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# SSRF BEAM OPERATION STABILITY EVALUATION USING BUNCH BY BUNCH BEAM POSITION METHOD *

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*Abstract*

In order to improve the efficiency and quality of light in Top-up mode at SSRF, disturbance caused by leakage fields mismatch during injection should be minimized and stable. This could be evaluated by analysis of bunch by bunch residual betatron oscillation data, using this method, instability of tune distribution and damping repeatability could also be calculated. So we could evaluate the beam operation stability by the data analysis and discuss in the paper.

## INTRODUCTION

In Shanghai Synchrotron Radiation Facility (SSRF), the accelerator injection mode has been upgraded from Decay mode to Top-up mode since late 2012[1], aiming to achieve uniform filling. This method results in more frequent beam injections (about 2 minutes per one injection period). Since the injection process involves a variety of equipment, Parameter imperfections can lead to a closed orbit distortion, which will leave a residual betatron oscillation during injection. For beam light users, this disturbance should be as little as possible.

Usually, parameter mismatches during injection mainly refers to:

(1) Kicker excitation current mismatch (current waveform amplitude and timing).

(2) Energy or phase mismatch, between the injected bunch from the booster and the stored bunches in the storage ring.

(3. Mechanical error in the kickers.

Injection performance evaluation and analysis have been done by SSRF BI group [2][3]. In the experiment, bunch by bunch position measurement system was employed. A complete residual oscillation distribution was obtained by combining several groups of injection, which could be used for evaluate issue(1), and by harmonic analysis, The spectrum of the injected bunch position signal can be obtained for issue(2). Turn by turn SA data from Libera was used to observe the effect of issue (3).

For SSRF beam operation, the closed orbit distortion caused by kicker leakage field mismatch as well as tune and damping time should be as stable as possible, which would be good for further optimization. So operation stability should be evaluated by long-term measurement and evaluating the variation of parameters from different period.

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## MESUREMENT SYSTEM

Raw position signals of beam in storage ring are excited by BUTTON BPMs installed in vacuum pipe. For building a bunch-by-bunch position measuring system to obtain the disturbance details of each bunch, the bandwidth of the system should be larger than 250 MHz, the data rates should be equal to or greater than 499.654 MHz (storage ring RF frequency), and the data buffer should be greater than 10 Mb.(determined by the loop damping time 5-6 ms).

The latest bunch by bunch position measurement method in SSRF is synchronous peak sampling at RF frequency [4]. The sampled pulse peak data with same phase from 4 input channels were calculated to obtain position and sum value for each bunch. For this purpose, ADQ14 data acquisition board developed by SP-devices Company was employed as Data Processing Board, used for raw BPM signals sampling and bunch position calculation in real-time. The board and chassis component were shown in Figure 1.


Figure 1: Data acquisition board and PXIe chassis forBTB position on-line measurement.

PC-based controller (Data I/O Unit) as well as Data Processing Board, was inserted into NI chassis, which controlled Data Processing Board using PXIe interface. We have designed an EPICS IOC running in Linux OS of the controller to implement DAQ control and data output.

Data Processing Board and Data I/O Unit consists the basic framework of bunch by bunch data acquisition system. By applying different front-end and IOC algorithm, the system could achieve transverse and longitudinal parameters [5] measurement. For bunch by bunch position, the front-end was designed for Phrase adjustment, Delay adjustment, Signal attenuation and Generating RF frequency doubling phrase-lock signal for external clock. The system structure is shown in Figure 2.

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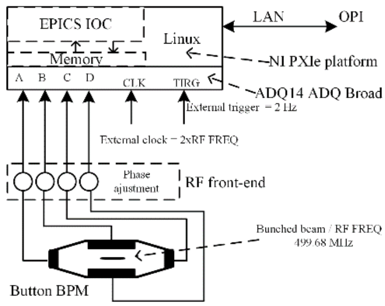



Figure 2: Bunch by bunch position DAQ system diagram in SSRF.

## EXPERIMET AND DATA ANALYSIS

In SSRF normal Top-up operation, there are 720 buckets in the storage ring. 500 bunches was grouped as 4 bunch-trains in bunched beam, which spaced about 50 empty buckets, beam current was kept around 250mA, the filling pattern is shown as Figure 3 . The injected bucket jumps 6 bunches for each injection.

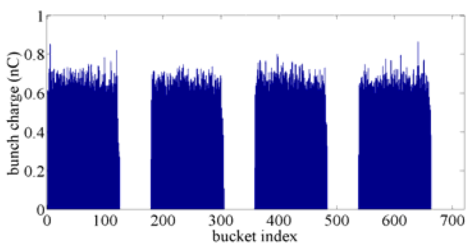



Figure 3: Measured Filling pattern of a snapshot duringTop-up operation.

### *Bunches Oscillation Processing*

Bunch by bunch position data could be recorded and saved during each injection process by the measurement system. Using PYTHON or MATLAB script, individual bunch time-domain waveform could be easily curved, which was shown in Figure 4. The damping time could be calculated by counting the interval of damping.

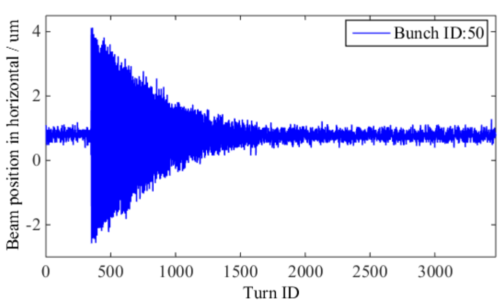



Figure 4: Individual bunch betatron oscillation during injection in horizontal plane.

And normalized frequency spectrum of each bunch was obtained by FFT to position array shown in Figure 5. The oscillation amplitude and tune could be calculated using this method.

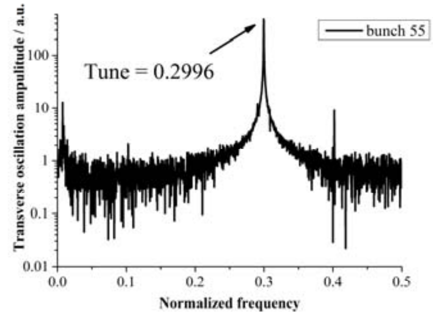
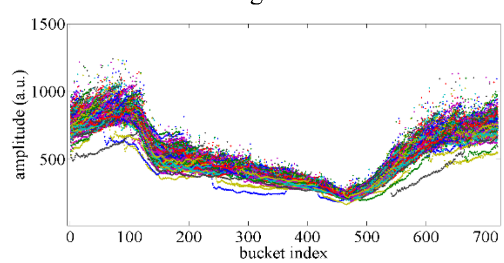



Figure 5: Individual bunch transverse oscillation normalized frequency.

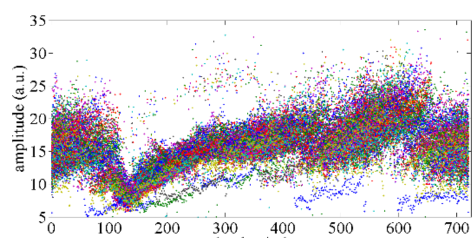
### *Beam Parameter Drift Observation and Analysis*

For observing the time drift of oscillation amplitude, damping time and tune, and evaluating the injection effect to operation stability, residual oscillation data during 18 hours was recorded and off-line processed. Using the time-domain and harmonic analysis discussed above, bunch by bunch parameters could be extracted and expressed in different way.

Since the effect of kicker leak fields mismatch to the injected bunch is strictly synchronous, residual oscillation distribution for all buckets could be obtained by combining several groups of injection data, stability of leak fields mismatch could be characterized by the time drift of the distribution. Figure 6 showed the long-term amplitude difference of the oscillation in vertical and horizontal plane. And Figure 7 showed the oscillation amplitude distribution variation during time.




(a): Horizontal plane




(b): Vertical plane

Figure 6: Residual oscillation distribution amplitude difference during 18 hours.

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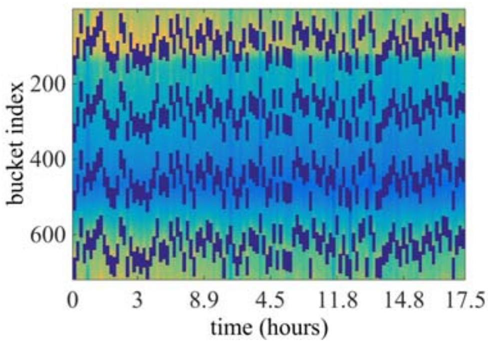
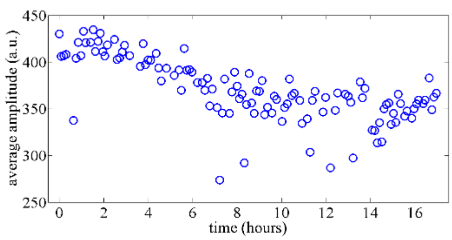
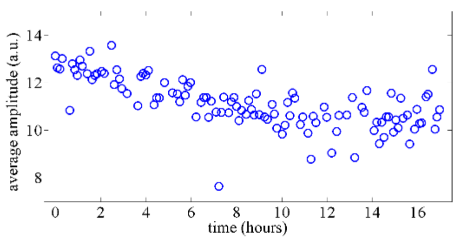



Figure 7: Buckets oscillation amplitude variation during time.

Regarding the bunch train as a whole, the average residual oscillation amplitude is the charge weighted average of each bunch oscillation amplitude. The time drift of the average oscillation amplitude in shown in Figure 8.




(a): Horizontal plane




(b): Vertical plane

Figure 8: Time drift of average residual oscillation amplitude.

The whole beam damping time in horizontal plane could also be obtained by charge weighted average of the bunches damping, and the long term variation was shown in Figure 9.

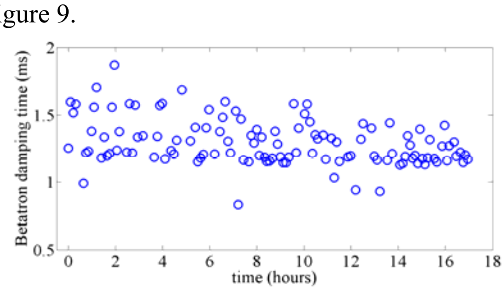
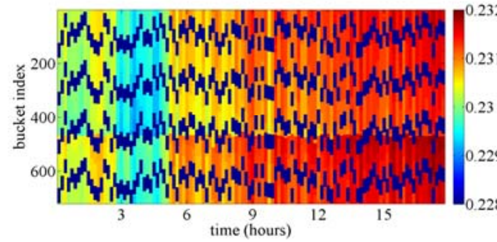
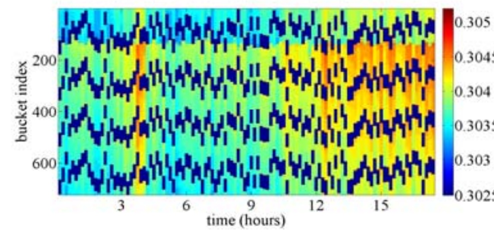



Figure 9: Beam damping time variation in 18 hours.

Tune drift indicate the Lattice structure instability of accelerator system, tune value of individual bunch could be acquired, and the tune distribution variation could also be expressed as Figure 10.




(a): Horizontal plane




(b): Vertical plane

Figure 10: Time drift of tune distribution during budget ID.

## CONCLUSION

The bunch-by-bunch position measurement system is very effective in the evaluation and analysis of SSRF operation instability. It could obtain transient information for the injection and is more conducive to optimizing the injection system.

The analysis of multiple sets of data indicates that the distribution shape of the kicker leakage field is stable, but the long-term observation also showed the time drift of the distribution shape and damping time is serious, which is not constructive to feed-forward compensation in the future. The tune drift means that there is still optimization space for the whole accelerator system. Also, month-level observation is planned to enrich the long-term injection characteristic.

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