TURN-BY-TURN BEAM POSITION MEASUREMENT FOR 1.3 GeV BOOSTER SYNCHROTRON

T. S. Ueng, K. T. Hsu, C. S. Fang,
Y. M. Chang, K. K. Lin
Synchrotron Radiation Research Center, Hsinchu 300, Taiwan

Abstract

A prototype turn-by-turn beam position measurement system has been implemented to characterize machine properties of 1.3 GeV booster synchrotron at SRRC. The signals picked up by button electrodes are processed by heterodyne receivers. The output of the receiver is digitized by VXI module with digitizing rate equal to the beam revolution frequency. The beam positions are calculated at embedded VXI controller under HP/UX environment. The performance of the data acquisition system and the measured data are presented.

I. INTRODUCTION

The booster of SRRC is a 10 Hz resonance type machine [1]. The booster accelerates the 50 MeV electron beam injected from Linac to 1.3 GeV in 50 msec. Then, the beam is extracted for storage ring injection. The revolution frequency of the booster is 4.167 MHz, in terms of orbit period 240 nsec. Turn-by-turn beam positions are very important for the beam physics study. The study plan will be concentrated on the beam behavior when it is moved toward a resonant mode. The turn-by-turn beam position measurement system has been implemented recently for the booster synchrotron. The system has 500 kwords memory which can record the beam positions during the whole ramping cycle.

II. BPM ELECTRONICS

Two beam position monitors was used to measure the horizontal or the vertical beam position at current stage. The separation of these beam position monitors is chosen with phase advance near $3\pi/2$. Knowing the beta function and the phase advance between both BPMs, one can calculate the displacement and slope at one of these two BPMs. Thus, the phase space plot can be obtained [2,3].

The processing electronics is a heterodyne receivers. One BPM has two channel receivers as shown in figure 1. The signals picked up by the button electrodes are added and subtracted to obtain the horizontal or vertical beam position signal. The heterodyne receiver filters and amplifies the 500 MHz component of the bunch signal and converts it into a wide bunch signal with the frequency equal to the revolution clock. The output of receiver is sent to multichannel digitizer which is located in VXI crate. The calibration signal is fed into the electronics to measure the loss variation of hybrid junction of different channel and the gain difference of receivers. These variations between different channels are compensated by embedded controller on the VXI crate.

The turn-by-turn beam position measurement electronics can be operated with multi-bunch or single bunch mode. The multi-bunch current can be varied form 1 mA to 5 mA. The bunch train in multi-bunch mode can have different behavior for different bunchs. It is no easy to define and analyze the turn-by-turn beam position of the multi-bunch mode. Hence, the turn-by-turn beam position measurement is not desirable for this operation mode. The nominal single bunch current is about 100-300 μA for the booster. The receivers have enough gain to operate in this current range. However, The S/N ratio of the receiver is lower for single bunch operation at current stage. The experiments were performed at multi-bunch mode with bunch train less than 50 nsec.

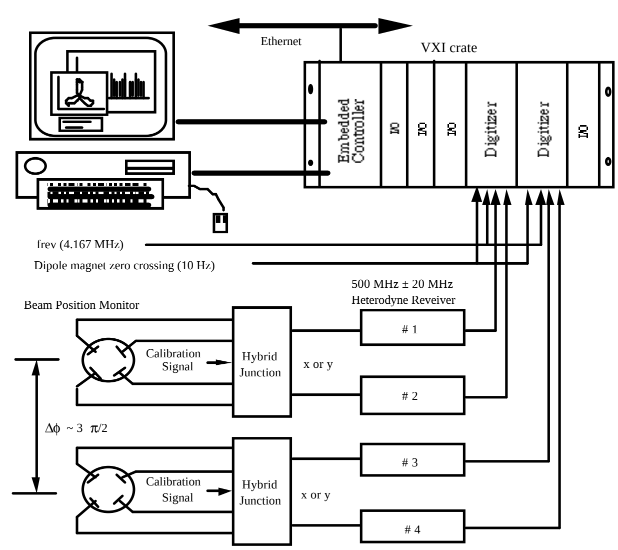

Figure 1. Hardware block diagram

III. DATA ACQUISITION SYSTEM

The data acquisition system is a VXI based system. Two dual-channel 12 bits digitizers are used to digitize bunch signal picked up by the button electrodes. VXI embedded controller is used to initialize digitizers and start the data acquisition operation. After receiving the booster injection trigger signal (10 Hz), the digitizer module starts to convert the beam signal. The acquired signals from button electrodes are filled into the memory of the digitizer with a revolution clock of the booster (4.167 MHz).

The memory depth of the digitizer is 512 Kwords. Maximum record length is about 123 msec. Since the booster has cycling period of 100 msec, the turn-by-turn beam position of the booster can be recorded for full booster cycle. The acquired raw data is normalized and the turn-by-turn beam position is computed by the VXI controller.

The VXI crate controller is a 68040 based embedded controller which running HP/UX operating system. The user interface is developed under X-Windows/Motif environment. The controller communicates with the digitizers via VXI bus by using compiled command system for programmable instruments (C-SCPI).

The raw data, the calculated beam position, the betatron tune and the phase space plot are presented on the screen in interactive basis. The experimental data can also be stored on mass storage devices for off-line analysis.

IV. PRELIMINARY RESULTS

The turn-by-turn beam position measurement system has been used to measure properties of the booster. The slow extraction scheme has been designed for the booster. The extraction system is composed of three bumper magnets, one extraction kicker and one extraction septum. The excitation of bumpers is a 2 msec half-sine pulse current. The pulse for the kicker has a 30 nsec rise time and about 250 nsec flat top width.

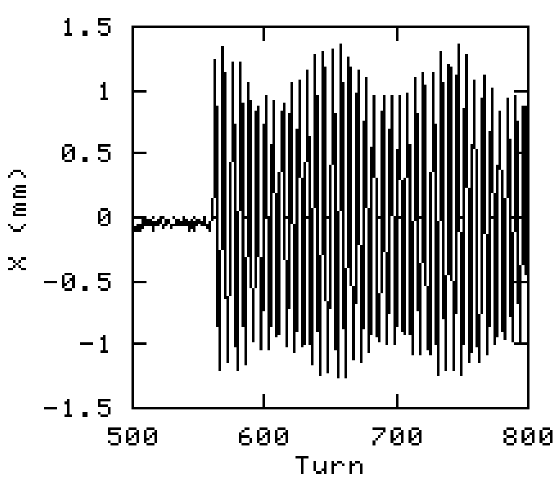

Figure 2: Turn-by-turn beam position at 1.3 GeV with 3 mrad kick

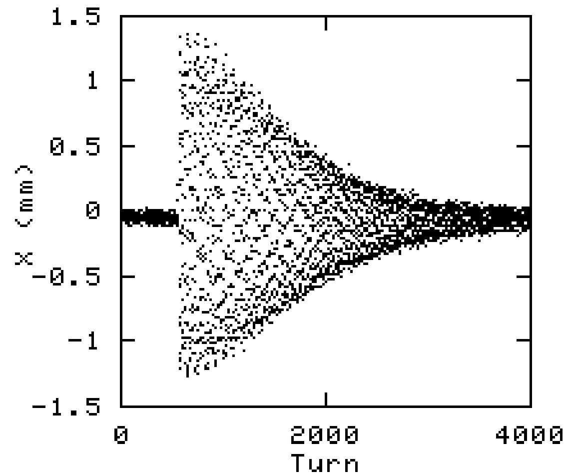

Figure 3. Turn-by-turn beam position at 1.3 GeV

The transverse motion of stored beam can be excited by the extraction kicker. The kicking strength of kicker is about 3 mrad at 1.3 GeV for the nominal extraction setting. Figure 2 shows the beam motion when a 3 mrad kick applied to the stored beam at 1.3 GeV. The coherent and the decoherent processes of the betatron oscillation are clearly observed. The damping effect of betatron oscillation can be seen in figure 3.

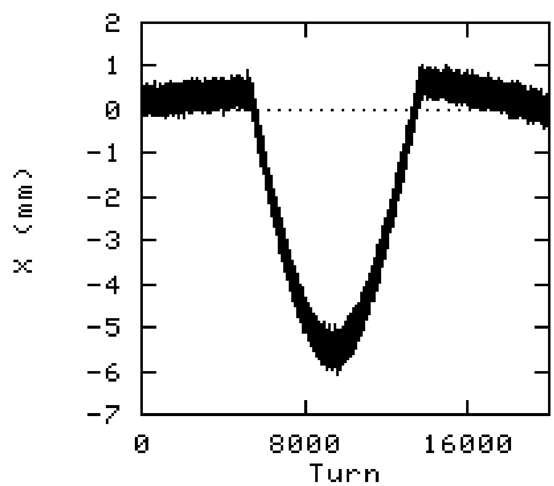

Figure 4. Turn-by-turn beam position change due to the energized of bumper #2 at 1.3 GeV

Another method to observe the disturbed beam motion is to measure the beam position under the kick by the bumper. The extraction bumpers are energized by a 2 msec half-sine pulsed current. With the bumper #2 excited at about half of its nominal strength, the turn-by-turn beam positions measured at BPM location are shown in figure 4. The phase advance between the bumper #2 and the BPM location is

5.8π. As the bumper applies a positive kick in the radial direction, the beam position at BPM is excursive toward the opposite direction.

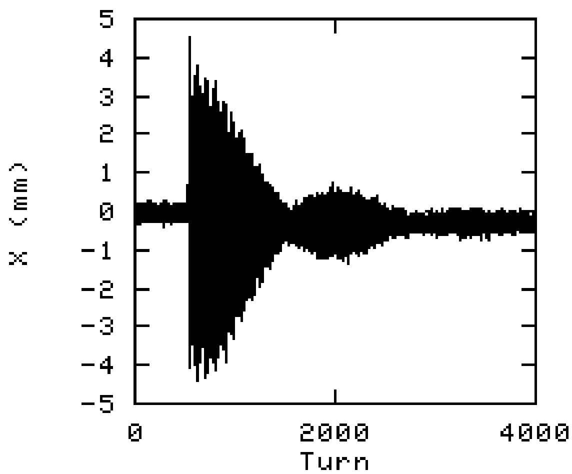

Figure 5. Turn-by-turn beam position of multibunch filling

With a longer bunch train length (> 100 nsec) the result is more complicated than that of short bunch train length. Beside the modulation of synchrotron oscillation, the beating effect during the damping period can also be observed. In figure 5 it shows clearly that the damping as well as excitation for the measurement [4].

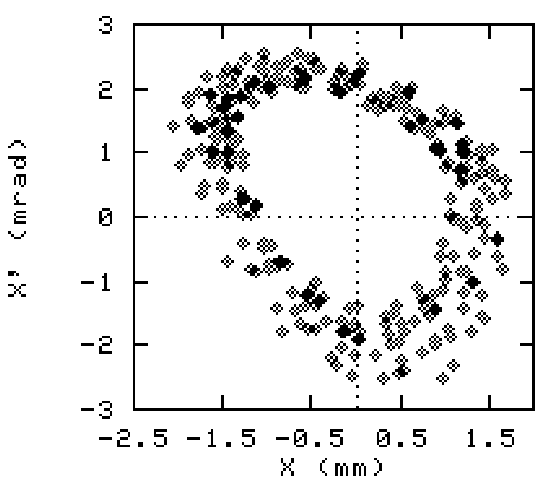

Figure 6. Phase space plot with 3 mrad kick at 1.3 GeV

Using the measured turn-by-turn beam positions at two BPM locations, the phase space plot of 300 turns with 3 mrad kick at 1.3 GeV is constructed and shown in figure 6. There is no significant nonlinearity found in the plot. The size of the ellipse is slightly reduced due to the damping effect of the electron beam.

V. SUMMARY

The prototype turn-by-turn beam position measurement system for the booster has been implemented. The system test and the preliminary experiments are in progress. The system is working for both multi-bunch and single bunch operation modes. One can excite the stored electron beam by the extraction kicker at any energy range to study the behavior of the electron beam dynamically. Upgrading this system to accommodate the sixth dimensional turn-by-turn measurement has been initialized.

VII. ACKNOWLEDGMENTS

The authors would like to thank J. P. Chiou, J. I. Huang, and S. Y. Hsu for their professional skill to operate the Linac and the booster. The help from C. H. Kuo is also appreciated.

VIII. REFERENCES

[1] K. K. Lin, et al., "Performance of SRRC 1.3 GeV electron booster synchrotron", to be published in Nuclear Instruments and Methods in Physics Research, Section A, 1995.

[2] E. Crosbie et al., "Non-linear resonance studies at the synchrotron radiation center, Stoughton, Wisconsin", Proceedings of the Particle Accelerator Conference, PAC'91, San Francisco, CA, 1624 (1992).

[3] J. Liu et al., "Difference resonance study on the electron storage ring Aladdin at SRC", Part. Accel. 41, 1 (1993).

[4] M. Schürmann, "Preparation of an experiment to investigate nonlinear beam dynamics at the storage ring DELTA", Particle Accelerator Conference PAC'93, 264 (1993).