LONGITUDINAL FEEDBACK SYSTEM FOR PLS STORAGE RING*

H. S. Kang, W. H. Hwang, H. J. Park, D. T. Kim, J.Y. Huang, and S. H. Nam
Pohang Accelerator Laboratory, Pohang, 790-784, Kyungbuk, Korea

Abstract

The Pohang Light Source (PLS) storage ring uses a longitudinal feedback system (LFS), which is a bunch-by-bunch feedback system, to cure the longitudinal coupled bunch instabilities due to higher order modes of RF cavities. The LFS employs the digital electronics and the DSP filter algorithm, and uses a cavity-type kicker. We carry out the experiment on the basic performances of the LFS such as the effects of the RF gap voltage variation and the RF phase shift, and the timing, etc. This paper will describe the basic performance analysis as well as the test results of curing the instabilities due to the HOMs.

1 INTRODUCTION

In a third generation light source the strong coupled bunch instability is a big concern, which limits beam current and degrades photon beam quality by amplifying beam oscillation or by blowing up beam emittance.

The design beam currents of the PLS storage ring are 400mA and 250mA at 2GeV and 2.5GeV, respectively. Even though the stored beam current was higher than the design value at 2GeV, a big longitudinal instability begins to appear at the current higher than 200mA at 2.0GeV, above that a peanut-shaped beam is borne, which is apparently useless for beam line users.

To minimize the beam coupling impedance in RF cavities for higher current operation, the HOM tuning method is exploited intensively, which includes the fine adjustment of cavity temperature and an insertion of HOM tuning plunger into RF cavity [1]. RF Cavity HOM tuning and chromaticity can reduce the instabilities to some extent, but not enough because there are still residual impedances in a ring not to be removed so that an active bunch-by-bunch feedback system is required to perfectly remove the instabilities.

In order to cure the coupled bunch instabilities in longitudinal direction, a longitudinal feedback system was installed and successfully commissioned in 1999. The longitudinal feedback system, originally developed for the PEP-II, DAΦNE and ALS machines, shares common architectures [2]. However, since then, we have encountered a few problems in operation of the LFS: especially, the lack of repeatability and reliability. The bottom lines the LFS functions well are: to accurately measure the phase oscillation amplitude of all bunches and to calculate the appropriate correction value, and the correction kick to the exact bunch. The main causes that deteriorate the good operation turned out to be the external fiducial problem and the RF cavity gap voltage variation, especially during beam injection.

The external fiducial from the timing system to the LFS timing module helps the LFS to recognize the first bunch in a bunch train. Recently the timing system was added an ECL fan out module, which can provide the external fiducial signal to the LFS timing module. It enables the LFS to be exactly timed to the right bunch position.

In this paper, we will describe the basic performance analysis as well as the test results of curing the instabilities due to the HOMs.

2 PERFORMANCE TEST

Figure 1 depicts the block diagram of the longitudinal feedback system. To damp the longitudinal bunch oscillation, the longitudinal feedback system measures the energy of particle bunches and computes a correction signal from the energy errors, and corrects the energy of the particles. The LFS uses a digital signal processing formalism to compute correction signals. Signals from four button-type pickups are combined and fed to stripline comb generator. The generator produces a four-cycle burst at the sixth harmonic of the ring RF frequency (3 GHz). The resultant signal is phase detected, then digitized at the bunch-crossing rate. A correction signal for each bunch is computed by a digital processing module and applied to the beam through a fast D/A, an output modulator, a power amplifier and a kicker structure.
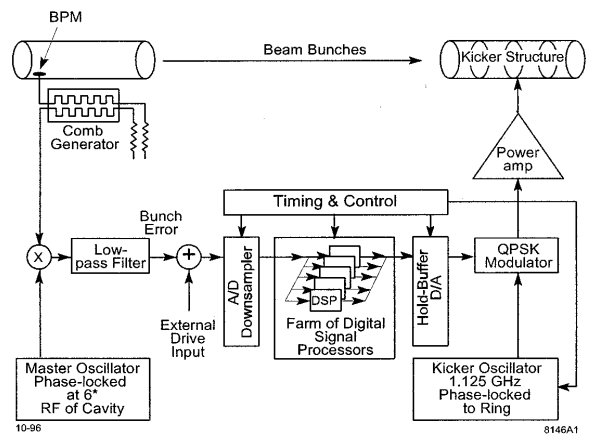

Figure 1: Block diagram of the longitudinal feedback system.

Table 1 lists the machine parameters of the LFS. The sampling frequency of the FIR (Finite Impulse Response) filter is f_0 / n, where f_0 is the revolution frequency of the bunch and n is the downsampling factor. The number of taps means the sampling number per one synchrotron oscillation period. A computing of new correct kicking

value of phase error is done after turns of the downsampling factor times the number of taps.

Table 1: Machine parameters of the LFS

Energy, GeV	2.0
Bunches	468
Sampling Frequency, MHz	500.063
Revolution Frequency, MHz	1.0685
Synchrotron Frequency, kHz	11.4
Down-sampling factor	15
Tap Number	12
Sampling Rate, kHz	71
Numbers of DSPs	60
Kicker type	Cavity
Number of kickers	1
Kicker frequency	9/4 RF
Amp Power	250 W

Table 2 lists the operating range of the control parameters for the LFS to suppress the instabilities, which are obtained with the beam current of 135mA at 2GeV. The front-end that measures the energy of each bunch has a limit of reference position drift about 29 degree. This result is same to specification: The full operating range of the front-end is only 30 degree at 500 MHz, 166ps. The back-end delay which times the kick to the exact bunch has a very small stable range, which means a very precise back-end timing is absolutely necessary. The back-end timing span of 115 ps corresponds to one eighth of 1125 MHz kicker frequency. On the other hand, the filter and the down sampler that compute a correction signal have a large operation range.

Table 2: Setting parameters for the LFS to damp the instabilities.

Module	Setting parameter	Operating range for damping	Span
Filter	Phase	0 ~ 75 degree	75
	Shift gain	3 ~ 4	
Down Sampler	Synchrotron frequency	10.5 ~ 12.3 kHz	1.8 kHz
Front-end	Phase shift	-11 ~ 18	29
Delay	Back-end	1597 ~ 1712 ps	115 ps
	Front-end	5273 ~ 6248 ps	975 ps

Figure 2 shows the measurement result of backend timing. In the test the front-end delay was set to 5560 ps, and phase error signal in front-end module was measured with SRS780 spectrum analyser. The amplitude response has about 440 ps periodicity, a half the kicker frequency. The optimum backend timing was found to be around 4275 ps. The operation range of backend delay in Table 2 is one of many lobes below the peak around 4275 ps.
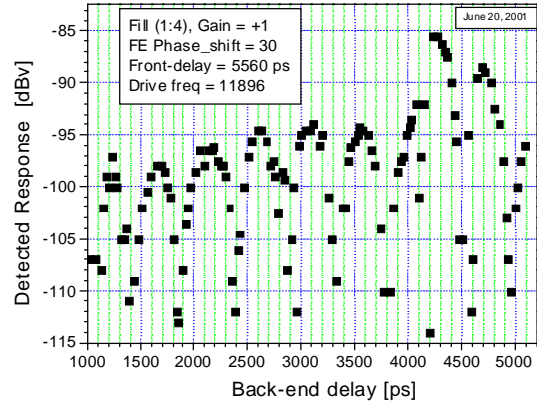

Figure 2: Amplitude of phase error monitor in front-end module as a function of backend delay.

The beam test of curing the instabilities due to the HOMs was carried out. Figure 3 shows the x-ray beam images measured at the diagnostic beam line when LFS is OFF (a) and ON (b). The beam currents are 250 mA and 260mA, respectively. In (a), 758 MHz coupled bunch instability is induced by the TM011 higher order mode in RF cavity. The instability can be completely suppressed after LFS turned ON even up to 260 mA. The image sizes in (a) and (b) represent the real size, which means a great reduction of energy spread and bunch length.
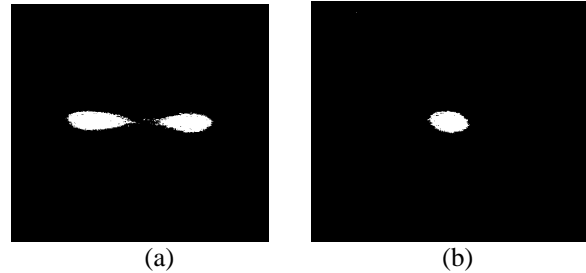

(a)   (b)

Figure 3: x-ray beam images measured at the diagnostic beam line when LFS is OFF (a) and ON (b). The beam currents are 250 mA and 260mA, respectively.

So far, it is not clearly understood why the LFS cannot suppress the instabilities at beam current higher than 260 mA. But, two causes are suspected: one is cavity gap voltage variation and the other is a high beam-coupling impedance of RF cavity HOM.

The large variation of RF cavity gap voltage occurs during the beam injection as shown in Figure 4. The variation of cavity gap voltage is due to the low speed of cavity voltage feedback loop of the low-level RF feedback system: less than 1 Hz. The synchrotron frequency varies with an amount of about 100 Hz as the RF gap voltage changes during the beam injection. This causes the longitudinal position of the synchronous particle to move around, which disturbs the accurate measurement of the phase oscillation amplitude. The

motion of a significant amount of reference position will cause a loss of feedback control.

The low-level RF feedback system is now in upgrade, which incorporates the amplitude and phase feedback loops for klystron and RF cavity, each. [3] The upgrade will be completed by the end of 2001. The upgrade system is expected to guarantee the constant gap voltage control even during beam injection.
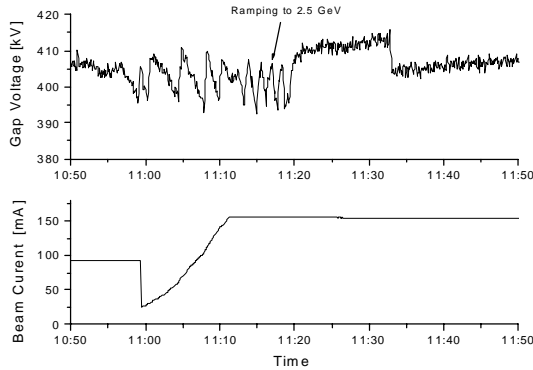

Figure 4: Gap voltage variation during beam injection.

3 BEAM DIAGNOSTIC

The LFS provides detailed information on longitudinal characteristics of filled bunches; synchronous phase of each bunch and bunch current, and instability growth rate. It also can measure the synchrotron frequency very precisely, which helps to calibrate the RF voltage of four RF cavities.

Figure 5 shows an interesting example of coupled bunch instability, which is recorded by the LFS diagnostic tool. The data show a strong 15 MHz oscillation which appears when a very strong longitudinal instability is induced under the poor vacuum condition. The 15 MHz oscillation induces the current variation in a 400 bunch train at the same frequency as shown in top figure.

4 SUMMARY

The operating ranges of the control parameters for the LFS to suppress the instabilities were searched for by the performance verification test of each module of the LFS. The longitudinal instability can be completely suppressed with the LFS up to 260 mA at 2 GeV. Further study is underway on the suspected reasons make the LFS fail to suppress the instability over 260 mA. Moreover the new low-level RF feedback system is expected to ensure the longitudinal motion stability.
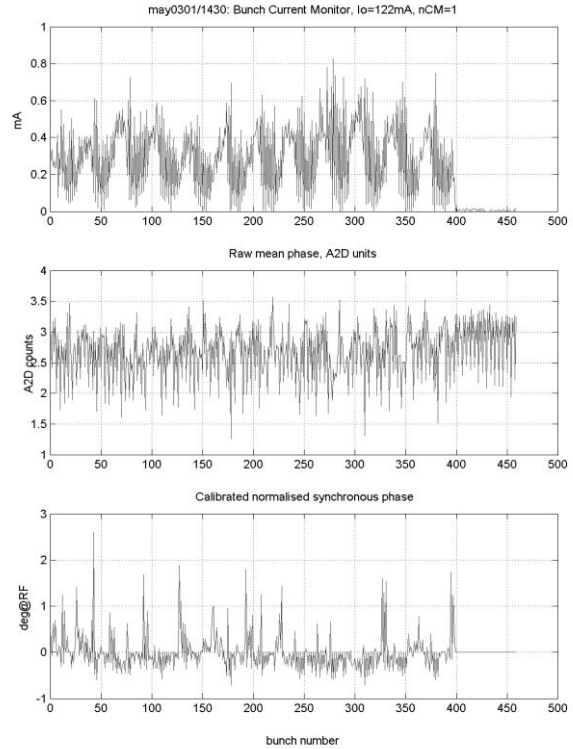

Figure 5: Top figure: The current variation in a 400-bunch beam. Medium figure: The A/D counts at down-sampler module. Bottom figure: The synchronous phase.

5 ACKNOWLEDGEMENTS

6 REFERENCES

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