TRANSVERSE FEEDBACK SYSTEM AND INSTABILITY ANALYSIS AT HLS

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Abstract

In this paper, the BxB transverse feedback systems at Hefei Light Source (HLS) are introduced, which employ an analog system and a digital system. The experiment result of two systems. as well as the primary analysis of beam instability in HLS operation is also presented in this paper.

INTRODUCTION

HLS is a synchrotron light source, injecting in the energy of 200MeV and operating in the 800MeV. The multi-cycle multi-turn injection system is used for current accumulation. The range of horizontal tune of HLS is from 3.54 to 3.56, and the range of vertical tune is from 2.58 to 2.60 for user operation.

The injecting beam current usually cannot exceed 120mA without octupole magnet, and the injecting accumulating beam current is about 250mA with octupole magnet because the beam often occur sudden lose due to CB instabilities in storage ring to limit injection further increase. Therefore the constructing beam feedback system began from 2006 year. The analog feedback system has been built and commissioned at 2007[1-3], At the same time, the development of digital transverse BxB feedback system began at 2007 and has commissioned since 2008[4].

THE ANALOG TFB SYSTEM AND EXPERIMENT RESULTS

The diagram of analog TFB system is shown as Figure 1. The analog feedback system is made up of: 3-tap filter at centre frequency 612MHz (3*f_{RF}) , hybrid for obtaining beam position oscillation signal, vector algorithm for two BPMs to obtain feedback signal of independent adjustable gain, multiple frequency circuit for centre frequency 612MHz (3*f_{RF}) and 1.2GHz (6*f_{RF}), PXI digitizer for data acquisition modular, the fiber correlator filter for eliminate DC and revolution frequencies, the power amplifier and kicker for exciting beam current.

Commissioning Results of Analog TFB at HLS

During the commissioning, the damping time and betatron sidebands have been measured by Turn-by-Turn (TBT) [5].and bunch-by-bunch (BXB) [6]. measurement system at beam injecting is shown as Figure 1.

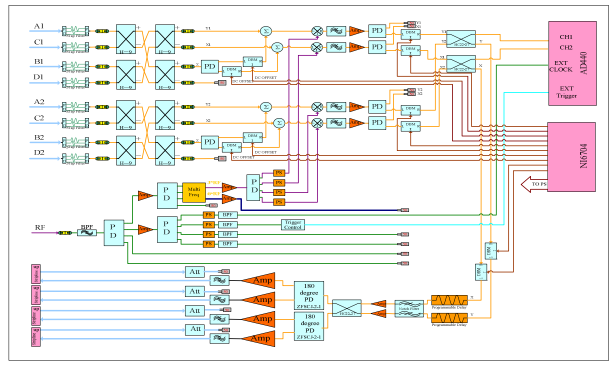
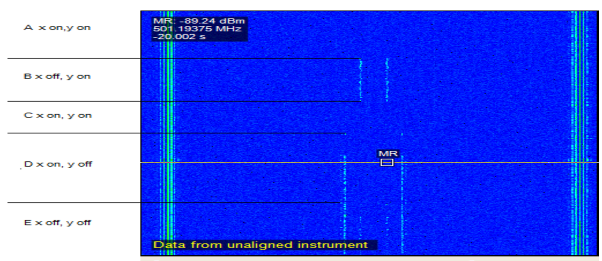
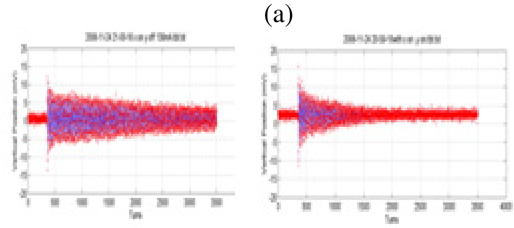


Figure 1: Overview of HLS analog TFB after update.



(a)



Analog TFB off Analog TFB on

(b)

Figure 2: Feedback effect with analog TFB system of HLS.

From Figure 2 (a) and (b) respectively, we could see, The betatron sidebands were suppressed entirely by the analog TFB , And the damping time could be decreased about a order, which is 0.16ms while the analog TFB on. and it is 1.22ms while it off. The beam current could be stored up to 250mA, comparing to the current with the octupole magnet.

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THE TRANSVERSE DIGITAL FEEDBACK SYSTEM

Due to small storage ring, HLS is difficult to choose two BPMs with 90° phase difference. There is a complex injecting process [7]. Therefore a digital TFB is constructed for commissioning to obtain higher beam current. The scheme of HLS digital TFB is in Fig. 3.

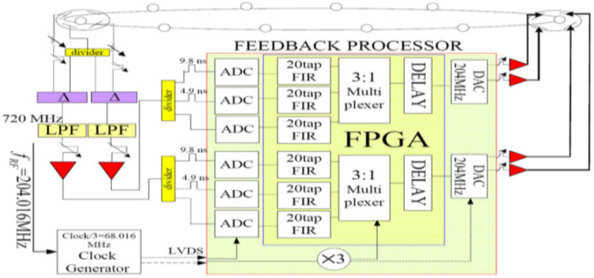


Figure 3: Overview of the HLS digital transverse Bunch-by-Bunch feedback system.

The system consists of a beam position monitor (BPM), a RF direct sampling front-end, a feedback processor, a clock generator, power amplifiers and a kicker. We employ the SPring-8 FPGA based feedback processor and modified it at NSRL to process horizontal and vertical oscillation signals, independently and simultaneously by one single processor. The processor operates with 1/3 RF frequency LVDS signal, which is produced by a clock generator offered by NSRRC Taiwan. RF direct sampling front-end makes the system simple and easy to adjust. Because ν_x and ν_y of HLS are close to each other, single-loop two-dimensional feedback scheme [8] is hard to be implemented, so a digital TFB is constructed at 2007. The horizontal and vertical beam oscillations are processed separately in the front-end and also in the feedback processor.

Commissioning Results of Digital TFB at HLS

The digital TFB system was commissioning primarily in June 2008 at 800MeV and operation with beam current 210mA. Fig.4 is the experiment when decreasing sextuple magnet current, and the horizontal betatron sidebands were observed and suppressed by the feedback system at the DAC output with a gate of 10Hz, shown as above curve in fig.4 .

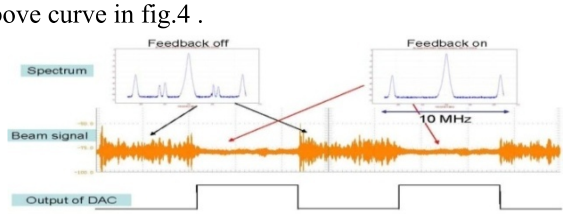
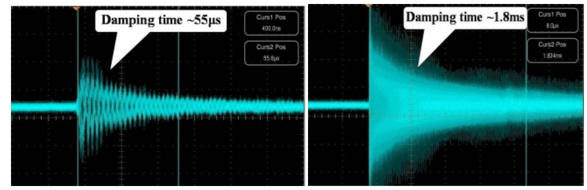


Figure 4: The horizontal betatron sidebands of beam in June 2008.

The digital transverse feedback was commissioning in 200MeV injection in April 2009. The damping time due to injection bump excitation could be decreased about two order by the digital TFB. The damping time is about 55us while digital TFB on, and without feedback and with octupole magnet, the damping time was about 1.8ms as shown in Fig. 5 (a) and (b).



(a) (b)

Figure 5: The damping time due to injection bump excitation was decreased by feedback system.

The digital transverse feedback system could improve injection to store more beam current. Without octupole magnet and feedback system, the beam became unstable and beam loss happened when beam current was over 70mA, With octupole magnet on only, the beam current could be stored up to about 250mA at that time And with feedback on only, the beam current could be stored up to 300~320mA. The 358mA peak current was stored when the feedback and octupole magnet were both turned on as shown in Fig.6.

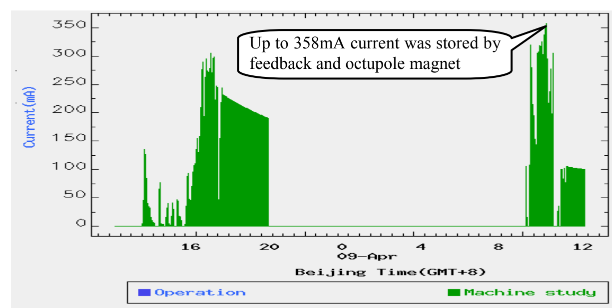


Figure 6: Injection current accumulated curve with Feedback system.

THE INSTABILITY ANALYSIS AT OPERATION

The big instability oscillations were observed without the feedback gate signal as shown in Figure 4. And the increase time of instability shown in Figure 7 is about 0.258ms.

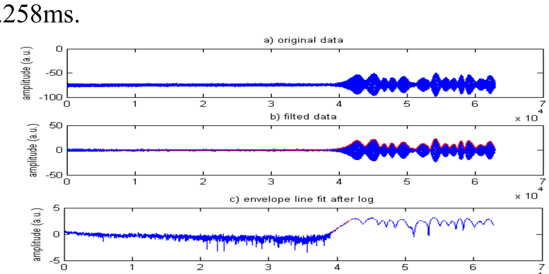


Figure 7: Instability increase process.

Phase space (Figure 8) and transient tune (Figure 9) as well as beta oscillation of turn-by-turn can be obtained by TBT systems. In Figure 8 (a-f), including one progress that the oscillation amplitude drop and increase again, when tune changed about 0.002 (Fig.10). The transient tune goes through the 5/9 resonance line many times.

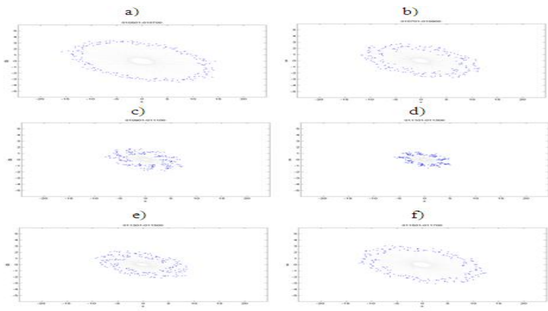


Figure 8: A group phase space following tune change.

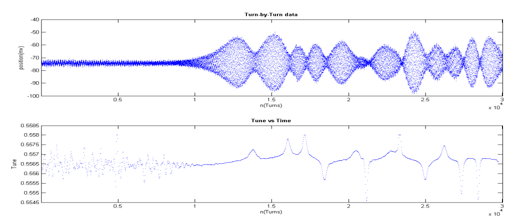


Figure 9: Transient tune on instability increase.

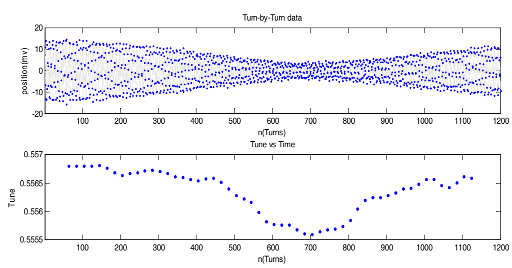


Figure 10: Transient tune corresponding a group phase space.

A simulation was carried out using Matlab to illustrate the physical meaning, and the result is shown on Fig.11. When ν changed from 5/9+0.001 to 5/9-0.001, the arm lines on phase space have changed its' direction. So, Fig.4 means that the tune have went through the 5/9 beam resonance line.

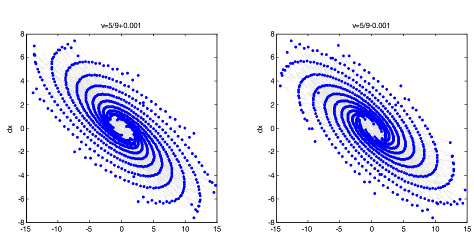


Figure 11: Tune simulation on resonance line.

SUMMARY

The BxB transverse feedback systems of both the analog and the digital system are constructed and commissioned successfully at HLS. Both analog and digital systems decrease damping time and suppress instability modes and improvement for accumulating current during injection. The digital system is easier for tuning and better for beam current accumulating. In HLS operation, the transient tune go through to 5/9 resonance line many times.

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