TURN-BY-TURN AND BUNCH-BY-BUNCH DIAGNOSTICS AT NSRRC

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Abstract

Turn-by-turn and bunch-by-bunch diagnostic systems were set up to support various studies. The beam oscillation signals were detected by transverse and longitudinal bunch signal detectors, and were digitized by a transient digitizer or oscilloscope. The signal data thus obtained were analyzed to extract information concerning the bunch oscillation on a turn-by-turn and bunch-by-bunch basis. The analytical results of this study are summarized herein.

INTRODUCTION

Turn-by-turn and bunch-by-bunch store beam parameters are useful in many studies [1]. Parameters which can be extracted for the data include the filling pattern, multi-bunch oscillation modes, ion instability, pseudospectrum growth and instability damping time. In this study, a system with this capability was setup up for measurement and analysis. Similar system have been set up and proved useful in many accelerator institutes. We set up the system accompany with the development of multi-bunch feedback system. Current effort is to improve the system to support study beam stabilities improvement.

SYSTEM DESCRIPTION

The turn-by-turn and bunch-by-bunch diagnostics are based upon transient digitizers. Time domain diagnostic tools with transient capability are useful for studying the multi-bunch instability and turning of a multi-bunch feedback system. A transient digitizer and feedback electronics are applied to record the bunch-by-bunch and turn-by-turn beam signal as shown in Fig.1. The digitizer acquires data from a transverse bunch oscillation detector and a longitudinal bunch phase detector [2]. The CompuScope 82G digitizer [3] was specified for this study because it provides a friendly application development environment (SDK for LabVIEW and MATLAB). Simple MATLAB scripts were applied to access transient digitizer hardware to enable capture data. These scripts were designed to be easily integrated with analytical scripts. The system supports transient domain data capture. A trigger signal and a feedback switch was used to capture the transient signal for 30 msec for all bunches without decimation.

Intensity gated CCD cameras with an IEEE-1394 interface were also set up to observe the oscillation of bunches. Single turn observation was performed to observe longitudinal stability of the stored beam. The cameras support triggering by revolution clock, adjustable exposure time and multiple exposure are supported.

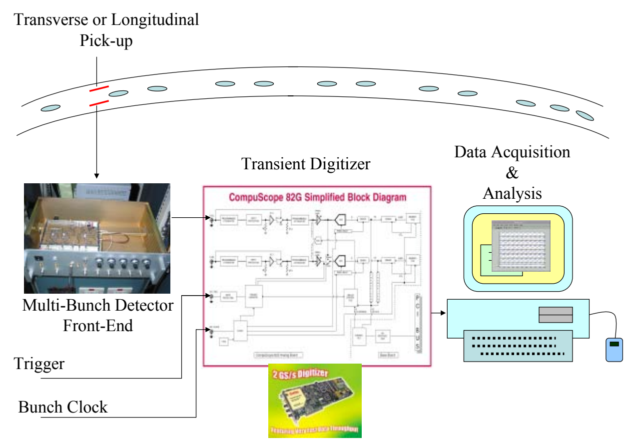

Figure 1: Transient signal capture system.

TIME DOMAIN DIAGNOSTIC

The acquired data can be arranged according to bucket address and bunch ID to reconstruct the individual bunch oscillation. Fig. 2 illustrates the captured data. The oscillation of each bunch is illustrated in Fig. 3. This study aims to use the proposed system to measure growth time and damping accompany with the multi-bunch feedback system.

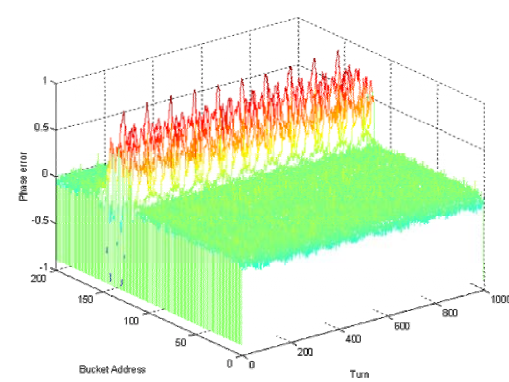

Figure 2: Turn-by-turn and bunch-by-bunch signal captured.

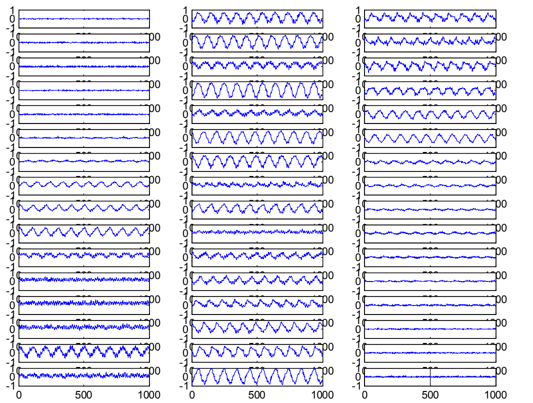

Figure 3: Oscillation of individual bunch is shown on the figure.

FREQUENCY DOMAIN DIAGNOSTIC

Fourier analysis was conducted on the acquired data, generating a high-resolution pseudospectrum, which is the beam spectrum without revolution harmonics, calculated from the digitized data. Typical beam pseudospectrum with the RF gap voltage modulation On and Off are shown in Fig. 4. The sharp peak near 190 MHz is the result of a HOM in the Doris cavity. The 2nd plunger of the Doris RF cavity is tuned to keep the magnitude of this peak. The RF gap voltage modulation further reduces the strength of the instability to provide stable beam [4]. The beam spectrum is much cleaner after the superconductor RF (SRF) upgrade than before it. However, residues transverse and longitudinal instabilities still exist. The transverse instabilities are much more severe due to the very high bunch charge density after the SRF upgrade. A transverse feedback system is needed to solve the instability problem. Fig. 5 illustrates the beam pseudospectrum with and without transverse feedback loop. The spectrum is clean when feedback is applied. The loop effectively suppressed instabilities.

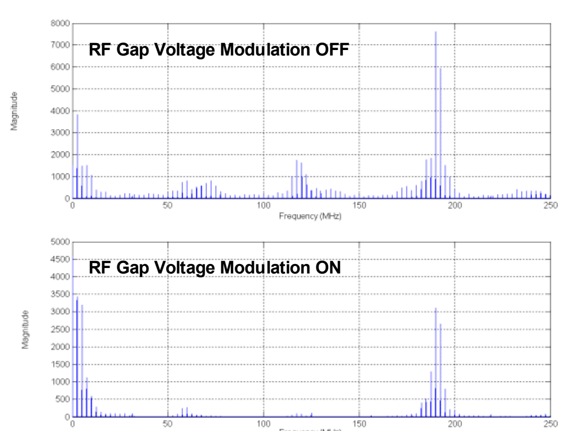

Figure 4: Longitudinal pseudospectrum of the stored beam without/with RF gap voltage modulation.

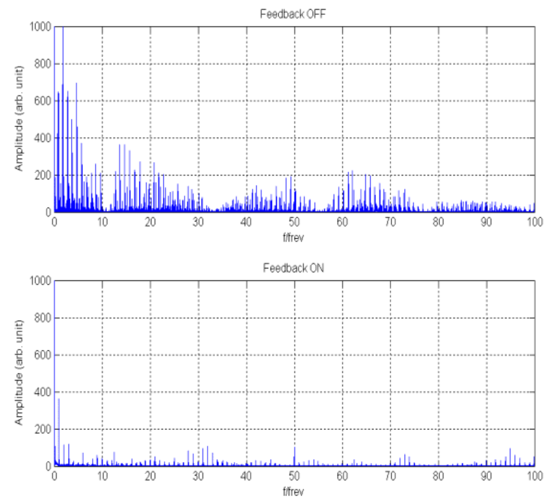

Figure 5: Transverse pseudospectrum of the stored beam without/with transverse feedback loop.

SINGLE TURN SYNCHROTRON RADIATION DIAGNOSTIC

Intensified gated CCD cameras were used adopted to observe the low-light turn-by-turn profile variation in different operation conditions [5]. The source point of the synchrotron radiation monitor located at the dispersion region) and the energy oscillation contributed to the horizontal beam size change of the observed profile. If the longitudinal is stable, then the energy oscillation is small, and the variation of horizontal beam size can be negligible. The high order mode of the Doris conventional cavities was severe, and the energy oscillation was unstable. RF gap voltage modulation was applied to help relieve the effect of the high order mode (HOM) of the DORIS conventional cavities and to stabilize the stored beam before the SRF upgrade. The modulation frequency and depth were twice the synchrotron frequency ($2f_s \approx 50$ kHz) and 5% of the total 800 kV RF gap voltage, respectively. For a single turn beam profile observation, the camera exposure was set to 400 ns, which is the revolution time of the stored beam. The trigger input to the CCD camera is synchronized with the RF gap voltage modulation source. Different post-trigger delay times were observed, as shown in Fig. 6. The horizontal beam size was smallest when the RF gap voltage was smallest, and the beam size was largest at the maximum gap voltage setting. Additionally, the period value was the same as modulation frequency. A stable horizontal beam size was obtained by a low speed imaging system, allowing the integration procedure to be performed effectively. Without this gap voltage modulation, the measured profile fluctuated, implying that the beam stability deteriorated severely because of the longitudinal instabilities. To improve the beam stability and double the maximum stored beam current, the two Doris conventional cavities were replaced by one CESR superconducting RF cavity in late 2004. Success commissioning was performed last December. This upgrade produced longitudinal stable beam, making the RF gap voltage redundant. The measured single-turn beam profile was much more stable than it was before the upgrade, as shown in Fig. 7. The variation of horizontal beam size because of longitudinal coupled bunch oscillation in the SRF cavity was much less than that in the Doris cavities due to the almost HOM-free nature of the SRF cavity.

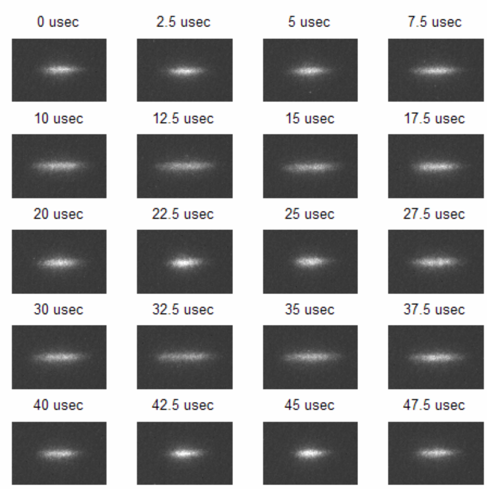

Figure 6: Observed beam profile at difference phase of RF gap voltage modulation cycle. Longitudinal stable beam is obtained by the aid of RF gap voltage modulation. Period of the modulation signal is about 20 μsec (50 kHz ≈ 2 fs).

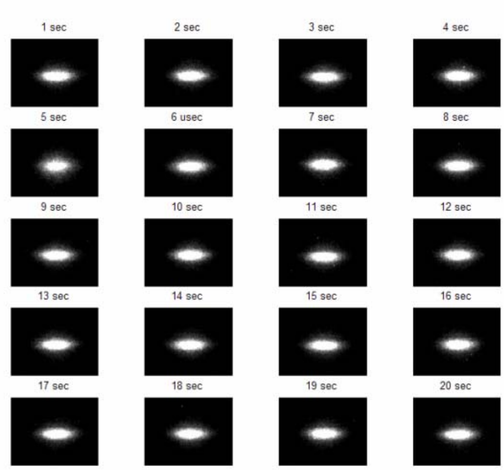

Figure 7: Single turn profile observation after SRF system upgrade during 20 sec observation time. The time on the top of each profile image is the elapse time after start of image acquisition. Longitudinally stable beam was observed.

SUMMARY

Turn-by-turn and bunch-by-bunch diagnostic systems were set up to support various studies. Preliminary results confirm that various stored beam phenomena are useful to observe. The analytical tools for these diagnostic systems are being further developed.

REFERENCES

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