# PERFORMANCE OF THE TRANSVERSE COUPLED-BUNCH FEEDBACK SYSTEM IN THE SRRC

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## ABSTRACT

A transverse feedback system has been implemented and commissioned in the SRRC storage ring to suppress transverse coupled-bunch oscillations of the electron beam. The system includes transverse oscillation detectors, notch filter, baseband quadrature processing circuitry, power amplifiers and kickers. To control a large number of transverse coupled-bunch modes, the system is broad-band, bunch-by-bunch in nature. Because the system is capable of bunch-by-bunch correction, it can also be useful for suppressing instabilities introduced by ions. The sextupole strength was then reduced to improve dynamic aperture and hence the lifetime of the storage ring.

## 1. INTRODUCTION

A transverse feedback system was implemented and commissioned in the SRRC storage ring to suppress transverse coupled-bunch oscillations of the electron beam [1]. This system composed of transverse oscillation detectors, notch filter, baseband quadrature processing circuitry, power amplifiers and kickers. To control a large number of transverse coupled-bunch modes, the system is broad-band, bunch-by-bunch in nature. Because the system is capable of bunch-by-bunch correction, it can be useful for suppressing any type of transverse instabilities. Using transverse feedback system, the sextupole strength can be optimized to improve dynamic aperture and hence the lifetime of the storage ring. Commissioning results and operation expressions is presented in this report.

## 2. SYSTEM DESCRIPTIONS

Block diagram of the transverse feedback system is shown in figure 1. The system is composed of transverse oscillation detectors, baseband processing circuitry, notch filter, delays adjuster, power amplifiers and kickers [2,3,4].

One horizontal pickup and one vertical pickup to detect transverse beam motions were used at prototype system. That particular system had difficulty in satisfying the quadrature condition for different working points. Consequently two pickups were used instead for the operational version to reduce system sensitivity with respect to the changing working tunes.

For the present system, whenever there is a transverse beam movement relative to its stable reference orbit, the pickups are able to detect the move on both horizontal and vertical directions. By summing movement signals from the two pickups in an appropriate ratio, proper kicking strengths for the kickers were generated to eliminate the transverse beam oscillation.

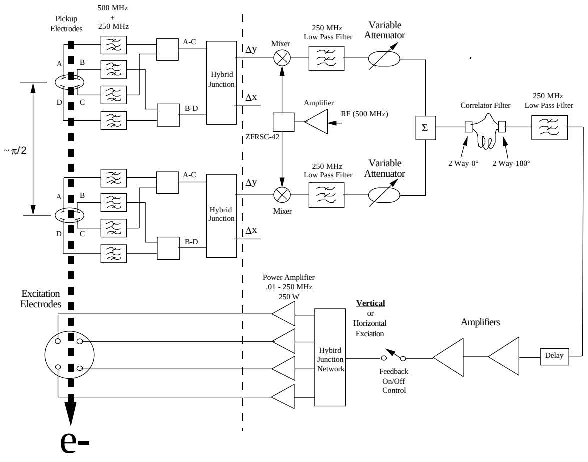

**Figure 1**. Functional block diagram of transverse feedback system.

The bunch oscillation detecting electronics is based upon heterodyne technique, this methods is insensitive to the strong sideband caused by synchrotron oscillation. Present system is working at 500 MHz with 250 MHz bandwidth. Beam signal was converted to DC-250 MHz baseband. It is expected that in the near future the center frequency will be changed to 1.5 GHz since capacitive coupled button electrode is more efficient at higher frequency.

The revolution harmonics were suppressed by one-turn coaxial notch filter (400.267 nsec). The filter is composed of matched power splitters, combiners, and 7/8" Helix coaxial cables [5]. The present notch filter provides more than 35 dB rejection of the 2.5 MHz orbit harmonics over the entire baseband frequency range.

The beam exciter is a combination of horizontal and vertical stripline kickers. Four sets of 250 W, solid-state, Class-A, power amplifiers were used to drive the beam with 10 kHz-250 MHz bandwidth. Each kicker electrode is driven by an independent power amplifier. The advantage of using high power amplifier in the system is

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+Permanent address: AGS Department, BNL, Upton, NY, USA to provide the capability of suppressing large transverse beam instability and reducing transient disturbance to the stored beam during injection.

At present, transverse feedback system is in operation for routine user shifts. One can also choose to disable the system from control console for machine study purpose.

## 3. SYSTEM PERFORMANCES

The transverse feedback system was put into operation since last October. Its performance is described in the following categories as status summary.

### *3.1 Transverse beam profile*

Vertical coherent oscillation was observed during the commissioning of SRRC storage ring in 1993. The excited coherent oscillation was observed with a synchrotron radiation profile monitor and is shown in the upper part of figure 2. When the feedback system was turned on, the stored beam was stabilized and its vertical dimension was reduced as indicated in the lower part of figure 2. The vertical beam size was effectively reduced to less than 100 mm.

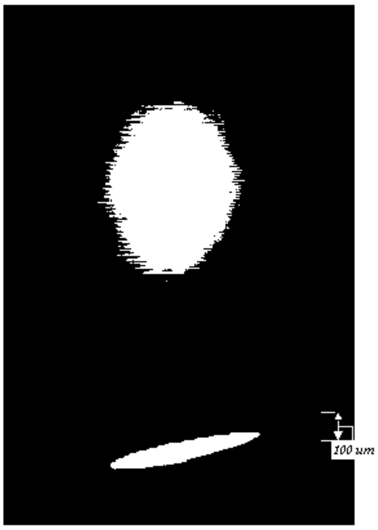


**Figure 2**. Synchrotron radiation beam profile versus feedback effect. The upper profile was with feedback off, the lower one was with feedback on.

### *3.2 Damping time observation*

Since this feedback system is bunch-by-bunch correlated, the suppression of instant betatron excitation can be much faster than that of the radiation damping case in the ring. This behavior was studied and verified with either the transverse feedback system was turned on or turned off. The stored beam damping time was measured with a digitized oscilloscope which was synchronized with the excitation pulse generated by an impulse generator. Figure 3 gives betatron sideband amplitude variation as a function of time when the transverse feedback turn off and on. Feedback loop control signal is shown as upper trace for comparison. The time evolution of the betatron sideband amplitude with mode number n=1 are displayed together on lower trace. Although the lattice transverse damping time was 10 ms, the measured growing time of sideband amplitude was observed to be 30 ms at the beginning of the feedback loop open. On the other hand, the corresponding damping time right after close the feedback loop was found to be about few millisecond. This observation indicated that the transverse feedback system was able to suppress instability built up in the stored beam and to reduce the damping time effectively whenever there was a transverse beam disturbance occurred.

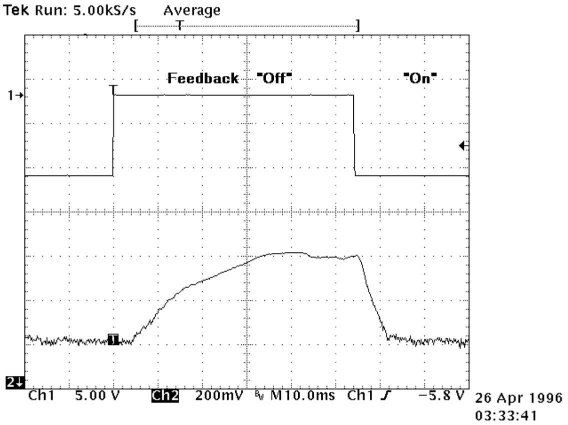


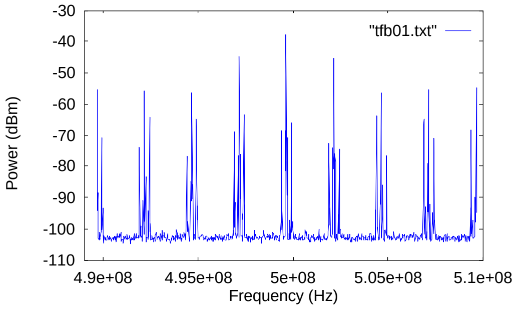
**Figure 3**. Growth versus damping of mode number n = 1for feedback loop open and close.

### *3.3 Betatron sideband suppression by feedback system*

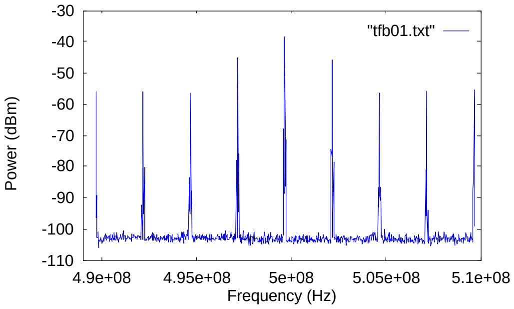
Figure 4 shows comparison spectra of the undamped and damped vertical betatron sideband. It is clear that the vertical betatron sideband disappears after turning on the feedback system. These spectra were taken without and with the feedback system.

### *3.4 Lifetime effect due to feedback system*

Figure 5 shows typical lifetime changed with and without the feedback system in operation. Although the transverse feedback system provided reproducibility in terms of beam orbit and stability between injection cycles, it was clear that the smaller the beam size was in the ring, as shown in figure 2, the shorter the beam lifetime it would be, as pointed out in figure 5. This feature indicated that the storage ring beam lifetime is predominatedly Touschek limited.



(a) Feedback “off”



(b) Feedback “on”

**Figure 4**. Vertical betatron sideband suppression by the feedback system.

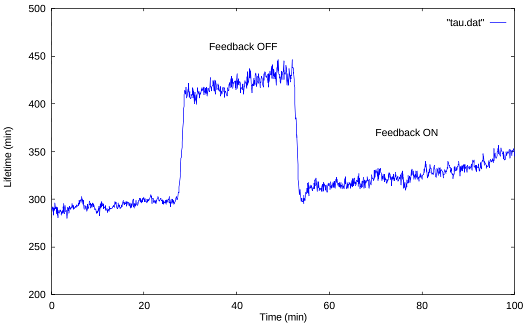


**Figure 5**. Lifetime change due to feedback on and off with 150 mA stored beam current.

### *3.5 Side benefit of transverse feedback system from operation point of view*

coupled bunch instability, certain positive chromaticity was applied to the lattice. In routine operation, the strength of the appropriate chromaticity changed for most of the injection cycle. This was mainly due to different bunch filling pattern in the storage ring hence the coupled bunch oscillation amplitude varied among injection cycles.

It was noticed that the beam orbit also changed because of different applied chromaticities. Typically, orbit changed of 100 mm was observed. Beamline users were annoyed with this situation for frequent readjustment of optical components after reinjection. Moreover, it reduces the dynamic aperture of the stored beam, and is not sufficient for higher stored current of 400 mA anticipated for future operation.

When the transverse feedback system was turned on, orbit reproducibility was drastically improved in contrast with the case that positive chromaticity was used to stabilize the stored beam.

## 4. CLOSING REMARKS

The transverse feedback experiment was performed for one BPM and one kicker prototype as well as two BPMs and one kicker operational version. The main effort for the upgraded system was emphasized on reducing its sensitivity with respect to the tune change of the stored beam. The 1.5 GHz central frequency and digital delay upgrade will certainly enhance performance of the transverse feedback system.

It is expected that the SRRC storage ring will be operated at both higher stored current and higher beam energy (300 mA to 400 mA @ 1.5 GeV) in the coming year. The upgrade activity will increase robustness and effectiveness of the feedback loop for future requirements.

## 5. ACKNOWLEDGMENTS

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## 6. REFERENCES

[1] W. T. Weng et al., “Beam Stability at SRRC Storage Ring”, Proceedings of the 1995 IEEE Particle Accelerator Conference, May 1995.

[2] J. D. Fox et al., “Feedback Control of Coupled-Bunch Instabilities”, Proceedings of the 1993 IEEE Particle Accelerator Conference, May 1993.

[3] W. Barry et al., “Transverse Coupled-Bunch Feedback in the Advanced Light Source (ALS)”, 4th European Accelarator Conference (1994).

[4] W. Barry et al., “Commissioning of the ALS Transverse Coupled-Bunch Feedback System”, Proceedings of the 1995 IEEE Particle AcceleratorConference, Dallas, May 1995.

[5] John Galayda, “Performance of a Correlator Filter in Betatron Tune Measurement and Damping on the NSLS Booster”, IEEE Trans. on Nucl. Sci. NS-32, 2132 (1985), and reference therein.