BUNCH-BY-BUNCH ONLINE DIAGNOSTICS AT HLS*

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Abstract

The design goal for the bunch-by-bunch analogue transverse feedback system at the Hefei Light Source (HLS) is to cure the transverse coupled bunch instabilities. The prototype implemented bunch-by-bunch feedback in 2006. Then we changed the circuit and replaced some components by ones of higher performance in order to get better effect. Diagnostic techniques are important tools to determine instabilities and to confirm the performance of the feedback systems. In addition to transverse feedback this system can provide online beam diagnostics and analysis in transverse and longitudinal directions. The diagnostic functions can record the response of every bunch while the feedback system manipulates the beam. The experimental results are presented.

INTRODUCTION

The HLS is a facility dedicated to synchrotron radiation. Its electron storage ring, with a circumference of 66 meters, operates with 45 bunches in 204.035MHz Radio Frequency (RF), and contains 31 BPMs. Each BPM has a four-button type pick-ups mounted in a skew of 45°. 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. There are three operating states: injection (200MeV), 800MeV Optics-Normal, and 800MeV Optics-Wiggler.

A bunch-by-bunch transverse feedback system has been under commissioning at HLS, and it is introduced in this paper. The transverse prototype implemented bunch-by-bunch feedback in 2006. In order to get better effect, then we replaced some components by ones of higher performance, such as the strip line feedback kicker, the optical fibre notch filter. We moved the 3-tap filter in front of the hybrid network and add DC offset in the circuit to gain better signal to noise ratio.

In addition to transverse feedback this system can provide online beam diagnostics and analysis in transverse and longitudinal directions. The diagnostic functions can record the response of every bunch while the feedback system manipulates the beam. Some phenomena observed are presented, as well as the feedback experimental results.

THE FEEDBACK SYSTEM

Prototype

The bunch-by-bunch analogue transverse feedback system at HLS consists of 2 signal detectors (pickups), a RF front-end, a signal processing, a frequency doubling circuit, a vectors operation and control module, 2 Notch Filters, 4 RF amplifiers and a kicker. An overview of it is in [1].

We use double balance mixers (DBM) to substitute for the attenuators and phase shifters. This new method can simplify the system. It supports a range of 360 degree phase adjusting the feedback signal by vector computation. The signal can be controlled as either a feedback signal or an exciting signal arbitrarily.

In order to test the prototype serial experiments were performed on timing, phasing, and powering of the feedback signal with the old 73cm general kicker. This system also works well in 800MeV operation [1].

Improvements

In order to get better effect, then we replaced some components by ones of higher performance.

An analogue or digital notch filter is select to eliminate the revolution frequency components in most feedback system. Cooperating with YY lab, an optical fibre notch filter has been developed and used in HLS. The fibre filter has higher operation frequency, more stable amplitude response and the same filter depth wider working span in frequency domain (more than 1GHz), and it is much more compact than the cable notch filter[2].

A 21cm-long dedicated feedback kicker is manufactured and installed in the storage ring. The kicker has four electrodes of strip line type mounted in a skew 45°. Each electrode have an open angle of 60°. So it has much bigger shunt impedance than the 73cm general kicker.

Fig. 1 shows the experimental result in 200MeV. The left plot is captured without feedback system, and the right one is acquired during feedback system operation. Other experimental results are shown in next chapter.

Following the advice of Dr M. Tobiyama of KEK, we moved the 3-taps FIR filter to be in front of the hybrid network. Signal from BPM is of very wideband. While most of the RF components work well under narrow band conditions. So people should limit bandwidth before RF components. We also add DC offset to avoid the signal error in cases that the beam departs from the pipe centre. The feedback system of new state will be tuned in machine study time.

BEAM DIAGNOSTICS AND ANALYSIS

Online Diagnostic Program

Diagnostic techniques are important tools to determine instabilities and to confirm the performance of the feedback systems. As a part of the analogue transverse bunch-by-bunch feedback system, With an 12-bit digitizer (Acqiris DC440CompactPCI Digitizer) plugged in a PXI control box the online bunch-by-bunch

* Work supported by the National Natural Science Foundation of China under Grant 10175063 and by the National Natural Science Key Foundation of China under Grant No. 10535040

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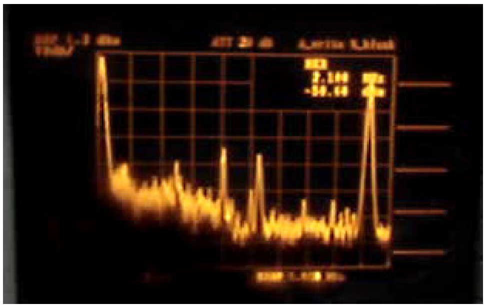
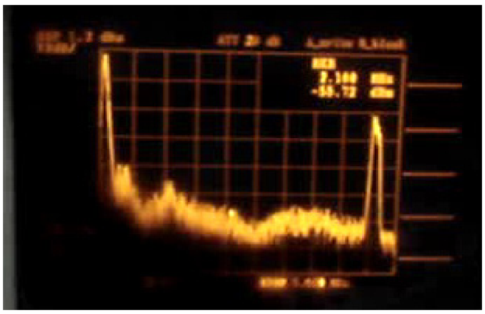


(a)Feedback off



(b) Feedback on

Figure 1: The frequency spectrum of the beam at injection (200MeV)

measurement system can provide beam diagnostics and analysis in transverse and longitudinal directions. The transverse part of the measurement system works at 612MHz (3* f_{RF}), the longitudinal one works at 1224MHz (6*f_{RF}), both of them with 100MHz bandwidth. The 12-bit digitizer has an up to 400 Million Samples Per Second and simultaneous in two channels, An in-phase RF signal is used as the external clock of the digitizer, and an in-phase Revolution Frequency signal is used as the External Trigger. The diagnostic functions can record the response of every bunch while the feedback system manipulates the beam.

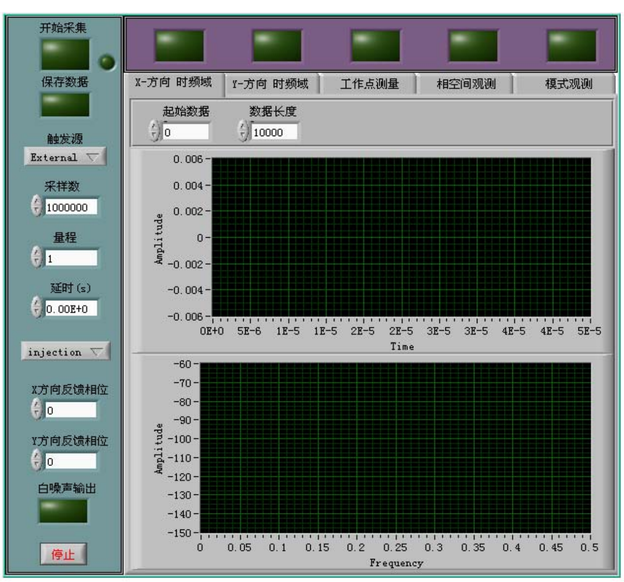


Figure 2:User Interface of the beam bunch-by-bunch diagnostic program

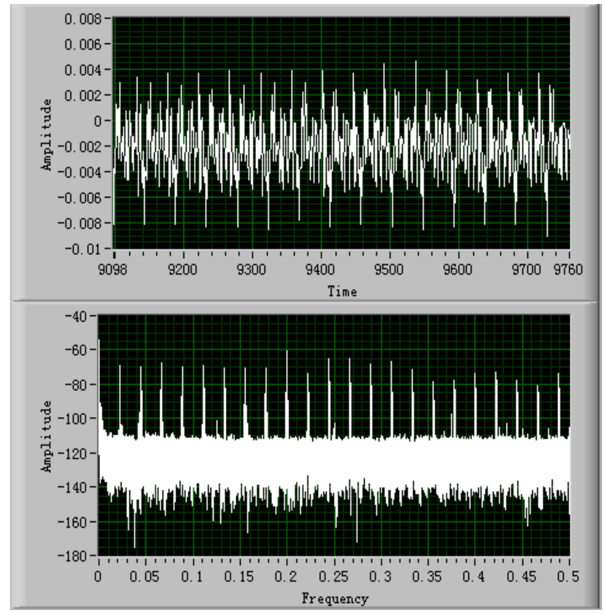


Figure 3: Simple analysis in time domain and frequency domain

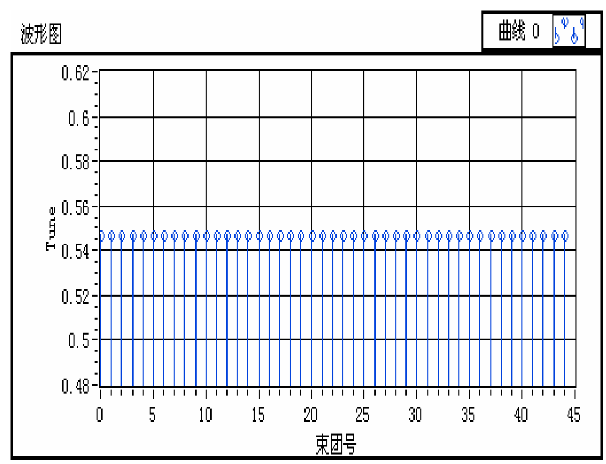


Figure 4: Bunch-by-bunch tunes measurement in horizontal directions. This Diagnostic program can do tune measurement using NAFF method.

The program design has been carried out mainly by means of LabVIEW code of the National Instruments [3]. The graphic user interface is shown in Fig.2. User can run this program to acquire and analyze data (see Fig.3), to measure tunes bunch-by-bunch (see Fig.4), to measure the transverse phase space of the beam centroid, to analyze the coupled bunch mode, and to measure growth and damping rates and injection transients.

Measurements of Beam Transverse Phase Space

By virtue of phase space reconstruction method based on Hilbert transform, phase space plot of the No.45 bunch is obtained [4], which is in vertical direction (see Fig.5).

There are 22 arms on the 2 phase space plots, while the tune in vertical direction is 2.591, and the decimal fraction approximates 13/22. The oscillation amplitude of beam reduces in the anterior 1000 turns, and grows in the following 1000 turns. In HLS, bunch circulating a turn

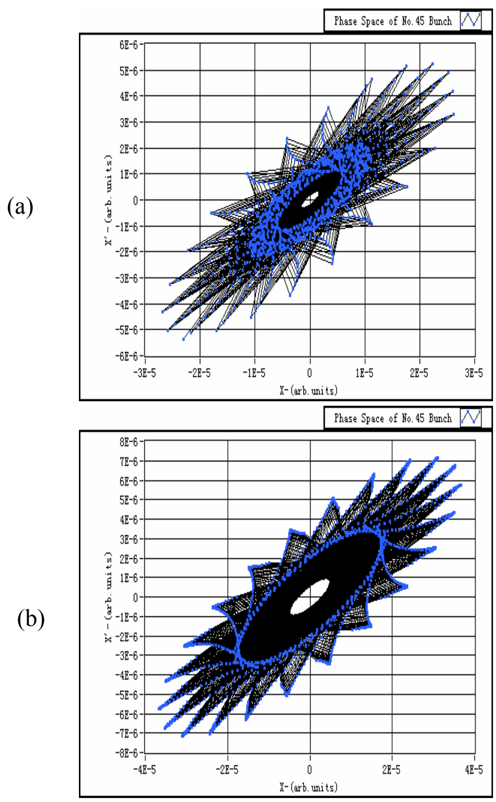


Figure 5: Phase space plot of the bunch using the Hilbert transform.Fig.5 (a) shows the anterior 1000 turns of the No.45 bunch, and Fig.5 (b) the following 1000 turns.

cost 220 nanoseconds. The variation process is only hundreds microseconds, faster than any damping process in our machine. Which mechanism drives this process is still being investigated. We attempt to design an experiment to determine it.

Mode Tracking in Feedback

We also do mode tracking in time domain. Using a signal to turn off/on the feedback system and to trigger the ADC at the same time, it is possible to capture transverse grow/damp transients.

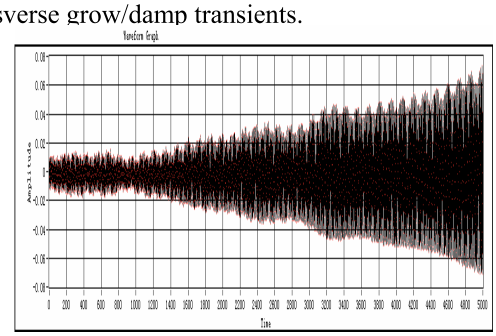


Figure 6: Evolution in time domain the oscillation amplitude was growing in positive feedback state.

Fig.6 shows the growth of the oscillation amplitude when the feedback system was turned to an exciting phase. The process of modes growing is tracked, shown in Fig.7. In 800MeV Optics-Normal state, the beam seems quite stable, and the growth rate of the unstable modes is almost zero. So, positive feedback is used to speed up the growth.

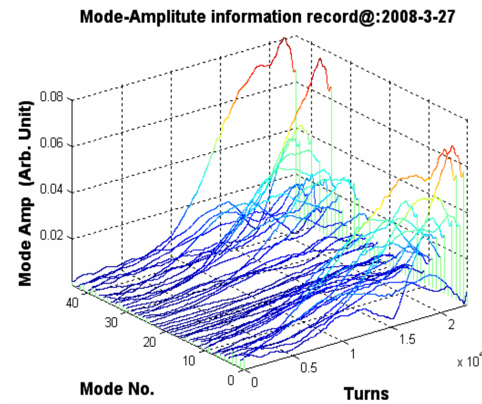


Figure 7: Mode tracking when the beam was excited by positive feedback.

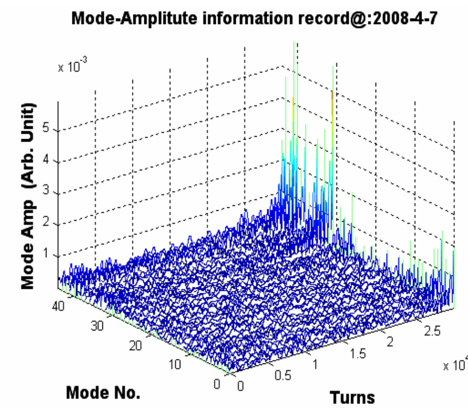


Figure.8: Mode tracking in time domain when the feedback turned off.

We also carried out another experiment: At first it was of negative feedback. All of the modes oscillated in very low level. After the feedback was turned off, modes grew rapidly. Fig.8 shows evolutions of modes.

SUMMARY

After the primary experiments, further investigations of the feedback system are needed to improve and consummate the performance. Diagnostic techniques based on the bunch-by-bunch time data are important tools to study beam dynamics and to confirm the performance of the feedback systems. The online bunch-by-bunch measurement system at HLS will help us to tune the feedback.

ACKNOWLEDGEMENTS

Authors would like to thank Dr. K.T Hsu of NSRRC and T. Nakamura of SPring8 for their beneficial discussions and great help, to professor T. Kasuga, Dr. M. Tobiyama and Dr. T. Obina of KEK for their assistance, and also to the operators of NSRL for skillfully running the machine in the experiments.

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