BUNCH-BY-BUNCH STUDY OF THE TRANSIENT STATE OF INJECTION AT THE SSRF*

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Abstract

High current and stable beams are preferred to a light source, so the suppression of the oscillations due to the frequent injections during top-off operations get the attention at the Shanghai Synchrotron Radiation Facility (SSRF). To evaluate the possibility of further optimizations, a bunch-by-bunch position monitor is used to study the behavior of the injected bunch. The injected part is isolated from the stored one by decomposing the position matrix of all the bunches in the storage ring. Frequency feature, motion lifetime and other characteristic parameters of the injection mode have been compared with those of the stored mode.

INTRODUCTION

The SSRF is a third generation light source aiming to provide stable and brilliant synchrotron radiation. The high brilliance target was achieved by operating under top-off mode. But the frequent injections required by the top-off mode will decrease the stability of the beams. The behavior of the injected bunch has to be studied before finding a solution to minimize the effect of the injection.

BUNCH SEPARATION

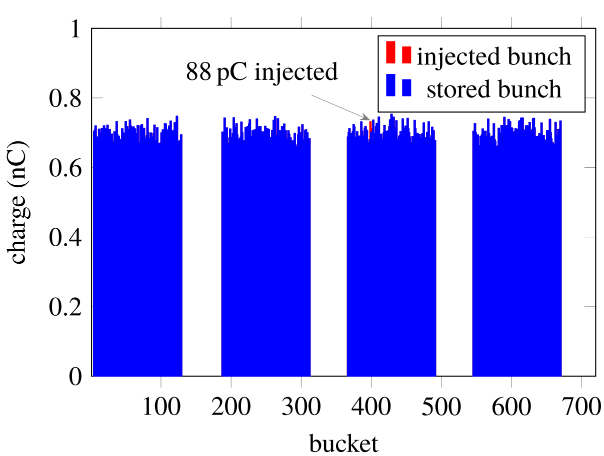

Figure 1: Filling patterns before and after an injection.

The goal of the study is to build an on-line feedback system to stabilize the injected bunch, so it's better to leave the beam undisturbed while getting its information. Signals from the electrodes of the bunch-by-bunch position monitor can easily be used to get the positions as well as the filling pattern of the bunch train. The data succeeded the injection were saved for further study.

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The injected bunch can be found by using the filling patterns (as shown in Figure 1). The adjacent bunches are used to interpolate the orbit of the stored bunch and the position of the injected bunch can be obtained by deducting the weighted stored part from the raw position data. The injected bunch can also be separated by decomposing the motion matrix of all bunches by using the singular value decomposition (SVD) [1]. Both methods gave the same—or extremely close—results.

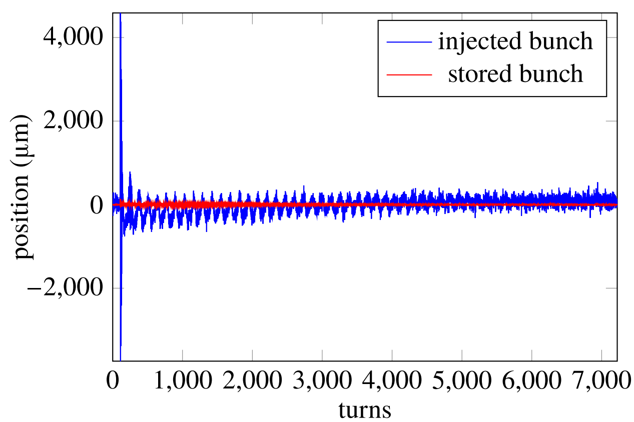

Figure 2: Horizontal positions of the injected bunch separated from the stored one.

The behavior of the stored bunch (red line in Fig. 2) is considered trivial, while the motion of the injected one (blue line in Fig. 2) shows the potential to give more information at the first glance.

A motion matrix was constructed to decompose the source signals. The columns of the matrix are shifted segments of the total waveform, so that the sources (the five major sources are shown in Fig. 3) can be separated after the independent component analysis (ICA) [2, 3]. The waveforms and the spectra (as shown in Fig. 4) of the sources indicates that the motion is dominated by the energy oscillation and its harmonics. The signal source 5 is pure horizontal betatron oscillation, and the rest sources are mixtures of horizontal and vertical betatron oscillations, judged by their characteristic frequencies.

The ICA is a time-consuming and semi-automatic method which requires human interference. Considering the on-line processing requirement in the future, the SVD method would be used and the ICA results would serve as a reference.

The singular values of the aforementioned motion matrix show that only the first ten modes make sense and the rest modes can just be considered as random noise (as shown in Fig. 5). The singular values and the spectra of the left-singular vectors implies that the modes are in pairs and the

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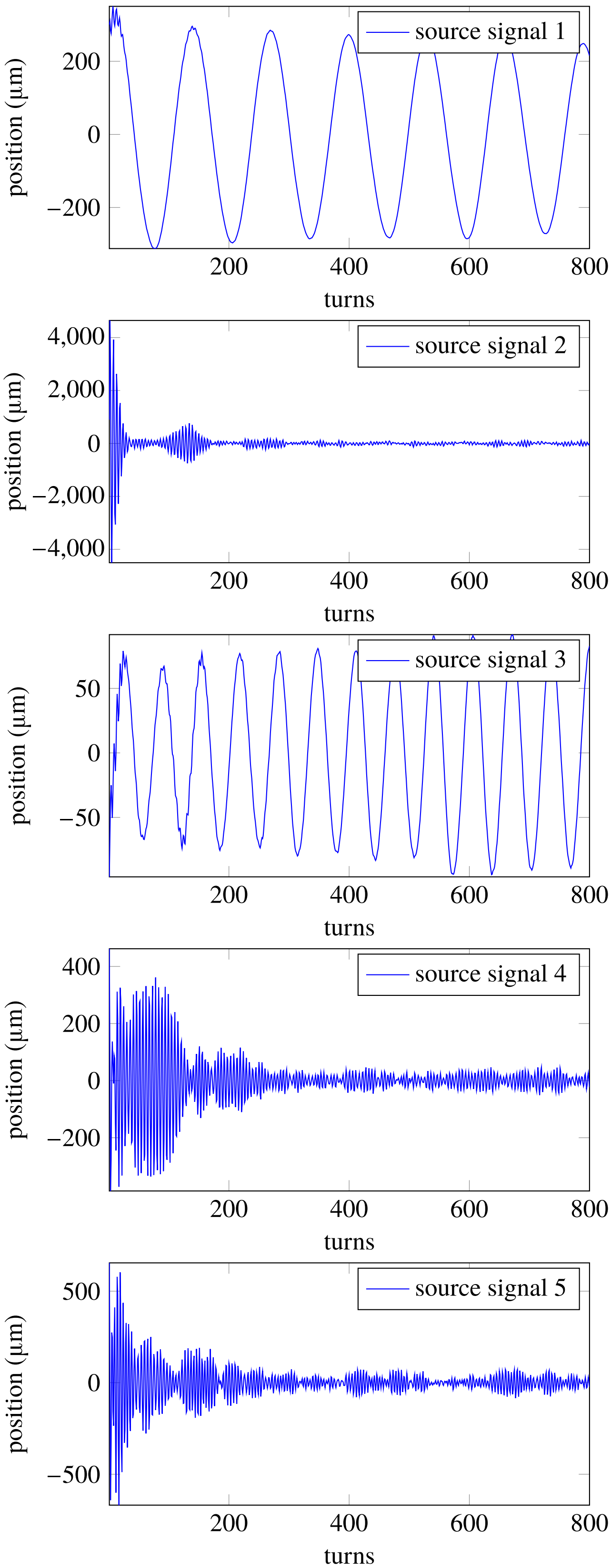

Figure 3: Sources separated from the motion matrix using ICA. The signals 1 and 3 are energy oscillation related and do not decay with time.

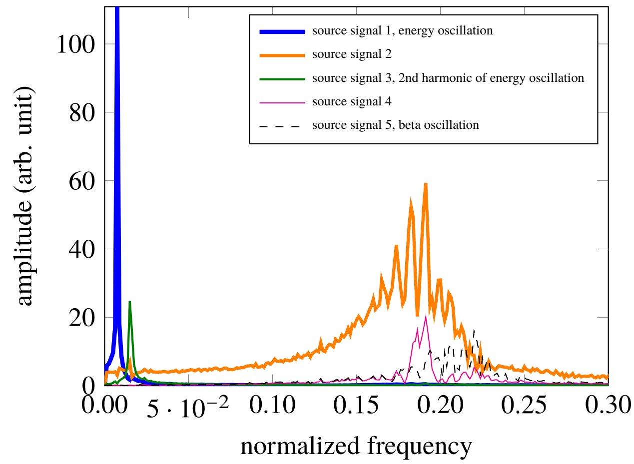

Figure 4: Spectra of the sources in Fig. 3.

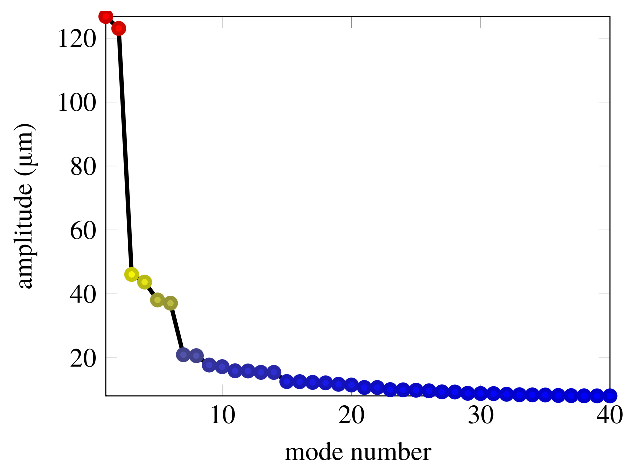

Figure 5: Singular values of different modes.

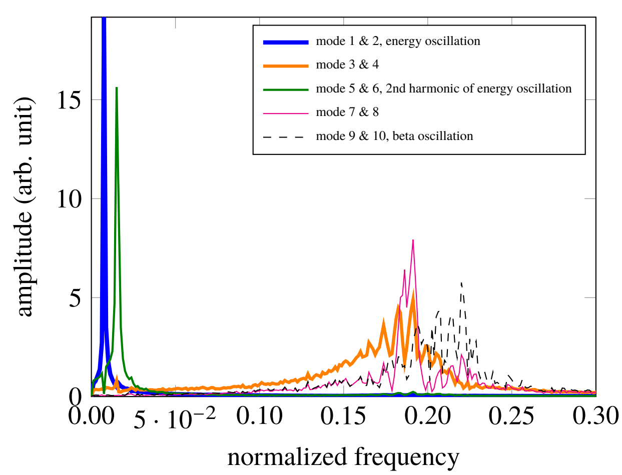

Figure 6: Spectra of the modes separated by SVD.

energy oscillation mode pair is still found to be the dominant modes. Comparing the spectra of both results (as shown in Figs. 4 and 6), the distributions of the components of the separated signals (or the corresponding modes) and their characteristics are roughly the same. It is safe to say that the

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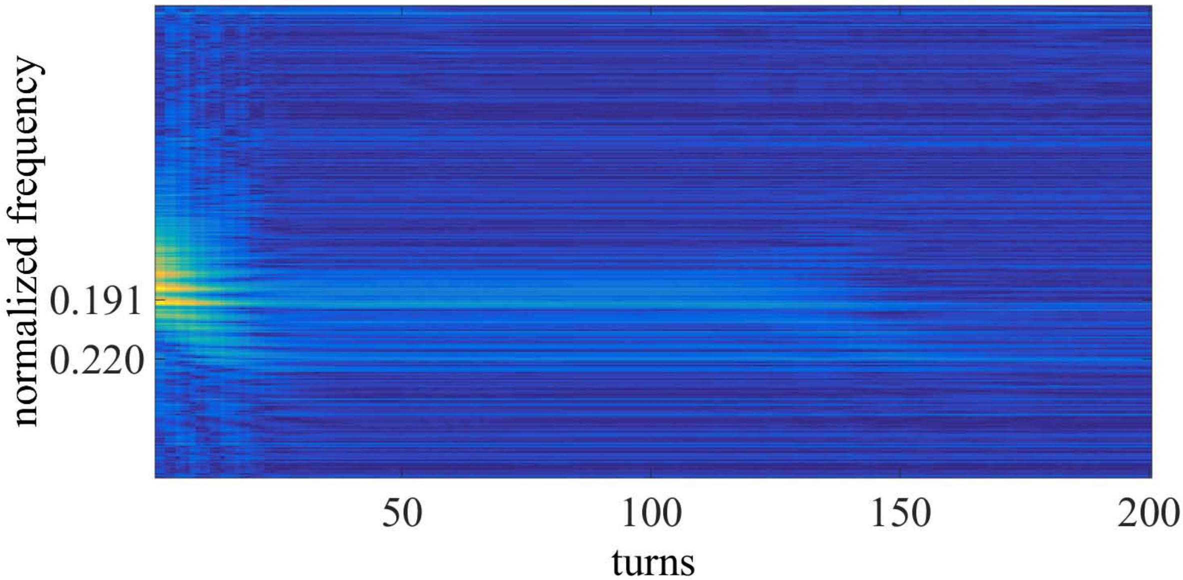

Figure 7: Spectra waterfall of the motion of the injected bunch.

ICA procedure can be replaced by the SVD method in this situation.

The spectrum of the injected bunch (blue line in Fig. 2) is not constant. The waterfall plot of the spectra (as shown in Fig. 7) shows that the distribution of the modes may vary with time. The detailed evolution of the modes can be obtained by using the right-singular vectors of the motion matrix of the injected bunch (as shown in Fig. 8).

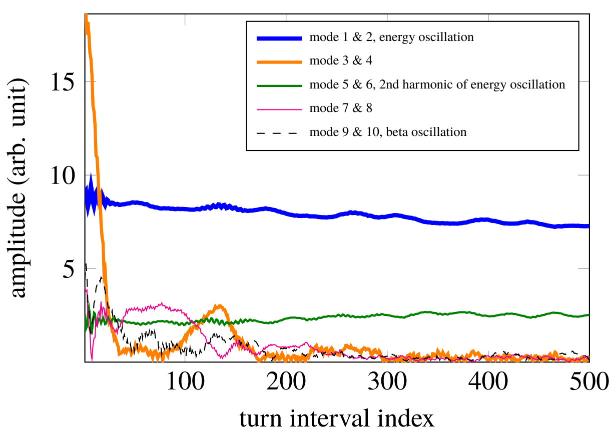

Figure 8: Samples from real measurements and its shifted, scaled reflection signal.

CONCLUSION

The motion of the injected bunch can be extracted from the stored bunch by singular value decomposing. It can be separated into the energy oscillations and the betatron oscillations on-line based on the SVD method. The betatron oscillation due to the mismatch between the transport line and the storage ring decays rapidly within 20 turns.

The second harmonic of the energy oscillation is obvious. The reason might be that the stored bunch and the injected bunch forms a two-body system, so the two parts are interfering with each other.

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