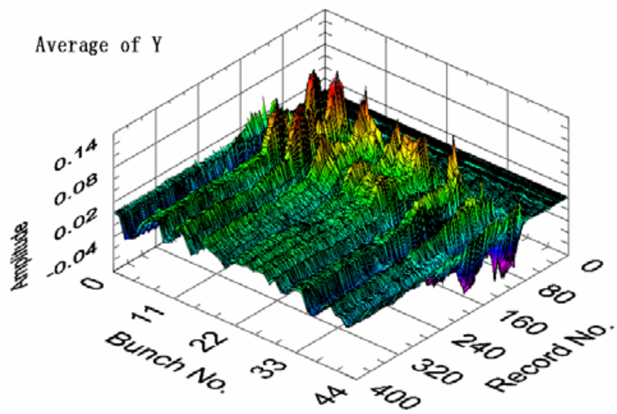

Figure 9: Average of beam position in the Y-direction.

Fig. 10 shows the standard deviation of the beam position in the y direction (see Eq. 3); the measurement result shows a great change after the depressing FRF and correcting the closed orbit. The differences of the outcomes are caused by the transverse beta oscillation, the differences of the bunch current and the longitudinal oscillation. The bigger oscillation in the longitudinal may cause the bigger standard deviation in the transverse.

$$S_{r,b} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_{r,b,i} - \overline{y}_{r,b})^2} \quad (3)$$

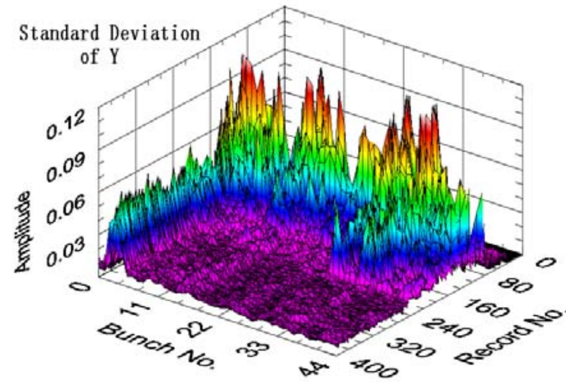

Figure 10: Standard Deviation of beam position in the Y-direction.

FUTURE WORK

After the succeed experiments of the BxB measurement system based on one BPM, the two BPMs measurement system and the BxB transverse feedback system will be established in the future. An on line phase space monitor of HLS based on this system is also under development.

ACKNOWLEDGEMENTS

The authors would like to present their thanks to Dr. Guangyao Feng and Prof. Hongliang Xu for their helpful discussion. Special thanks to Feng Zhao, who took in charge of the machine operation during the experiment.

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