EMBEDDED EPICS IOC DATA ACQUISITION SYSTEM FOR BEAM INSTABILITY RESEARCH

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Abstract

To be a part of beam diagnostics system in SSRF 3.5 GeV electron storage ring, a high performance oscilloscope is introduced to build a bunch by bunch data acquisition and processing dedicated system, which is mainly used to observe individual bunch position in transverse plane and bunch charge. By analysis of Betatron oscillation amplitude distribution and corresponding filling pattern, we hope to find phenomenon about multi-bunch Wakefield effect[1] on beam Betatron oscillation for beam instability research. The system is configured as a scope IOC, and integrated into the EPICS based control system. Application of this system and some data analysis results are also discussed in this paper.

INTRODUCTION

Shanghai Synchrotron Radiation Facility (SSRF) is a low emittance third generation light source located at Shanghai, P. R. China. In the 3.5GeV storage ring, beam is divided into 720 buckets in filling pattern (usually 500 bunches injected in normal case), the RF frequency is about 499.654 MHz, and revolution frequency is 694 KHz.

Beam position monitor (BPM) is an indispensable beam diagnostic tool. In SSRF storage ring diagnostics system, hundreds of BPMs with the four button electrodes distributed around storage ring to monitor signals excited when beam passed though. Libera embedded IOCs with running Linux OS, are launched to accessing BPM signals for beam position measurement. Because of the limitation of Libera front-end sampling rate, Algorithm for this type of device mainly based on under-sampling and digital down conversion in the mode of narrow bandwidth，and get turn-by-turn beam position information by multi-turn fitting and usually used for a long-term stable beam operation.

Our research mainly refers to observe beam transverse oscillation around the time when bunches are injected into storage ring and related data analysis. So bunch-by-bunch beam parameters by direct data acquisition in wide bandwidth mode are needed. For this purpose we employed a Tektronix DPO70604 oscilloscope (6 GHz bandwidth, 25 G/s sampling rate for 4 channels, 8- bit, P4 3.4 GHz CPU, Windows-XP based) to be the core part of the data acquisition system. Similar scopes have been tested and used for data acquisition in KEK[2] and SSRF[3]. In our programming, we have upgraded the device and designed new data acquisition software for a greater data acquisition and processing ability. The Tektronix DPO oscilloscope would be configured as a scope IOC and integrated into EPICS system in SSRF. Data acquisition experiment and data analysis would also be introduced in the following.

SYSTEM OVERVIEW

For this data acquisition system, there are no dedicated front-ends, all front-ends functions are integrated into the DPO scope circuit board. The trigger pulse signals, which are synchronized with the transverse feedback system, are provided to the oscilloscope at the rate of 2 Hz. Newly developed Tektronix DOP digital oscilloscope can flush input data into its memory at the record length of 1000-k for each input port at one time. The four signals coming from one BPM are fed directly to the four corresponding input ports of the oscilloscope, and are digitized at the sampling rate from 10 GHz to 25GHz. Input pulse signal from BPM captured by oscilloscope is showed by Figure 1, and the spectrum data transformed by Fast Fourier Transform(FFT) is charted in Figure 2

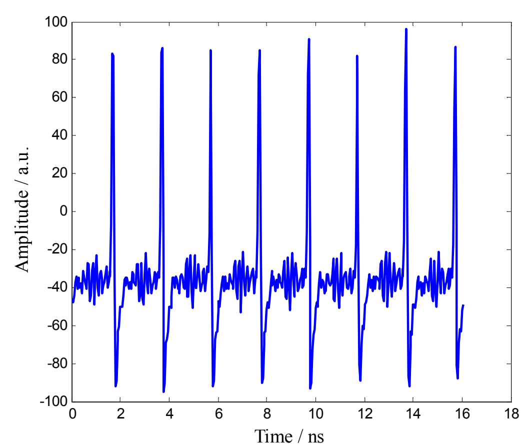

Figure 1: Beam excited BPM signal captured by oscilloscope

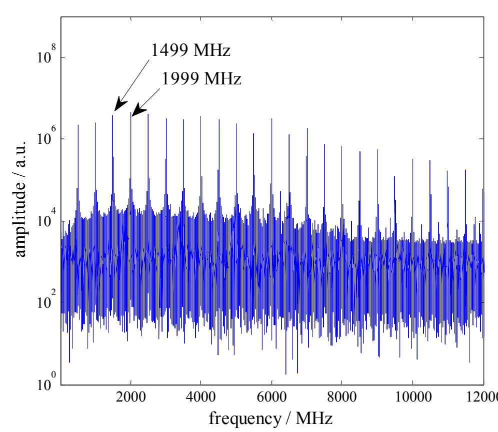

Figure 2: Spectrum data transformed by FFT.

In order to narrow the bandwidth around RF frequency and decrease sampling error, 500 MHz centre frequency band-pass filters were inserted between BPM outputs and oscilloscope. As is shown in Fig.4, the maximum amplitudes correspond to 3rd and 4th harmonic. Hoping to get better signal noise ratio raw data, we also employed 1.5 GHz and 2 GHz centre frequency band-pass filters to replace the 500 MHz ones. For deducing beam position and charge, there are two algorithms: Area or peak-detection algorithm for 500 MHz filtered raw waveform which can be easily achieved by on-line programming; Interpolation FFT algorithm for 1.5 GHz or 2 GHz filtered data which can not be achieved by on-line calculation but off-line analysis due to the limitation of CPU and memory usage. The schematic drawing of the system is shown in Fig.3

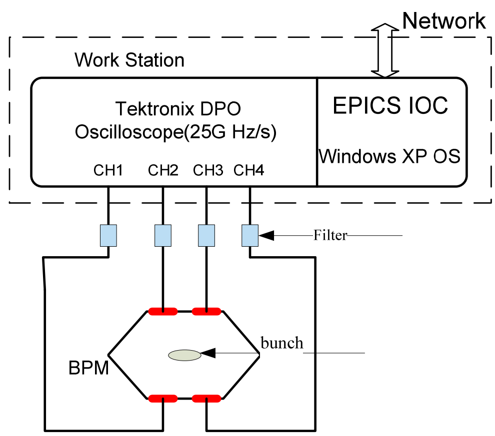

Figure 3: The schematic drawing of the system

Scope embedded IOC software was built by using MS VC++, TekVisa and Epics R3.14.11 library[4]. Raw data stored in memory could be shared by scope command 'Curve' or 'CurveStream', and formatted into Waveform type record. For on-line deducing beam parameters such as bunch position and bunch charge by malti-waveform records analyzing, a new dedicated IOC record and related support was designed. A couple of new algorithms for raw data processing have been employed for present and future usage. This IOC software structure block diagram showed in Fig.4

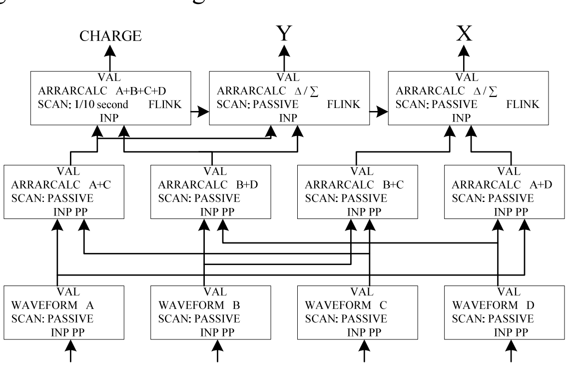

Figure 4: IOC software structure block diagram.

EXPERIMENT AND DATA RESEARCH

For monitoring beam Betatron oscillation amplitude and distribution and corresponding filling pattern, the scope IOC data acquisition system was employed to record raw waveforms from BPM electrodes. For the SSRF storage ring, 500 bunches were stored with tune value 0.22 in horizontal and 0.29 in vertical. The experiment consists of two parts: observing beam Betatron oscillation and filling patterns changes caused by beam injection with transverse feedback system turned on; observing beam Betatron amplitude changes of stored beam with Transverse Feedback System turned off.

Before experiment, 3 types of band-pass filters (500 MHz, 1.5 GHz, 2 GHz center frequency) were tested to evaluate the performance and effects. Fig.5 showed the filtered signal power for the 3 type filters. It is demonstrated that signal filtered by 500 MHz band-pass filter have the maximum frequency amplitude and the performance of other two types were not as good as expected, so 500 MHz filtered data would be chosen for data analysis.

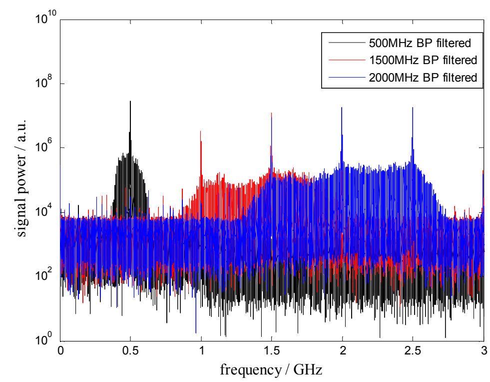

Figure 5: Signal power filtered by 3 types of filter.

Transverse Feedback System Turned On

In this experiment, bunch by bunch position charge data was captured during injection. Fig.6 showed 70 turns position of 6 picked bunches from 10 μs before injection in horizontal. The oscillation amplitude increased greatly after injection.

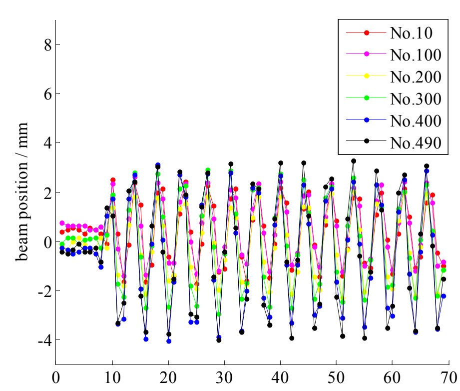

Figure 6: Position of 6 picked bunches in horizontal direction

Betatron oscillation amplitude of individual bunch could be picked up in frequency domain by FFT method. By deducing many sets of data recorded during injection, the amplitude distribution and corresponding filling pattern of all the 500 bunches are acquired. Fig.7 showed the amplitude distributions in 4 types of filling pattern. Amplitude distribution curve in Sample 1 and Sample 4 are of same shape as well as that of their filling patterns, although the beam charge was different.

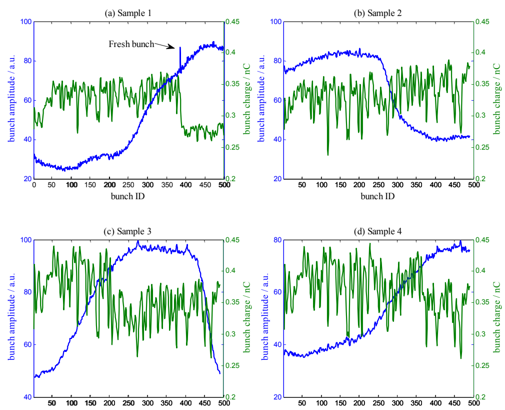

Figure 7: Amplitude distribution curves in horizontal & corresponding filling patterns.

It is clear that in Fig.7 the amplitude from No.1 bunch to No. 500 showed regular changes in the 4 sub-figures. It was speculated that the Wakefield effect from anterior bunches to posterior ones affect differently in different filling pattern. Further research would be done in future. In this figure, it is also shown in Sample 1 that the position of No.386 bunch deviated from the curve of amplitude distribution. Combined with deduced bunch charge, it is demonstrated that the bunch is the injected fresh one which is deviated from equilibrium orbit.

Transverse Feedback System Turned Off

In this experiment, the Betatron oscillation of all stored 500 bunches were recorded and calculated by the oscilloscope data acquisition system. Fig.8 showed the deduced bunch charge, and Fig.9 showed 5 sets of amplitude distribution data of Betatron oscillation in vertical direction.

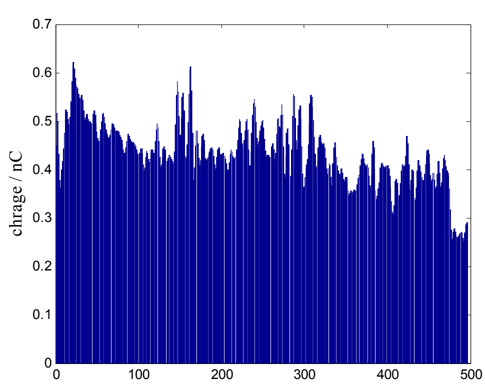

Figure 8: Deduced bunch charge.

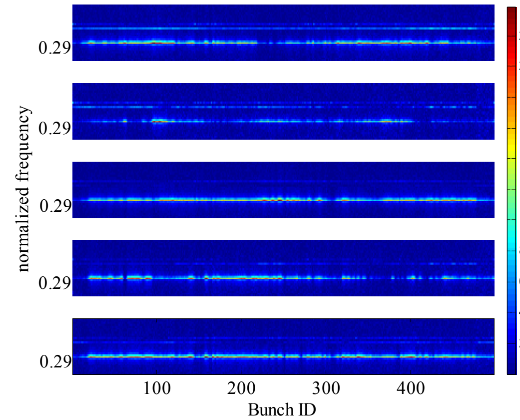

Figure 9: 5 sets of amplitude distribution data in vertical.

Colour showed in colorbar from blue to red express the amplitude strength from weak to strong. The Betatron oscillation amplitude of anterior 20 bunches kept weak, while the amplitude strength of posterior ones distributed randomly. This phenomenon is consistent with our speculation that non-Wakefield keeps the amplitude strength of head beam weak, while Wakefield from head and bunch self-excited oscillation makes the amplitude strength of beam posterior part changed randomly.

CONCLUSION

Parameters of Betatron oscillation could be acquired by the oscilloscope data acquisition system. For transverse feedback system turned on, Betatron amplitude distribution in different filling patterns is charted. While for feedback system turned off, the amplitude distribution could reflect Wakefield effect and bunch self-excited oscillation. More accurate designed experiments are needed for further research, which would be done recently.

ACKNOWLEDGEMENTS

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EFERENCES

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