TUPWC02

Three-Dimensional Bunch-by-Bunch Position Measurement at SSRF

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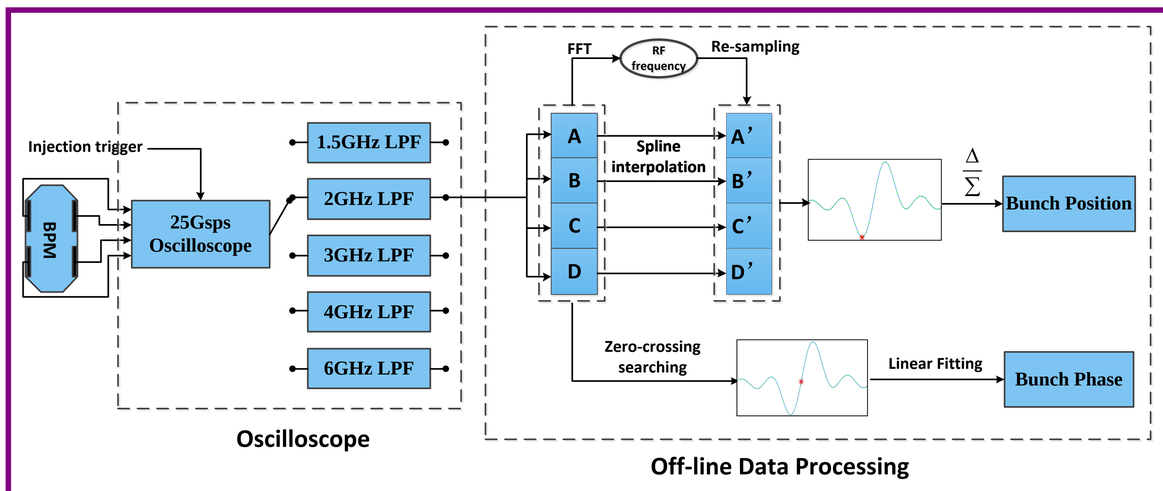
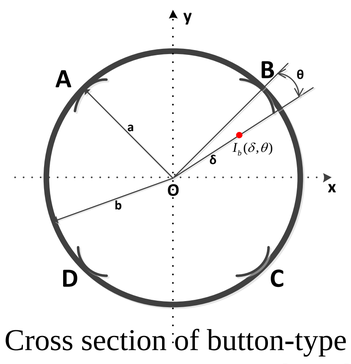
Introduction

Measurement of the bunch-by-bunch particle beam position related to dynamic instability is a useful input to accelerator optimization. And the bunch-by-bunch information has been contained in the BPM signals, including bunch charge, transverse position and longitudinal phase information. This paper reports a 3D beam position monitor system based on a high speed digital oscilloscope, which has been used to capture three-dimensional position information during the injection transient at the Shanghai Synchrotron Radiation Facility. With this information the traces of stored bunch and refilled bunch, and the mismatch of energy, transverse position and longitudinal phase between them can be precisely retrieved. The progress of this work and several particular experimental results will be discussed in this paper. The details of data processing method so-called software re-sampling technique will be discussed as well.

3D beam position monitor system based on digital oscilloscope





Cross section of button-type position monitor. Bunch with charge $I_b(t)$ in the position (δ,θ)

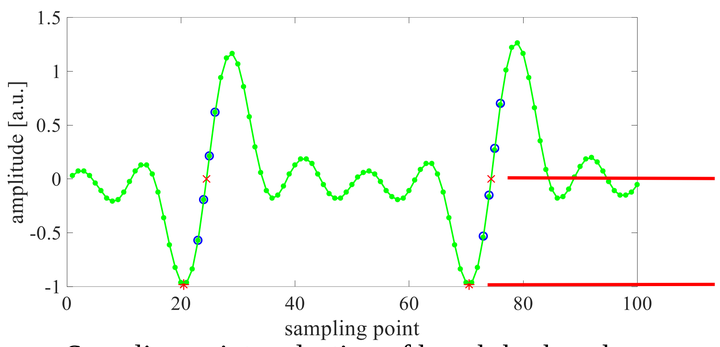
Induced voltage of the button BPM:

$$V_b(t)=\frac{\pi a^2 Z}{b\beta c}\cdot I_n\cdot 2f_0 A\sin(\omega_s t+\phi)e^{in\omega_0(t+A\cos(\omega_s t+\phi))}\cdot F(\delta,\theta)$$

The electrode induced voltage is related to the two parts of information:

- the beam intensity I_0 and the bunch length σ
- the transverse position $F(\delta, \theta)$ and longitudinal phase φ

Algorithm of bunch transverse position and longitudinal phase measurement



Sampling points selecting of bunch-by-bunch position measurement.

Spline interpolation:

Zero-crossing points: for phase measurement

Negative peak points: for position measurement

Method:

Bunch position measurement:

- four channel
- negative peak points
- difference over sum processing

Bunch phase measurement:

- one channel
- four sampling points around zero-crossing point
- linear fitting processing

Separate the injected bunch from the measured signal:

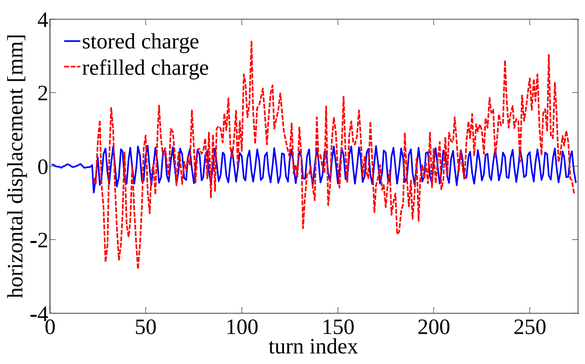
Transverse position:

$$X_r=\frac{Qs}{Qr}\left(X_m\left(1+\frac{Qr}{Qs}\right)-X_s\right)$$

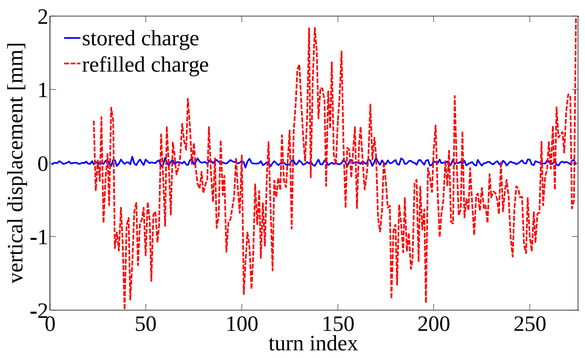
Longitudinal phase:

$$z_d=z_m\exp(-\alpha_s t)\cos(\sqrt{\Omega^2-\alpha_s^2}t+\theta_0)$$

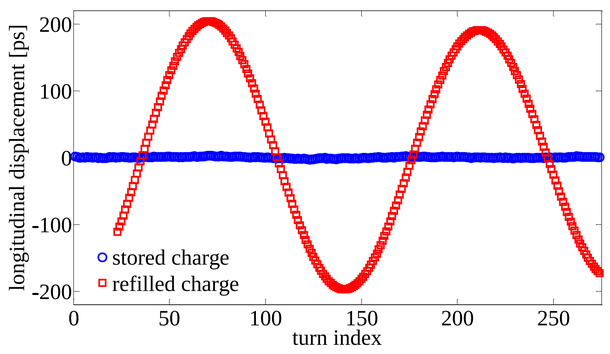
Three-dimensional displacements after injection



Horizontal displacement of the injected bunch



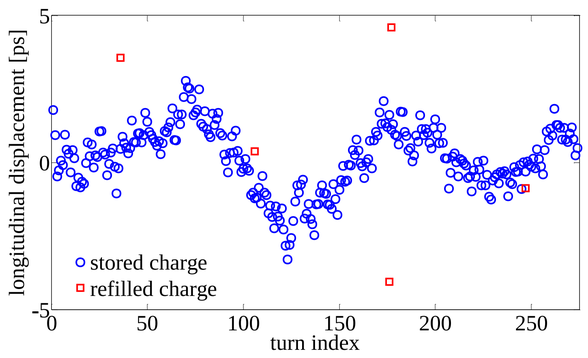
Vertical displacement of the injected bunch



Longitudinal displacement of the injected bunch

Discussion

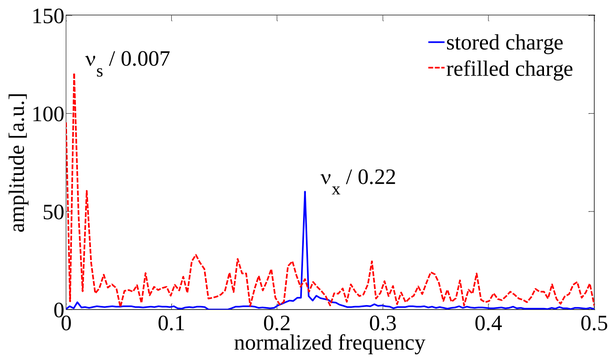
- Refilled bunch oscillated around the stored bunch asymmetrically.
- Longitudinal oscillation is much smaller than the transverse oscillation.
- Transverse displacement of the refilled bunch is about 2mm and longitudinal displacement is 200ps.
- 3D beam motion can be constructed according to the three-dimensional position information.
- To track the three-dimensional oscillation of instable beam , an intelligent trigger system based on FPGA is being developed.

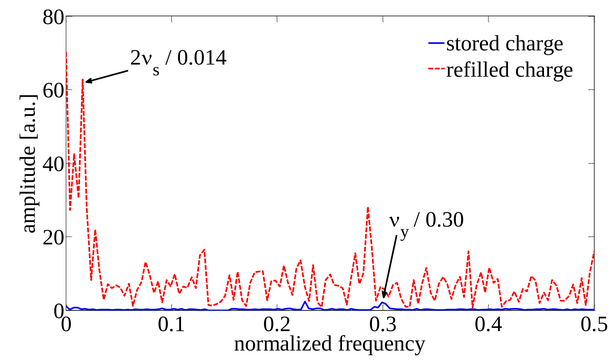


Details in longitudinal displacement of the stored bunch

Longitudinal displacement of the stored bunch is not zero. There are still several picoseconds phase oscillation in the stored bunches.

Frequency spectrum





Frequency spectrum of the injected bunch

Beam tune can be measured by the frequency spectrum of the injected bunch. Transverse tune is (0.22, 0.30) and the longitudinal tune is 0.007.

Conclusions

- A bunch-by-bunch 3D position monitor system has been developed in the SSRF.
- Three-dimensional position information can be measured directly from the button electrodes.
- The refilled bunches have been separated from the stored bunches.
- During the transient injection process, the refilled bunches oscillated around the stored bunches.
- The transverse displacement of the refilled bunches is about 2mm and the longitudinal displacement is 200ps.