BUNCH-BY-BUNCH INTENSITY, POSITION MONITOR FOR THE TAIWAN LIGHT SOURCE

C. S. CHEN, JENNY CHEN, K. T. HSU, C. H. KUO, K. K. LIN

Synchrotron Radiation Research Center
No. 1 R&D Road VI, Hsinchu Science-Based Industrial Park, Hsinchu, Taiwan, R. O. C.

Abstract

A data acquisition system to acquire beam signal with bunch-by-bunch and turn-by-turn capabilities have been implemented recently. The system composed RF processing circuitry, 500 MS/sec digitizer, memory, and software applications. The RF processing electronics are use to extract intensity, transverse oscillation as well as longitudinal oscillation. A 500 MS/sec transient digitizer and memory can acquire beam signal bunch-by-bunch and turn-by-turn. The control interface assists the data acquisition and raw data manipulation. The intensity monitoring function acquires intensity of individual bunch. Real-time filling pattern are available at console computer for monitor, injection control and various applications. Resolution is increase by appropriate average. Transverse beam oscillation and longitudinal oscillation can also record by the transient digitizer for time-domain observation of coupled-bunch oscillation. Performance and application of this bunch-by-bunch intensity, position monitor will describe on this reports.

I. INTRODUCTION

Coupled-bunch oscillation is strongly dependent on the filling pattern of stored beam. How to control filling pattern and coupled-bunch oscillation is a big issue for new generation light source or factory type machine. Significant efforts around the world have been devoted to these topics. At Taiwan Light Source, several projects have been launched and proposed to deal with control of coupled-bunch instabilities. Improve timing system and gun electronics to achieve reproduce filling pattern is underway. Transverse coupled-bunch feedback system is in service. Longitudinal coupled-bunch feedback system will commissioning soon. Usually, filling pattern is observed by oscilloscope on the signal come from pickup electrodes or photomultiplier tube that is mounted at synchrotron radiation diagnostics port. Due to the recently advanced in ADC technology, high performance digitizer with sampling rate in 500 MS/s to 1 GS/s is feasible with reasonable costs. Commercial digitizer module to acquire filling pattern is implemented as dedicated subsystem. Population of every bunch can be digitized. Further control of filling pattern is possible in injection process. Incorporate transverse oscillation detect electronics and phase detect electronics observed coupled-bunch oscillation in turn-by-turn and bunch-by-bunch is easily to achieve. Time domain signal provides an elegant tool for diagnostics purpose has been prove by several longitudinal feedback projects. The system describes here will the similar use for the coupled-bunch instabilities study in TLS. Following paragraphs will describe the implementation and the preliminary results in briefly.

II. FILLING PATTERN MONITOR

Population distribution in stored beam can be observed by wide bandwidth oscilloscope easily. However, dedicated filling pattern measurement [1] is useful from injection control and instabilities study. Control filling pattern is possible if real-time filling pattern information available. The injection parameters can be adjusted dynamically to achieve desire filling pattern.

The filling pattern acquisition system is shown in Figure 1. The digitizer use 500 MHz RF as external clock to synchronize with bunch signal. Phase trim is done by a phase shifter. One data point is acquired for each bunch. Consecutive 200 data points represent filling pattern. Data acquisition is trigger with booster repetition rate, 10 Hz. Memory can record 8 msec of signal, or about 20000 turns. Data of consecutive turns can be post-processing to improve amplitude resolution. Achieve 1000:1 dynamic range is possible with appropriate average applied.

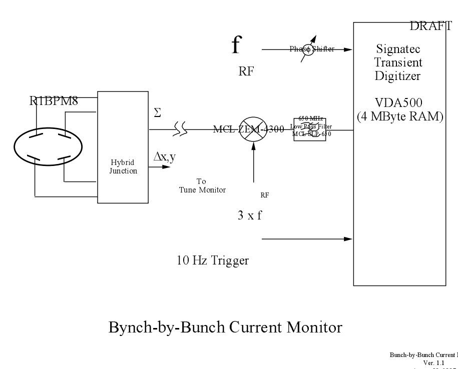
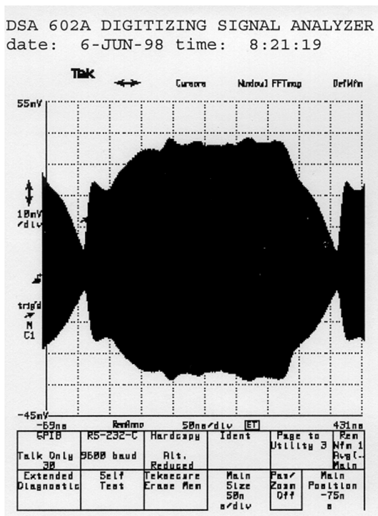
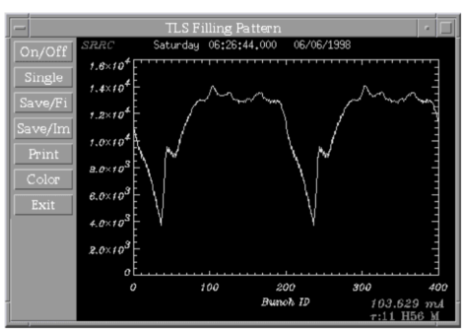


Figure 1: Bunch-by-bunch intensity monitor data acquisition system.

Figure 2 shown the filling pattern acquired in a particular shift. There are some distinct features on the population distribution shown on the waveform of the oscilloscope. The same structures are also shown on the bunch-by-bunch intensity monitor also. Bunch-by-bunch current monitors provide data in compact form compare with oscilloscope. Only one data point per bunch reduces data quantity. Using the real-time filling pattern during injection scenario can control filling pattern. Full integrated with control system make easily to use than use off-line oscilloscope and fast access than on-line oscilloscope that connect to control system by using IEEE-488 interface.



(a)



(b)

Figure 2: Filling pattern observed by oscilloscope in average mode (a); Filling pattern observed by bunch-by-bunch intensity monitor (b).

III. COUPLED-BUNCH OSCILLATION OBSERVATION SYSTEM

Time-domain coupled-bunch oscillation data are an elegant tool for diagnostic purpose [2]. Such system is also play an important role in the fast beam-ion instability (FBII) experiment in many facilities [3]. This system will help FBII study at TLS soon. Help to the commissioning of longitudinal feedback system in TLS is also expected in near future.

Coupled-bunch oscillations in longitudinal as well as transverse direction are detected by a bunch-by-bunch, turn-by-turn phase detector and transverse oscillation detector. Data is digitized by a ISA bus based 500 MS/sec ADC and store in 8 MB on board memory. The 8 MB memory is capable of storing signals for every bucket of TLS up to 40000 turns. Digitizer use external 500 MHz RF as clock that is locked with electron bunch. Trigger source is 10 Hz and also locket with the revolution frequency of the storage ring. Hence, bunch-by-bunch and turn-by-turn data are record on memory. Data of every bunch is reconstruct from the data stored in memory. The schematic diagram is shown in Figure 3. Raw data pack in personal computer. Control console access bunch oscillation data which store on local disk via NFS file system.

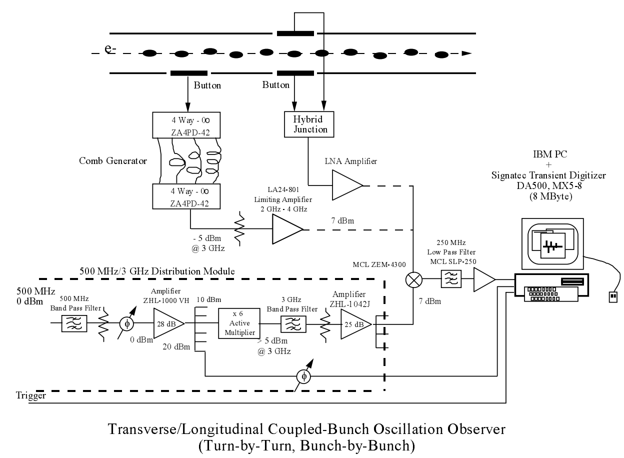


Figure 3: Functional block diagram of the 500 MS/sec digitizer system.

To test the performance of this coupled-bunch oscillation observe system, the stable stored beam has been excited intentionally by 50 cycles burst in synchrotron oscillation frequency. Figure 4 shown the synchrotron oscillation of three consecutive bunches on 15000 turns. Strong damping was observed for the test lattice.

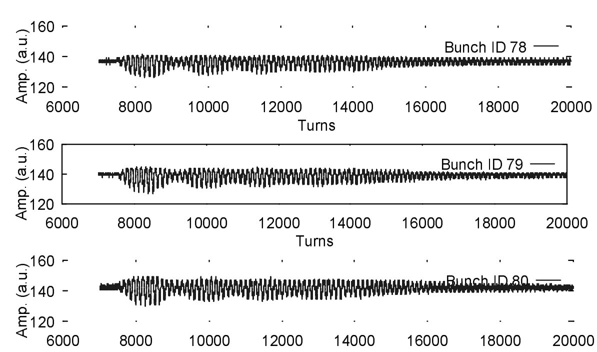


Figure 4: Observed synchrotron oscillation of three consecutive bunches, beam is excited by 50 cycles burst in synchrotron oscillation frequency.

Stable stored beam has been excited intentionally by 500 cycles burst in betatron oscillation frequency. Figure 5 shown the betatron oscillation of four consecutive bunches on 40000 turns. Oscillation amplitude is gradually increase for tail bunches. Detail of the betatron oscillation of bunch ID 81 is shown on Figure 6. Betatron oscillation is clear shown on the figure.

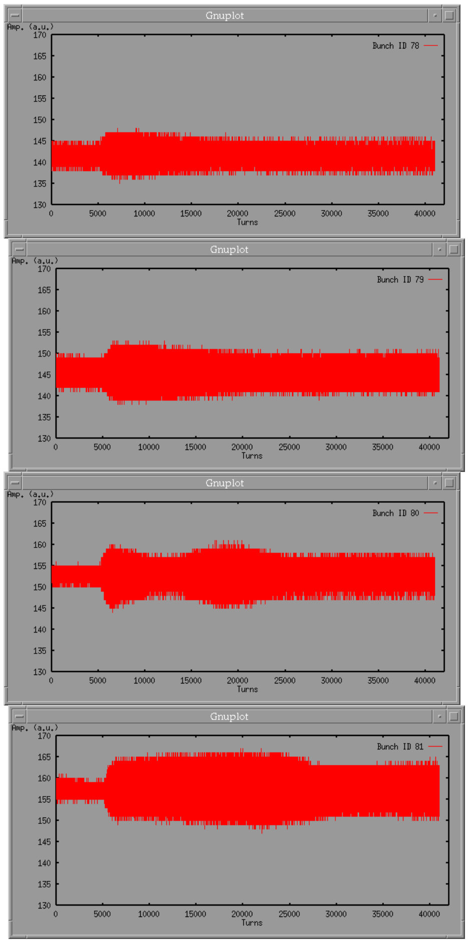


Figure 5: Observed betatron oscillation of four consecutive bunches, beam is excited by 500 cycles burst in betatron oscillation frequency.

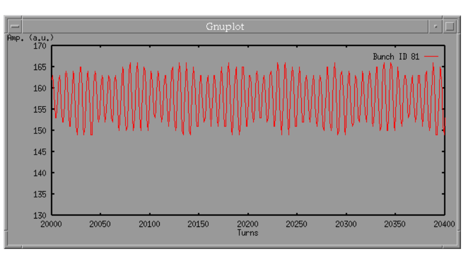


Figure 6: Portion of betatron oscillation in bunch ID 81.

Tune shift along the bunch train is also interested in multi-bunch instabilities study. Tune of individual bunch can be obtained by perform FFT on acquired data. Since, the frequency precision of the FFT is limited by the discreteness, however, theoretical resolution of 32 K points FFT achievable tune resolution about 0.00005. Further improve in resolution is possible by interpolate FFT spectra peak [4] or to use maximum entropy method and numerical analysis of fundamental frequency method (NAFF) by J. Laskar [5].

Analysis tools that are used to aid identify mode parameter is very useful. Develop such type tool kit is in progress. The tool kit will include various formats convert program to help the acquired data can as input of MATLAB, PVWAVE packages for analysis and visualization.

4. SUMMARY

Data acquisition system to acquire bunch-by-bunch intensity and turn-by-turn, bunch-by-bunch coupled oscillation has been set up recently. Preliminary results shown that its working well in functionally. Purpose of bunch-by-bunch intensity monitor is to replace oscilloscope to provide filling pattern. Archive filling pattern for routine operation and control filling pattern in injection will put into practice soon. The major goals of the coupled-bunch oscillation observe system is to provide an elegant tool for operator and machine physics to observe beam oscillation in time-domain of the stored beam. Post-processing tool kit is in developing. This system and post-processing tools will be helpful for FBII study and longitudinal feedback system commissioning. Upgrade the performance of the transverse feedback system can also be benefit from this observe system.

5. ACKNOWLEDGMENTS

The authors express their thanks to the operation group staffs, their skillful operation of the machine during test is highly helpful. The helps come from staffs of instrumentation and control group is also appreciated

REFERENCES

[1]. M. J. Chin, J. A. Hinkson, " PEP-II Bunch-by-Bunch Current Monitor" , Proceedings of the 1997 Particle Accelerator Conference, 1998.
[2]. R. Claus, J. Fox, H. Hindi, I. Linscott, S. Prabhakar, W. Ross, D. Teytelman, "Observation, Control and Model Analysis of Coupled-Bunch Longitudinal Instabilities" , Proceedings of the Fifth European Particle Accelerator Conference, EPAC 96, Sitges (Barcelona), 10-14 June 1996, pp 346 -348.
[3]. Edited by Yong Ho Chin, Proceedings of the International Workshop on Multibunch Instabilities in Future Electron and Position Accelerator (MBI97), Tsukuba, KEK, 15-18 July, 1997.
[4]. R. Bartolini, et al., Particle Accelerators, 1996, Vol. 52, pp.147-177.
[5] J. Laskar, Physica D67 (1993) 257.