COMMISSIONING OF THE HLS ANALOG TFB SYSTEM*

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Abstract

As low injection energy and multi-turn injection at Hefei Light Source (HLS), the task of diagnosing and curing coupled-bunch instabilities becomes ever harder. The HLS analog transverse bunch-by-bunch feedback (TFB) system has been redeveloped to improve feedback effect, recently. In this paper, the new improved designs are described and new system's commissioning results are discussed. The transverse coupled bunch instability at 200MeV injection status is also experimentally studied.

INTRODUCION

HLS is a synchrotron light source injecting in the energy of 200MeV with 204.048MHz RF, and operating in 800MeV with 204.016MHz RF. The circumference of electron storage ring is 66 meters and the harmonic is 45. A multi-cycle multi-turn injection system is used for current accumulation. The multi-bunch instabilities are observed at injection and energy ramp by bunch-by-bunch measurement system. To improve the feedback effective and satisfy the requests of practice, the TFB prototype has been redeveloped. Also the debugging and process experiments are made.

TFB SYSTEM DESCRIPTION

The analog transverse bunch-by-bunch feedback system prototype of HLS is build at 2007 [1] [2]. To update TFB system performance for 200MeV injection status, the system is redeveloped since 2008. An advanced design has been made. The block diagram of the new system is shown at Figure 1.

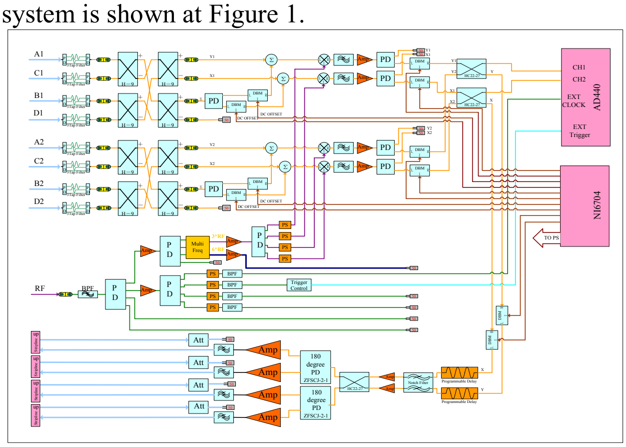

Figure 1: Overview of improved HLS analog TFB.

The main improvements of the redeveloped system include that:

- Front-end signal processing module reconstruction.
- Joined the DC component removed units before down-transducer module
- Added four high-frequency phase control modules to the $3 * f_{RF}$ signal to maximize the output amplitude
- Fully optimized the signal transmission line, effectively soluted the issue of signal reflection
- Added independent adjustable gain module for x and y feedback signal

EXPERIMENT RESULTS

Injection Transient Tune and Phase Space

Transient tune (Figure 2) and phase space (Figure 3) as well as Beta oscillation of turn-by-turn can obtain by TBT system at injecting beam current accumulation [3].

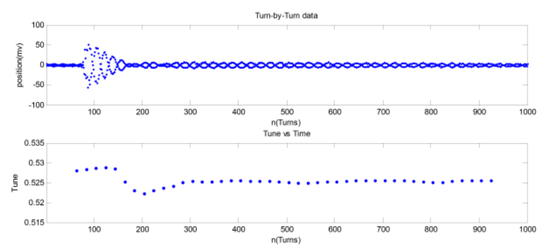

Figure 2: Turn by turn tracking of horizontal direction at 200MeV injection with octopole magnet on, low part show the transient tune.

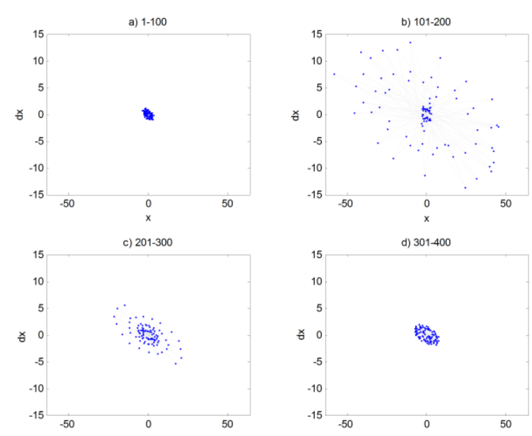

Figure 3: Phase space tracking of horizontal direction at 200MeV injection with octopole magnet on.

Figure 2 and Figure 3 shows that, at beam injecting, the tune x is near 1/2 resonance because of tune drift. The tune x of resonance is adverse to beam current accumulating.

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Damping Time Measurement

The important criterion for the feedback effect is damping time and modes tracking. During the commissioning, the damping time and modes tracking have been measured by Turn-by-Turn (TBT) and bunch-by-bunch (BXB) measurement system at beam injecting. In order to reduce DC-drift and other unvalued frequency components, the turn by turn data are all applied to high-pass filtering.

Figure 4 and Figure 5 show the turn-by-turn (TBT) position of beam in vertical direction at 200MeV injection status when feedback system is keeping off and on. To compute the damping time, the turn by turn data are applied to digital lock-in detection in order to obtain the signal envelope.

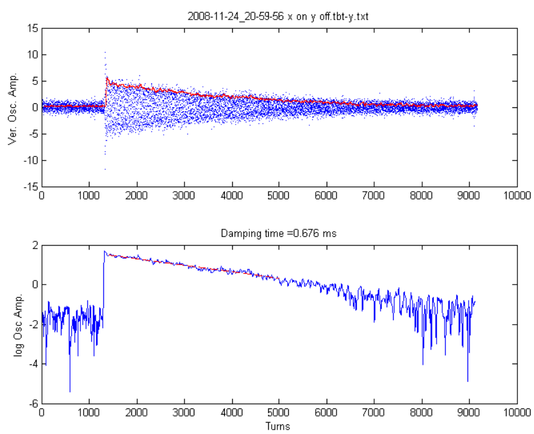

Figure 4: Turn by turn tracking of vertical direction at 200MeV injection status with feedback off. a) Turn by turn position, the red line is envelope. b) Logarithm arithmetic envelope of position, the red line is linear fitting for damping rate.

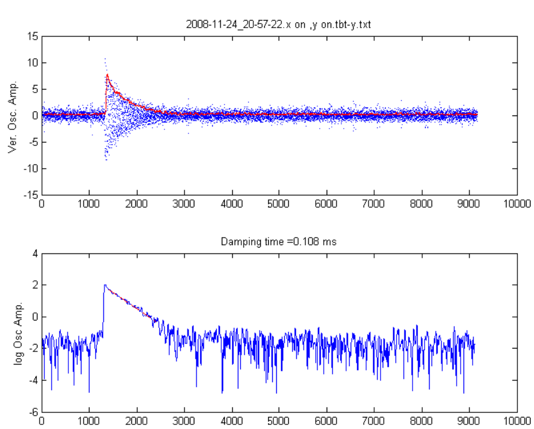

Figure 5: Turn by turn tracking of vertical direction at 200MeV injection status with feedback on. a) Turn by turn position, the red line is envelope. b) Logarithm arithmetic envelope of position, the red line is linear fitting.

At 200MeV injection status, the damping time is about 1ms with feedback system and Octupole magnets off. After turning on the feedback system, the damping time is reduce to about 0.1ms.

Time Domain and Modes Tracking

By the BXB measurement system, we can observe bunch vibration in transverse direction. If we adopt space reconstruction method [4] [5] [6] which based in Hilbert transform, we can track bunches' motion in phase space and modes, that would be more interesting and more helpful.

At injection status, an injection kicker sync signal is connected to BXB digitizer as a trigger signal, and then the damping progress after injection kicker kicking beam can be recorded in time domain. Figure 6 and Figure 7 show the 45 bunches turn-by-turn position of vertical direction at 200MeV injection status when feedback system is keeping off and on. We can observe that, after feedback on, the β residual vibration is cured.

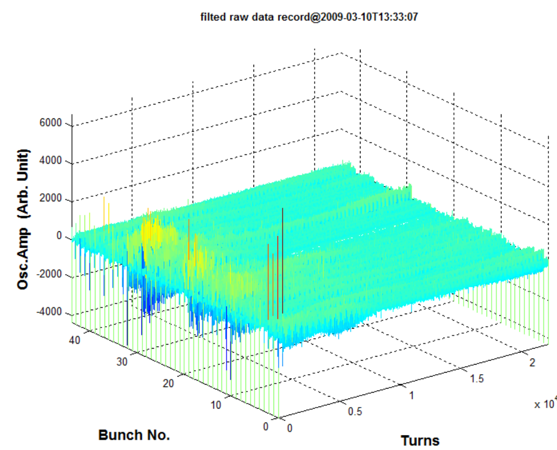

Figure 6: Bunch tracking with feedback off.

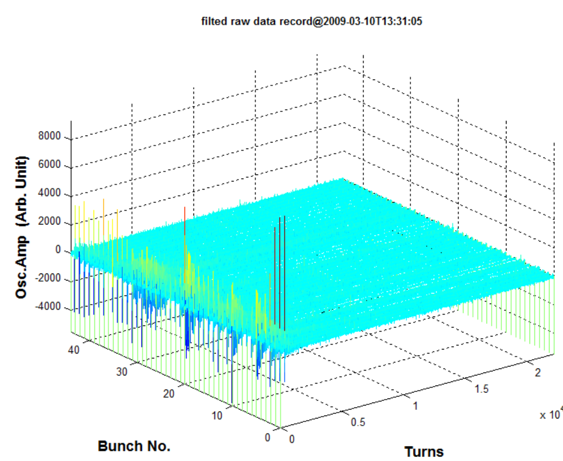

Figure 7: Bunch tracking with feedback on.

From the bunch tracking data, the mode tracking can get by Hilbert transform. Figure 8 and Figure 9 show the modes tracking map with feedback system keeping off and on.

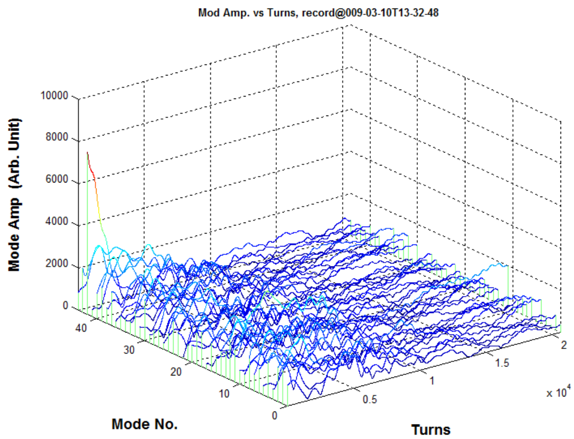

Figure 8: Mode tracking with feedback off.

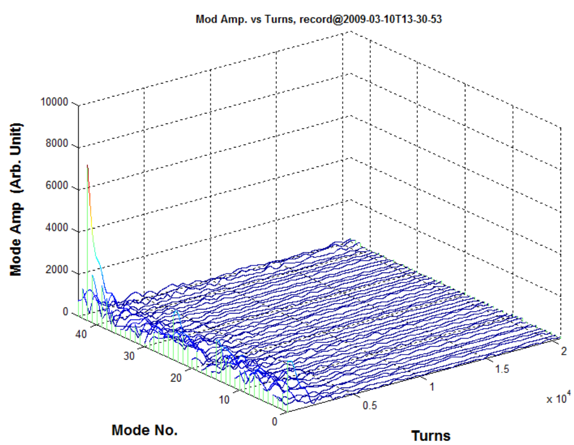

Figure 9: Mode tracking with feedback on.

Figure 8 and Figure 9 shows the presence of one mode of oscillation (modes-42) on vertical direction in the transient. When transverse coupled-bunch modes are driven by resonant impedances such as higher-order modes in the RF cavities, large synchrotron oscillations can have a strong damping effect with the analog TFB system on.

SUMMARY

The information obtained from the analysis of the time domain data reveals growth rates and damping rates of beam modes and is useful in checking or adjusting the feedback system. With digital lock-in detection techniques, the oscillation envelope of beam can get easily. The time domain techniques, in conjunction with off-line FFT analysis, are complementary to narrowband detection in the frequency domain, in that they allow the quantification of many unstable modes in a single non-destructive transient, and do not require repetitive narrowband steady state swept frequency domain measurements of each potentially unstable mode.

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