SUPPRESSION OF LONGITUDINAL INSTABILITIES BY LFS IN PLS STORAGE RING*

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Abstract

The Pohang Light Source (PLS) storage ring uses a longitudinal feedback system (LFS) that is a bunch-by-bunch feedback system employing the digital electronics and the DSP filter algorithm to cure the longitudinal coupled bunch instabilities due to higher order modes of RF cavities. The LFS could suppress all longitudinal instabilities in stored beam up to 320 mA at 2 GeV. The performance of the LFS was very reliable and repeatable. Above 320 mA, transverse instabilities became severe including ion instability, and the impedances of longitudinal HOMs became so high that the LFS could not damp them. This paper describes the test results of suppressing the longitudinal instabilities as well as the control settings for the best performance of the LFS.

1 INTRODUCTION

In the third generation light source the beam instabilities are big concerns because they deteriorate electron beam quality so that photon beam has low intensity and fast fluctuations in energy and position. Among them longitudinal coupled bunch instability is the most severe problem in a storage ring with the beam energy below around 3.5GeV and the beam current above 200mA. Longitudinal instability comes from the interaction of multi-bunch electron beam with higher order modes of RF cavities.

The PLS was designed to have the beam energy of 2 GeV and the beam current of 400mA. From the beginning of 2001, the operating beam energy was changed to 2.5GeV, which was done by energy ramping. For 2.5GeV operation the operation beam current is around 200mA. The PLS was built in the beginning of third generation light source projects. At that time the RF cavities were for the 2nd generation light source. Now the PLS had a big difficulty to cure the longitudinal instability above 200mA at 2GeV. Therefore, the PLS adopted the longitudinal feedback system (LFS) developed in SLAC and used in PEPII, ALS, DAFNE, and BESSYII [1]. After the completion of installation of LFS in 1999, the performance optimisation tests had been carried out [2,3,4], and finally the LFS was proved to suppress all longitudinal instabilities in stored beam up to 320mA at 2GeV. From the several tests, the performance of LFS was confirmed to be very reliable and perfect.

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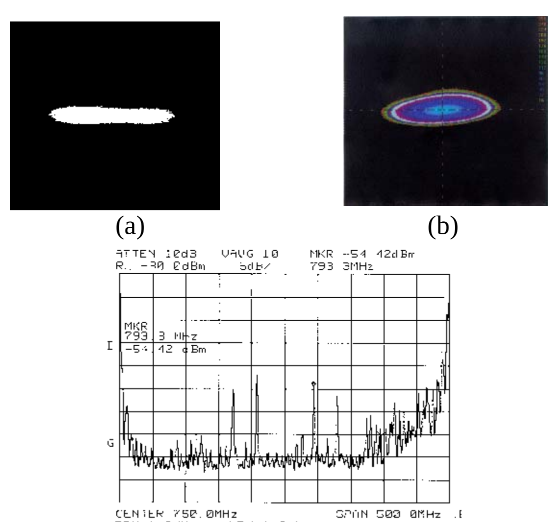
2 SUPPRESION OF INSTABILITY

2.1 Longitudinal Instabilities

The PLS RF system consists of four RF cavities and four 60 kW klystrons. And a very accurate temperature control system can set the inlet cooling water temperatures for each cavity in the range of 35 to 60 degree Celsius and maintain the temperature within ± 0.05 Celsius degree. The PLS storage ring RF cavities have many higher order modes with large shunt impedance. The dominant modes are TM011 (758 MHz), TM020 (1300 MHz), TM213 (1670 MHz), and TM013 (1707 MHz). The amplitudes of these higher order modes can be suppressed to some level with the beam current up to 200mA at 2GeV by changing the cavity temperature of each cavity [5]. However, above 200mA it is impossible to suppress instabilities.

Figure 1 shows the X-ray beam images measured at the diagnostic beam line and the BPM pickup spectrum when the longitudinal coupled bunch instabilities were severe. Fig. 1(a) and (b) are the measured photon beam shape at the same beam current of 300mA, but the beam shape are quite different, which is due to the dependence of the HOM on frequency tuner position and beam loading of each cavity. Fig. 1(a) is when TM011 is dominant; (b) when TM020 and TM213 are dominant. The BPM spectrum in case (b) is shown in (c).



(a) (b) (c)

Figure 1: X-ray beam shapes and spectrum when a big longitudinal instability exists.

2.2 Suppression of Longitudinal Instabilities by LFS

Table 1 shows the major 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.

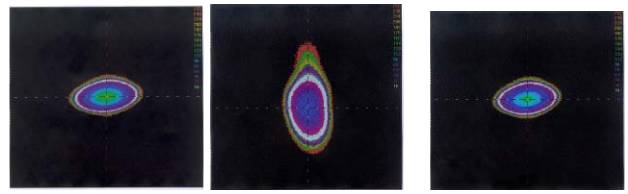
Table 1: Major parameters of the LFS [6]

Energy, GeV	2.0
Bunches	468
Sampling Frequency, MHz	500.076
Revolution Frequency, MHz	1.0685
Synchrotron Frequency, kHz	11.7
Down-sampling factor	15
Tap Number	6
Kicker type	Cavity
Number of kickers	1
Kicker frequency	9/4 RF
Amp Power	250 W

After the optimisation tests, we could find the optimum settings of FIR filter parameters (filter phase, shit gain, down sampling factor, and tap number) and analog (front and backend delays) and digital signal delays (hold-buffer offset). Even though the LFS employs the digital electronics and the DSP filter algorithm, the analog signal delays are necessary for fine adjustment of BPM pickup and kick signal with respect to the reference RF signal.

When the beam was injected with LFS turned ON, the LFS could suppress all longitudinal instabilities in stored beam up to 320mA. Figure 2 shows the X-ray beam shapes at 2GeV / 300mA when the LFS is working. When the LFS suppresses all longitudinal instabilities, the photon beam shape is shown in (a). Compared to Fig. 1(b), a very high quality beam was stored by LFS. After about 5 minutes, the beam shape changed to (b), blew up vertically and finally the beam current dropped to 275mA as shown in Figure 3. By adjusting the sextupole current (SD) from 138A to 140A the beam shape changed to (c).

There might be an ion instability that was due to vacuum degradation in storage ring chambers. In Fig 3, vacuum pressure in RF cavity is also shown. The position of vacuum degradation is not clearly known yet. It is expected the position to be at the high longitudinal broad-band impedance components such as bellows and RF cavities or at the vacuum chambers irradiated by mis-guided photon beam. Anyway this vertical instability could be cured by chromaticity.



(a) 300mA, SD=138A, SF=92A; (b) 275mA, SD=138A, SF=92A; (c) 275mA, SD=140A, SF=92A

Figure 2: X-ray beam shapes when the LFS is working.

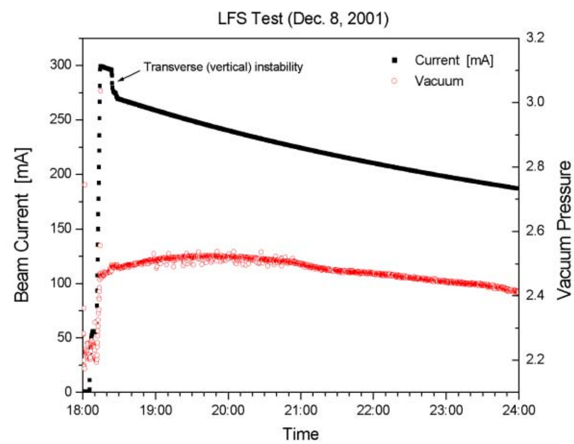
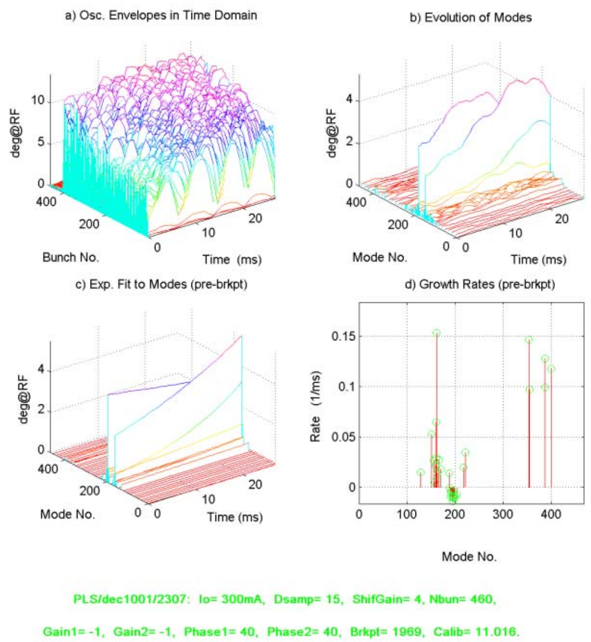


Figure 3: Beam current and vacuum trend when the LFS is working.

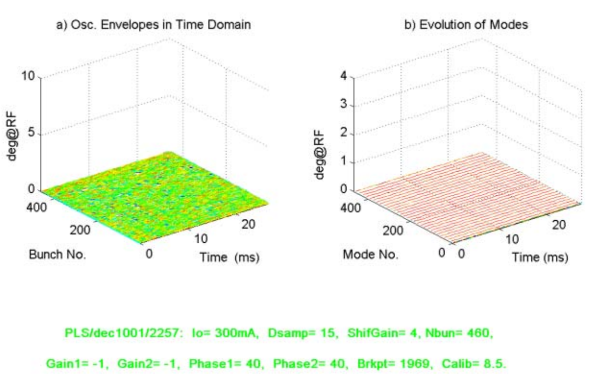
2.3 Data Analysis

Figure 4 shows the oscillation envelop in time domain and evolution of modes in time obtained by LFS diagnosis tool. Fig. 4(a) is when the longitudinal instabilities existed and (b) is when disappeared. In Fig. 4(a) a very large synchrotron oscillation of up to 10 degree in 500 MHz RF is observed in all bunches, which means a strong coupled bunch instability. In the measurement of Fig. 4(a) the LFS diagnostic module, Grow/Damp routine, is used; both Gain2 for "Grow" and Gain1 for "Damp" are set to –1. Even the instability approaching the saturation, the measured instability growth rate was about 0.15 /ms which is balanced with the damping rates of feedback system and radiation damping. At 2 GeV the radiation damping rate is about –0.125/ms. When the LFS was turned ON at 300mA, the LFS could not suppress the instabilities.

Fig. 4(b) shows the oscillation envelop and evolution of modes when the beam instabilities were perfectly suppressed by the LFS. The oscillation amplitudes of all bunches are almost noise level, and no coupled bunch instability is not shown.



(a)



(b)

Figure 4: Data analysis by LFS diagnosis tool. (a) is when the longitudinal instabilities exist and (b) is when disappeared at 2GeV 300mA.

3 SUMMARY

The PLS LFS was successfully commissioned in 2001 after the completion of installation at the end of 1999. Since the installation, the performance optimisation tests had been carried out and some changes and improvements were motivated and added in other system especially timing system and low-level RF feedback system. Therefore, the LFS could suppress all longitudinal instabilities in stored beam up to 320 mA at 2 GeV. The performance of the LFS was very reliable and repeatable. Conclusively now the PLS has an ability to control the longitudinal instabilities arise when the high current beam more than 200mA is stored.

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