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TEST OF THE TUNE MEASUREMENT SYSTEM BASED ON BBQ AT HLS-II STORAGE RING*

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Abstract

The HLS-II storage ring is a crucial part of Hefei Light Source. Tune is one of the most important parameters of the electron storage ring, of which the tune measurement system is an integral component. In this paper, the design of a new tune measurement system based on BBQ (base band tune), is presented. Some experiments are performed to test this system. The new system is compared with the original system and the TBT (turn-by-turn) method respectively. The obtained results illustrate higher accuracy and higher stability for the new system. A new approach of calculating the betatron oscillation amplitude is proposed, and the betatron oscillation amplitudes in the normal running stage for the HLS-II storage ring are estimated at 95 nm (horizontal) and 60 nm (vertical).

INTRODUCTION

Traditional tune measurement method [1] is based on linear processing of the signals from beam position PU (pick-up), that is, directly analyzing the frequency spectrum of the beam position signals. Generally speaking, in traditional method only one or a few betatron sidebands on the revolution harmonics near the baseband are taken into account. Therefore in traditional method, it is usually necessary to properly excite the storage ring beam in order to effectively detect the tune content. The disturbance to the beam makes traditional tune measurement greatly limited in the application. 3D (Direct Diode Detection) method uses a simple peak detector to extend the short bunch pulse signals from the beam position PU in time domain. While maintaining betatron modulation, it moves most of the betatron oscillation energy to the baseband, so that the resulting betatron signal intensity on the concerned sideband is several orders of magnitude larger than in traditional method [2].

Considering the advantages of 3D, a new tune measurement system based on BBQ using 3D technique is designed customizedly for the HLS-II storage ring. Some comparisons are made with the original system and TBT method respectively, and the results illustrate high accuracy and high stability of the new system. In addition, a new method calculating the betatron oscillation amplitude is brought forward, and the betatron oscillation amplitudes in the normal running stage for the HLS-II storage ring are estimated.

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BBQ FRONT-END AND NEW TUNE MEASUREMENT SYSTEM

A BBQ front-end based on 3D technique has been specially designed for HLS-II storage ring. 3D-based BBQ front-end schematic block diagram and physical picture are shown in Fig. 1 and Fig. 2 respectively.

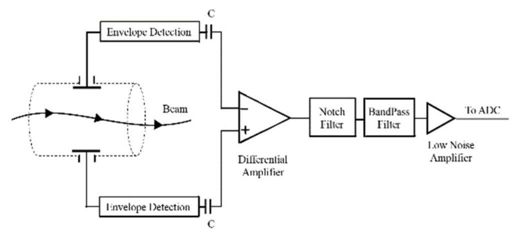

Figure 1: 3D-based BBQ front-end schematic block diagram.

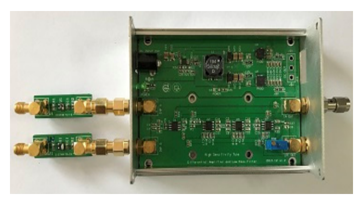

Figure 2: 3D-based BBQ front-end physical picture.

After the beam signals from beam position PU are input into BBQ front-end, the coupled signals are detected by utilizing a kind of envelope detection technology (3D in this paper) at first. Furthermore the opposite electrode signals after the detection processing are input into the differential amplifier via AC coupling. AC coupling is applied in BBQ front-end to remove the DC content of the signals. For the purpose of reducing the impact on the detection circuit, the input impedance of the differential amplifier should be as high as possible. Finally the differential signal after subtraction is filtered by a customized filtering circuit to filter out the signal content of revolution frequency and revolution harmonics. This kind of filtering processing effectively improves the power component at the tune frequency. The customized filtering circuit can be achieved by series-connecting a notch filter and a band-pass filter.

The newly designed tune measurement system is based on the BBQ front-end mentioned previously, as shown in Fig. 3. The new tune measurement system consists of three parts [3]: signal processing module, beam excitation module, and central controlling PC. Signal processing module includes a button BPM, a BBQ front-end, and a

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spectrum analyzer. Agilent N9000AEP Signal Analyzer serves as the spectrum analyzer, and meanwhile it also has a SFE (sweep-frequency excitation) output, which can be used as an excitation source. Beam excitation module includes a transverse dipole stripline kicker, a manually adjustable attenuator, a gain-fixed active amplifier, and selectable excitation sources. There are two kinds of optional excitation sources: Agilent N9000AEP Signal Analyzer provides SFE signal and Altera FPGA development board provides BWNE (band-limited white noise excitation) signal. The central controlling PC is responsible for the control of excitation sources, and analyzing the data from the spectrum analyzer.

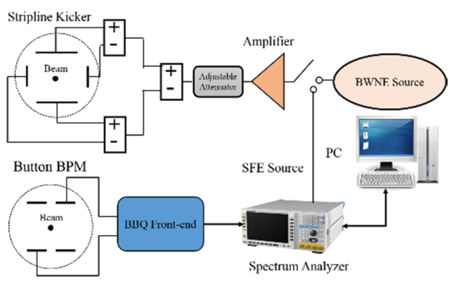

Figure 3: The new tune measurement system based on the BBQ front-end.

EXPERIMENTS ON THE NEW TUNE MEASUREMENT SYSTEM

Comparison between the New System and the Original System

In order to learn about the performance of the new tune measurement system more intuitively, we did some experiments on the new BBQ-based system and the original system for comparison. The original system takes traditional tune measurement method without BBQ front-end, using a stripline BPM instead of a button BPM, as shown in Fig. 4. Agilent N9000AEP Signal Analyzer is employed both to generate the excitation signal and to analyze the beam signal spectrum.

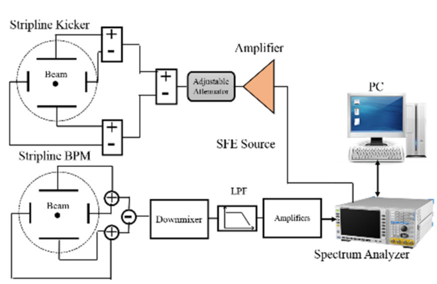

Figure 4: The original tune measurement system.

Both systems consider SFE, and the sweep-frequency range is set from 2.1 MHz to 3.5 MHz, which covers the tune-related frequencies in both horizontal and vertical directions. Fixing SFE power, the spectrum data from the spectrum analyzer is analyzed by PC to get the tune value and amplitudes corresponding to this SFE power. By changing SFE power as mentioned above, the tune values and amplitudes corresponding to different SFE powers can be obtained.

The tune value results (q_x and q_y, respectively the fractional part of horizontal and vertical tune value) are, 0.44445±0.00004 (horizontal) and 0.36979±0.00006 (vertical) in the new system, 0.44448±0.00004 (horizontal) and 0.36971±0.00004 (vertical) in the original system, respectively. The results of both two systems are shown quite consistent, and the tune values are found to remain almost the same with SFE power changing. Fig. 5 shows screenshots of the spectrum analyzer when the two systems were separately measured. It is very obvious that the horizontal tune amplitude of the new system is much higher than that of the original while the original system behaves a little bit better than the new in the vertical tune amplitude.

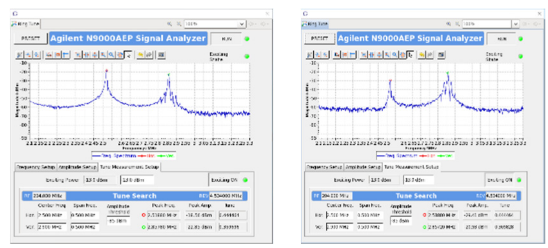

Figure 5: Screenshots of the spectrum analyzer when the two systems were separately measured. (left figure) new system; (right figure) original system.

The tune amplitudes of both two systems change linearly with SFE power, as shown in Fig. 6. It can also be seen from Fig. 6 that when SFE power is hold the same, the horizontal tune amplitude of the new system is about 11.2 dB higher than that of the original system, and around 2.3 dB lower in the vertical direction. The horizontal result meets our expectation, but the vertical doesn't. There are two possible reasons to explain the unexpected result: The beam induced signal of stripline BPM used on the original system is much stronger than that of button BPM for the new system; the two electrodes of button BPM of the new system are too far vertically compared to the horizontal situation, which causes the induced signal is quite unsensitive to the vertical betatron oscillation.

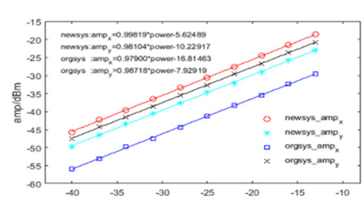

Figure 6: The tune amplitudes of both two systems varying with SFE power.

Comparison with the TBT Method

BWNE signal generated by beam excitation module of the new tune measurement system is used to motivate the betatron oscillation, as shown in Fig. 7. The Libera beam position processor obtains different kinds of beam position data and TBT data can be used to measure the tune

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values. FFT analysis is performed on the TBT data, and the tune values and amplitudes can be obtained from the transformed spectrum, as shown in Fig. 8.

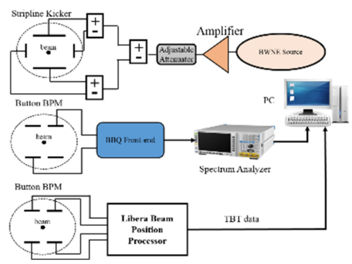

Figure 7: The experiment block diagram of comparing the new system with the TBT method.

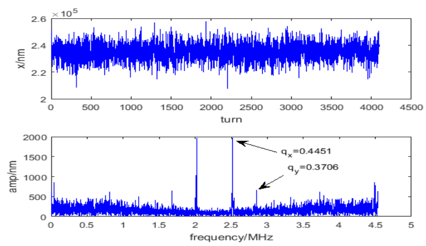

Figure 8: Analyzing TBT data to obtain tune information.

The new system works at the same time. The attenuator of the beam excitation module is manually adjusted to change the intensity of BWNE, and accordingly acquire the tune amplitudes corresponding to different BWNEs, as shown in Fig. 9.

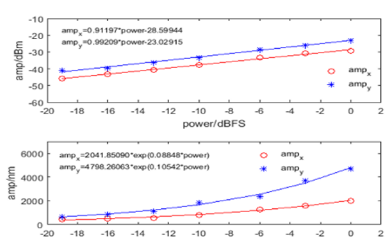

Figure 9: The tune amplitudes of both two methods varying with BWNE power (top: new system; Bottom: TBT).

The tune value results are, 0.44508±0.00039 (horizontal) and 0.37045±0.00034 (vertical) in the new system, 0.44491±0.00022 (horizontal) and 0.37022±0.00022 (vertical) by the TBT method, respectively. The tune values obtained by the two methods are almost the same, which reflects high accuracy and high stability of the new system again. The tune amplitudes obtained by the new system change linearly with the BWNE intensity, while the tune amplitudes obtained by the TBT method change approximately exponentially with the BWNE intensity, as indicated in Fig. 9.

The relation between the tune amplitudes calculated by the two methods can be concluded and an exponential fitting analysis is performed, as shown in Fig. 10.

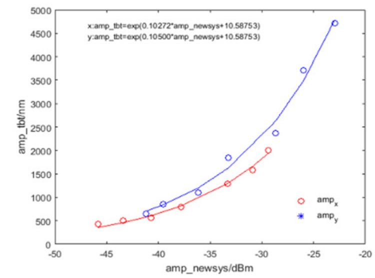

Figure 10: The relation between the tune amplitudes calculated by the two methods.

Since the tune amplitude calculated by the TBT method is equivalent to beam betatron oscillation amplitude, the betatron oscillation amplitude can be estimated by using the fitting result when provided the tune amplitude measured by the spectrum analyzer. When HLS-II is in normal operation (without any excitation), the tune amplitudes of the storage ring are -58.70 dBm (horizontal) and -61.80 dBm (vertical) respectively, as shown in Fig. 11. The betatron oscillation amplitudes estimated according to the above method are 95 nm (horizontal) and 60 nm (horizontal), respectively.

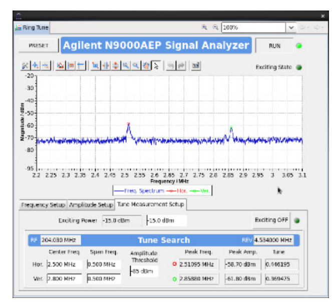

Figure 11: The tune amplitudes of HLS-II in normal operation.

CONCLUSION

This paper has introduced the design of the new tune measurement system based on BBQ for HLS-II storage ring. It has been shown to be very accurate and stable compared with the original system and the TBT method. The betatron oscillation amplitudes are reckoned according to the fitting results above, at 95 nm (horizontal) and 60 nm (horizontal), respectively.

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