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BUNCH-BY-BUNCH 3D MEASUREMENT SYSTEM IN HLS-II*

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Abstract

In order to improve the performance of Hefei Light Source (HLS-II) , it is necessary to study various problems of nonlinear beam dynamics in the storage ring, so as to optimize the beam filling mode and injection mode, and then improve the intensity and brightness of HLS-II. In beam dynamics, bunch-by-bunch can provide detailed information of beam bunches and help beam researchers to study the problems of beam bunches deeper. Therefore, HLS-II diagnostics group has developed an on-line bunch-by-bunch three-dimensional measurement system based on high bandwidth and high speed oscilloscope.

SYSTEM STRUCTURE AND FUNCTION OVERVIEW

The measurement system uses SDS6204 H12 Pro oscilloscope of Siglent company [1] as the front end of signal processing to collect bunch-by-bunch signal. The front-end oscilloscope uses the 0.1Hz trigger signal provided by HLS-II timing system. The signal processing back-end of the system is the win10 virtual machine created by Zstack IAAs platform [2]. In the back-end, all signal processing programs are written with LabVIEW. In these programs, calab writes the PV variable of EPICS into the IOC of CentOS system, and then displays the results of back-end signal processing through OPI, as Fig. 1.

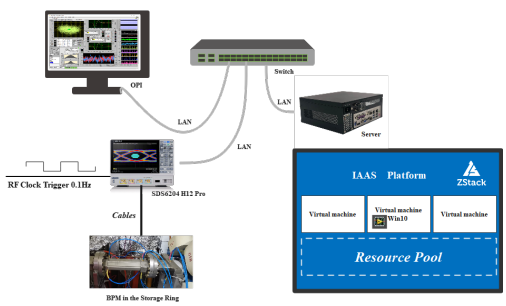

Figure 1: Overall structure of the system in HLS-II.

Driven by the 0.1 Hz trigger signal, the system updates every 10 seconds. Each time it is triggered, the back-end program will collect waveform data from four channels of BPM for 500 µs. The waveform data records 2266 circles of bunch-by-bunch. Through these data, various information of bunch-by-bunch can be calculated, such as time, amplitude, intensity and transverse information. Moreover, the system can obtain turn-by-turn information and the tune of each bunch through the waveform data.

OPI INTERFACE

Templates are provided for recommended software and authors are advised to use them. Please consult the individual conference help pages if questions arise.

After obtaining the three-dimensional information of bunch-by-bunch, the 3D position information of 2266 circles of bunch-by-bunch can be displayed through the three views function of OPI interface to clarify the distribution of the bunch-by-bunch centroid. As shown in Fig. 2, the OPI interface shows the bunch-by-bunch three-dimensional centroid distribution under the normal state, while in Fig. 3 it shows the bunch-by-bunch three-dimensional centroid distribution under the injection state. In the three views on the left are measured by stripline BPM and the three views on the right are measured by button BPM. And different colors in three views represent the average results of different numbers of bunch-by-bunch bunches.

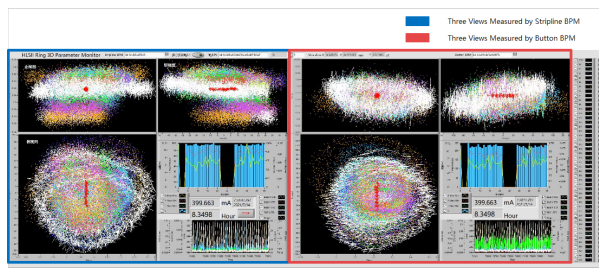

Figure 2: Three views under the normal state.

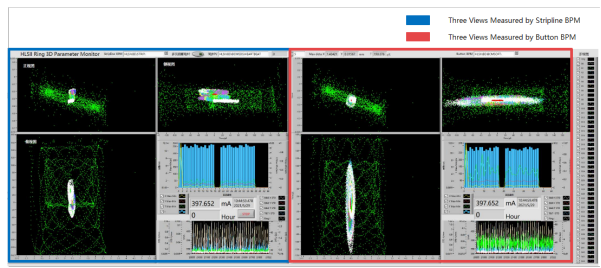

Figure 3: Three views under the injection state.

Moreover, the OPI interface also provides bunch-by-bunch tracking interfaces to track a specific bunch, as shown in Fig. 4. In Fig. 4(a), the upper left part is a two-dimensional diagram of the bunch-by-bunch current intensity. For this part, the abscissa is the number of 45 bunches in one circle, and the ordinate is the number of cycles of bunches running in the storage ring, while its colors indicate different current intensities. The lower left part shows the average current intensity of 2266 cycles for each bunch in

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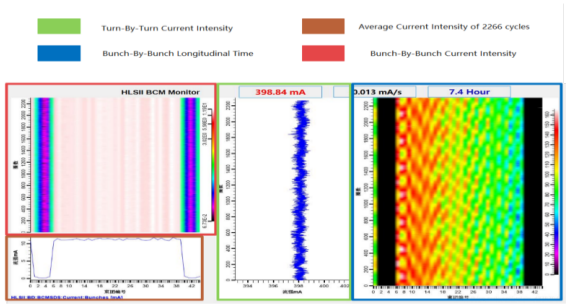
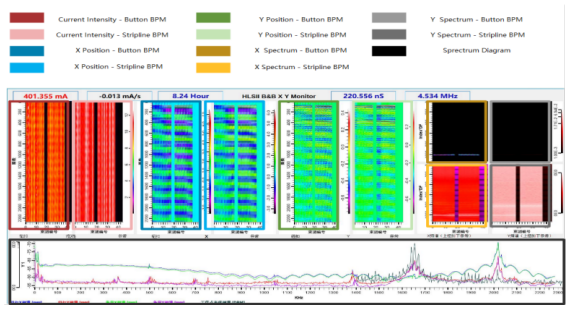


(a)



(b)

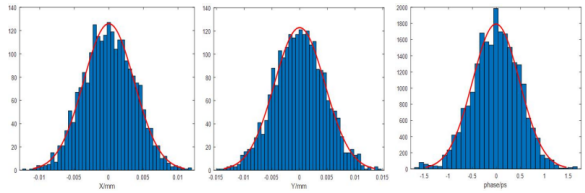
Figure 4: Bunch-By-Bunch tracking interface.

the storage ring. The middle part is the turn-by-turn current intensity curve, in which the abscissa is the current intensity and the ordinate is the number of cycles. The right part is a two-dimensional diagram of longitudinal time, its abscissa and ordinate is the same as the upper left part, while its colors represents different longitudinal times. In Fig. 4(b), all the diagrams except the "Spectrum Diagram" below has the same abscissa and ordinate as bunch-by-bunch current intensity diagram in Fig. 4(a). And their colors represent their corresponding bunch-by-bunch information shown in Fig. 4(b) legend. At the end, the spectrum diagram of the interface shows the transverse spectrum information. In this part, the tune can be clearly found.

SYSTEM ERROR ANALYSIS

Due to the couple of longitudinal oscillation to transverse direction, gyration can be observed in bunch-by-bunch three-dimensional centroid distribution OPI interface. After removing the low frequency part "gyration", the measurement error can be analyzed by calculating the standard deviation STD. The following figure Fig. 5 shows the distribution of the measurement of one bunch after excluding its low frequency part, corresponding to x, y and z. The STD of x, y and z are respectively 3.8 µm, 4.2 µm and 0.4 ps, their corresponding round up is 5 µm, 5 µm and 0.5 ps.

In order to further analyze the measurement error, the bunch-by-bunch three-dimensional system needs to be compared with Libera B+ commercial system. For three-dimensional system, the transverse information of each bunch obtained at trigger time can obtain the information of turn-by-turn, fast acquisition (FA) at 44 kHz and medium



(a) (b) (c)

Figure 5: Three dimensional error analysis diagram.

speed acquisition (MA) at 2kHz. While Libera B + commercial system measures slow acquisition (SA) at 10 Hz only. For comparison between three-dimensional system and Libera B+ commercial system, 200 points extracted from MA in three-dimensional system need to be averaged and then compared to Libera B+ commercial system's SA results. As in Fig. 6, it shows the STD results of one bunch measured by the three-dimensional bunch-by-bunch system. While Fig. 7 shows the measurement results of one bunch in close orbit diagnostics (COD) measured by Libera B+ commercial system.

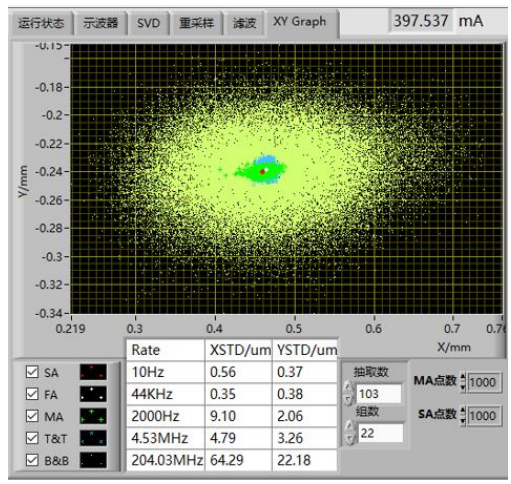


Figure 6: STD in three-dimensional system

Figure 7: Measurement results of Libera B+.

For short time measurements in Figs. 6 and 7, the STD of SA transverse data of 32 BPMs in COD system measured by Libera B+ is within 1 µm, while the STD of SA

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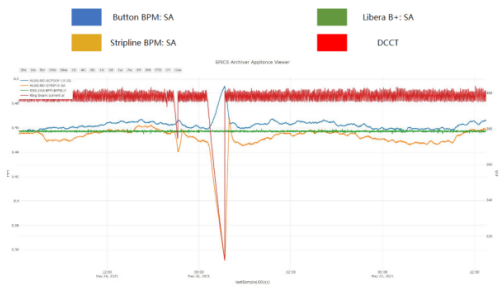
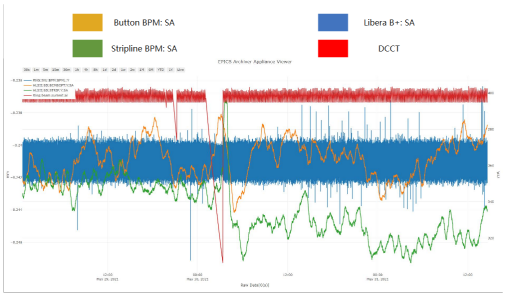
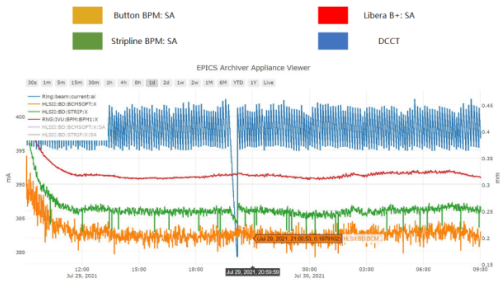


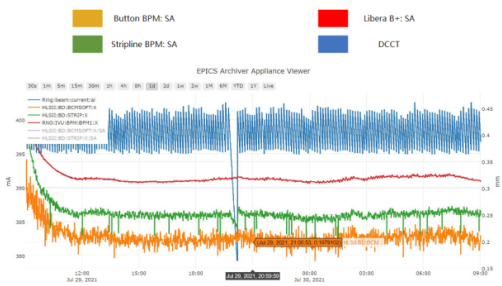
(a) X Direction Measurements with COD



(b) Y Direction Measurements with COD



(c) X Direction Measurements without COD



(d) Y Direction Measurements without COD

Figure 8: The measurements for long time.

transverse data averaged by oscilloscope is equivalent to it. Obviously, the performance of the two systems is equivalent in the short time measurements. Therefore, long time measurement comparison is required. The following Fig. 8 shows the measurements of three-dimensional system and Libera B+ commercial system for 2.5 days.

For long time measurements in Fig. 8, the SA STD of Libera B+ is stable within the range from 3 μm to 4 μm. However, for three-dimensional system, the SA STD of X direction fluctuates at 20 μm and the SA STD of Y direction fluctuates at 10 μm. This fluctuation is supposedly related to the temperature control mechanism of front-end oscilloscope and the signal channel inconsistency for long-term operation. At the same time, the measurement results of the three-dimensional system are strongly dependent on the current intensity. Further study is needed for all these phenomenon.

CONCLUSION

The bunch-by-bunch three-dimensional system has been working online in HLS-II. Based on the data generated by this system, a variety of bunch-by-bunch information can be easily obtained. Further, the version 1.0.X of this bunch-by-bunch three-dimensional system, now is open source on gitee [3], can easily set parameters to fit all light sources. And the next version system in plan will focus on the six-dimensional bunch-by-bunch centroid.

REFERENCES

[1] SDS6204 H12 Pro oscilloscope, https://www.siglent.com/products-model/sds6000-pro/#navs

[2] Zstack IAAS Platform Website, https://www.zstack.io

[3] Gitee Open Source Archives, https://gitee.com/lup9304/Ring3D