TRANSVERSE FEEDBACK SYSTEMS FOR PLS STORAGE RING*

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Abstract

In order to cure the transverse coupled bunch instabilities in PLS storage ring, a TFS system, a 250MHz bandwidth and bunch-by-bunch feedback system, was designed and tested. The TFS is now in upgrade to use one kicker per transverse plane to improve efficiency over the previous system with a kicker combining both planes in a single structure. This paper will describe system parameters, specifications of key system components, test results, and current status.

1 INTRODUCTION

Pohang Light Source(PLS) is a 2 GeV electron synchrotron light source dedicated to the beamline users since 1995. PLS storage ring has 12-fold symmetric TBA lattice with the operating tunes of ν_x = 14.28 and ν_y = 8.18. During the low current operation below 180mA, typical beam instabilities were the longitudinal coupled-bunch-instability(CBI) induced by the higher order modes(HOM) of rf cavity[1]. These longitudinal CBIs are suppressed by a longitudinal feedback system(LFS) developed by SLAC[2] and installed and commissioned in PLS[3]. As the beam current increases over 240mA by suppressing the longitudinal instabilities with LFS, transverse CBIs are amplified by 833MHz (TM110, horizontal) and 1073MHz (TM111, vertical) transverse HOM modes[4]. To suppress these transverse CBIs, a transverse feedback system(TFS) has been developed. It operates as a bunch by bunch feedback system in time domain[5, 6] with the frequency domain bandwidth of 250 MHz. The beam study has shown 30 dB damping of the beam oscillation of stored beam. In this paper, we describe the design and test result of the transverse feedback system.

2 FEEDBACK SYSTEM

The idea of the TFS is based on the feedback system developed in NSLS[5] and ALS[6]. The PLS transverse feedback system consists of pickup electrodes, signal processing electronics, power amplifiers, and a stripline kicker. Fig. 1 shows an overview of the transverse feedback system.

Two orbit BPMs located at the dispersion-free region are selected as the pickup electrodes. High frequency capacitance of a pickup electrode is 2 pF without any resonant structure up to 12 GHz [7].

Beam signals of BPM1 and BPM2 are detected at the third harmonic(1.5 GHz) of 500MHz rf frequency where the pickup signal is the largest(-10 dBm at 100 mA). DC component of the bunched beam signal appears as the revolution harmonics of the beam spectrum, and can be suppressed by two correlator notch filters[5] made by two coaxial delay-lines which differ in delay time by the ring revolution period T. The output signal $q(t) = \alpha q_0(t) - \beta q_0(t-T)$ is the difference of two input signals with delay-line attenuations α and β. Since the notch depth is sensitive to the mismatch of the delays and attenuations of two delay-lines, they are precisely adjusted by a variable delay-line and a variable attenuator to obtain the best notch depth. The sensitivity of notch filter against the delay error δT and the mismatch of attenuations α and β can be estimated from the frequency spectrum of the filter output $q(\omega) \propto [\alpha^2+\beta^2-2\alpha\beta\cos(\omega T+\omega\delta T)]^{1/2}$. By defining the notch frequency shift $\delta f = \omega\delta T/2\pi T = f_{rev}\delta T/T$ and the notch depth $R = q_{max}/q_{min} = (\alpha+\beta)/(\alpha-\beta)$, the notch depth is better than -46dB when β/α is adjusted within 1%.

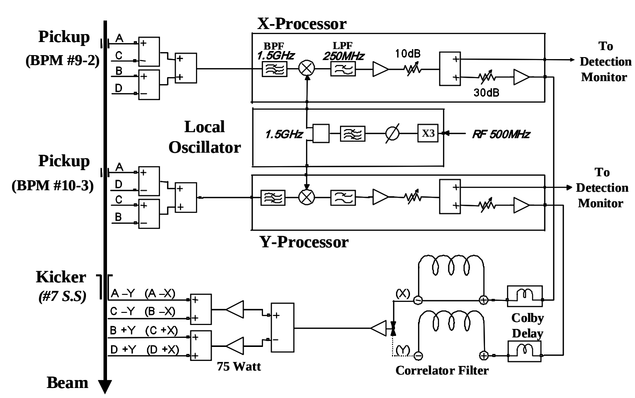

Figure 1: A layout of the transverse feedback system

Phase change by a notch filter should also be considered in tuning the $\pi/2$ relation between pickup and kicker of the feedback system. In this case, the phase change by a notch filter can be written as $\Delta\phi = \tan^{-1}[\beta\sin(2\pi\nu)/(\alpha-\beta\cos(2\pi\nu))]$. In practice, we can set $\alpha = \beta = 1$, and then the phase shift by the notch filter is $\Delta\phi = \tan^{-1}[\cot(2\pi\nu)] = \pi/2 - \pi\nu$. For the PLS system with ν_x = 14.28 and ν_y = 8.18, $\Delta\phi_x = 0.22\pi$, $\Delta\phi_y = 0.32\pi$.

Also, phase difference between pickup and kicker is $\phi = 2\pi[\nu_{ring} - (\nu_{pick\text{-}up} - \nu_{kicker})] - \Delta\phi_{filter}$. From Table 1, the phase difference in transverse feedback system is 74.2 degrees for horizontal and 91.1 degrees for vertical respectively.

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Table 1. Beam parameters of pick-up and kicker

Position	β_x	β_y	ν_x	ν_y
#9-2 for X	11.084	6.711	9.67	5.57
#10-3 for Y	2.672	19.670	10.81	6.28
#7 for Kicker	10.404	5.009	7.11	4.02

Beam induced transverse kick voltage $V_\perp$ by the transverse impedance $Z_\perp$ is given by $V_\perp = I_0 \delta q\, Z_\perp$ where δq is amplitude of the transverse oscillation and I_0 is the beam current. The required power of the kicker should provide more power than the beam induced power $P_b = V_\perp^2/2R_k$ where R_k is the kicker shunt impedance. For the PLS, the transverse HOM impedance $Z_\perp$ of the cavity is about 10 MΩ and the shunt impedance R_k of the transverse feedback kicker is 6.5 kΩ at 250 MHz. When I_0 = 100 mA and δq = 1 mm, $V_\perp$ = 1 kV and P_b = 77 watt respectively and we need minimum 310 watt power amplifier when the beam current reaches 400 mA. Two 75 watts, 50 dB gain power amplifiers are used for the PLS transverse feedback system. The 3 dB bandwidth of the amplifier is 10 kHz to 250 MHz.

Finally, a four-stripline type kicker is used for both horizontal and vertical. Striplines are 17mm wide and 300mm ($\lambda/4$ of 250 MHz) long, and are carefully assembled to make 50 Ω stripline impedance. The transverse kicker shunt impedance R_k is given by $R_k T^2 = 2Z_L(2gv/h\omega)^2 \sin^2(\omega l/v)$, where Z_L is the line impedance (50 Ω) of the stripline, g is the stripline coverage factor, v is the beam velocity, l is the length of striplines, and h is the distance between striplines. For PLS kicker, it is 6.5 kΩ at 250 MHz cutoff frequency.

3 RESULTS

Before turning on the feedback system, all the system components are tuned up with beam signal. The overall delays are adjusted within several ten picoseconds with individual line length adjusters and the phase of the local oscillator is adjusted to get the maximum signal detection. The depth of harmonic rejection of the beam signal is adjusted to have better than 25 dB rejection in all harmonics from DC to 250 MHz.

Since the spontaneous transverse beam instability is hardly observed in the PLS at low current operation, we used two different method to give rise to instability. First, the beam at low current of 150 mA is driven at the betatron resonance frequency using the stripline kickers of the tune measurement system to simulate transverse CBIs. Secondly, we make the ion instability by using longitudinal feedback system at high current of 180 mA. Beam test was performed in horizontal and vertical processor of TFS respectively. In measurement of feedback system by forced beam, the beam spectrum show about 20 dB suppression of betatron sidebands for horizontal direction and 25 dB for vertical direction as shown in Fig. 2. In ion instability, suppression of betatron sidebands was more than 30 dB for horizontal and vertical directions. When feedback system is turned on, the betatron sidebands by instability disappeared as shown in Fig. 3. And Fig. 4 shows a big change of the beam shape by vertical damping.

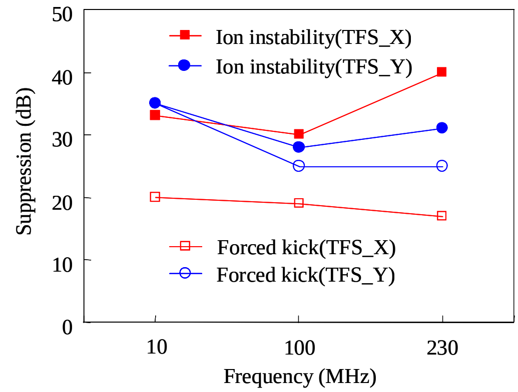
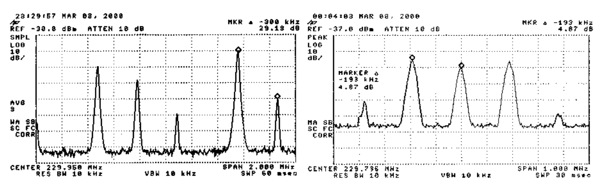
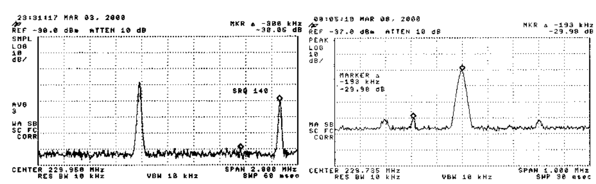


Figure 2: Suppression of betatron sidebands plotted for feedback on

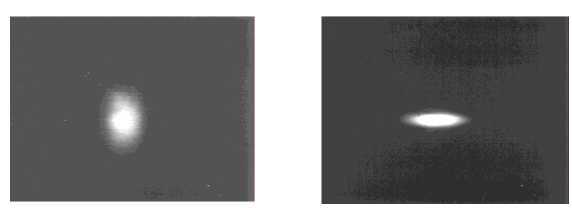


(a) TFS_X off (b) TFS_Y off



(c) TFS_X on (d) TFS_Y on

Figure 3: Spectrum of betatron sidebands for feedback on and feedback off (ion instability)



(a) TFS_Y off (b) TFS_Y on

Figure 4: Beam shape for feedback on and feedback off (ion instability)

For the better performance of the TFS, the system as shown in Fig.5 is now in upgrade to use one kicker per transverse plane to improve efficiency over the previous system with a kicker combining both planes in a single structure.

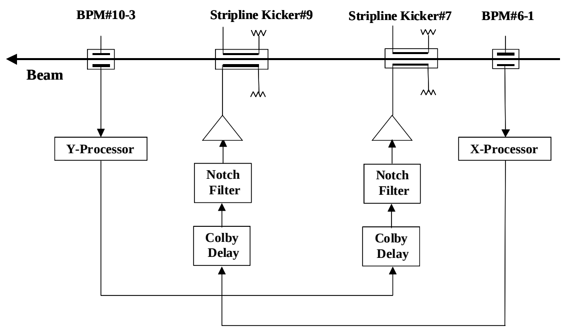


Figure 5: A layout of a upgrade transverse feedback system

4 SUMMARY

A bunch by bunch transverse feedback system is developed and tested in PLS to suppress the transverse coupled bunch instabilities. We demonstrated 20dB suppression of the betatron sidebands with resonantly driven beam at low beam current, and better than 30dB suppression of the betatron sidebands with ion instability at higher beam current in the whole bandwidth of the feedback system.

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