THE BPM MEASUREMENT SYSTEM IN HIRFL-CSR *

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Abstract

HIRFL-CSR [1], a new heavy ion cooler-storage ring in China IMP, had been installed and started commission from 2005. We report here the BPM system on the main ring (CSRm) and the experimental ring (CSRe). The BPM structure, the signal processing system and on-line measurement experiments are presented. The measurement results such as turn-by-turn bunch observation, closed-orbit measurement, Schottky noise measurement are also presented in this paper.

INTRODUCTION

HIRFL-CSR is a new heavy ion cooler-storage ring synchrotron system in Lanzhou. It consists of a main ring (CSRm) and an experimental ring (CSRe) with multi-usages and multi-functions, shown in Fig. 1. The two existing cyclotrons SFC (K=69) and SSC (K=450) of the Heavy Ion Research Facility in Lanzhou (HIRFL) are used as its injector system. The heavy ion beams from HIRFL with the energy of 7-25MeV/u will be first injected into CSRm, accompanying with the accumulation, e-cooling and acceleration, and finally extracted slowly with the energy of 500-1100MeV/u for many external-target experiments, or extracted fast with the energy of 200-700MeV/u to produce radioactive ion beams (RIBs) or high Z beams at the primary target of the beam line. The secondary beams will be accepted and stored in CSRe for many internal-target experiments. From 2006 to 2008 all the commissioning activities of HIRFL-CSR were made, including stripping injection, multi-turn injection, cooling accumulation with hollow electron beams, ramping in a wide range with different RF harmonics, isochronous mode commission of CSRe, mass measurement of RIBs in CSRe with ToF and slow extraction from CSRm.

As the eyes of an accelerator, the diagnostic system is built together with the construction of the CSR. The whole CSR commission was proceeded and succeeded with the support and help of it. Of course the BPM system is the key part of the diagnostic system. The shoe-box type BPMs are used in CSR because of its good linear dependence with respect to the beam displacement [2]. There are 16 BPMs distributed around the CSRm and 11 around the CSRe. The structure is shown in Fig. 2. The length of the BPM is 300 mm and the cross section is 170*110 mm^2 for the CSRm and 250*130 mm^2 for the CSRe. To avoid the influence of the beam injection and extraction of the CSRm, the dimension of the BPM at these two positions is larger than others and its cross section is 240*170 mm^2.

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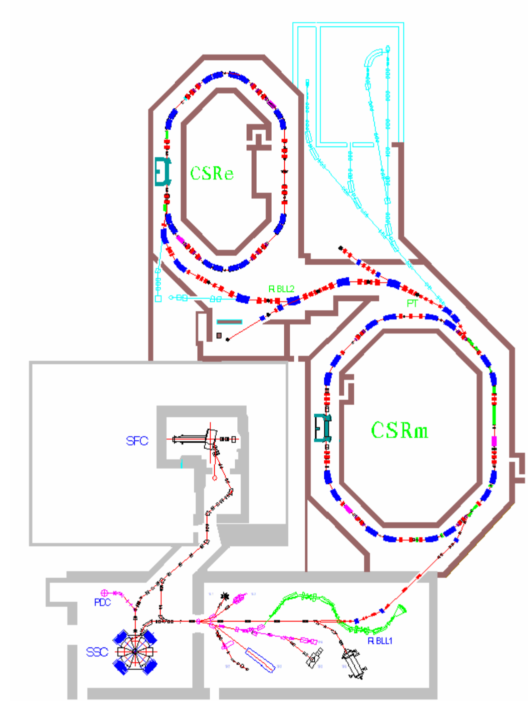

Figure 1: Overall layout of HIRFL-CSR.

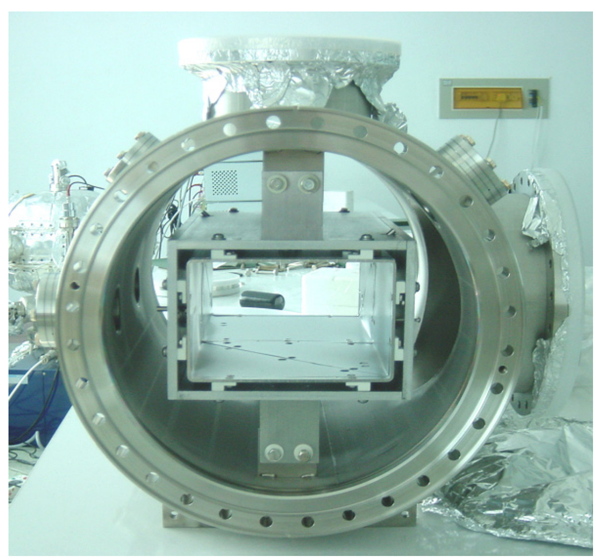

Figure2: The BPM structure of HIRFL-CSR.

BPM PROCESSING SYSTEM

As the beam frequency is low in CSR and the range of the frequency is 0.25~1.7MHz in CSRm and 0.5~2.0MHz in CSRe. So the broadband processing is used in the CSR BPM system, as in Fig.3. After pre-amplification, the BPM signal is directly digitized by a fast ADC. The low-noise amplifier has the bandwidth of DC-1GHz, the gain of 52dB and the noise figure of 1.7 $\mu V/\sqrt{Hz}$. It has a good stability and linearity in the dynamic range. Then the plate signal is digitized with the NI PXI-5105. This digitizer has a 12-bit vertical resolution rate, 60 MS/s real-time sampling rate and 60 MHz analog bandwidth. After that, the digitized signals are done by the LABVIEW software to get the beam signal, beam position and orbit, to do the Fourier transform to get the beam frequency, energy, frequency spread and also the tune value of the machine and so on. The trigger of the ADC is from the accelerator trigger system and the sampling time can be controlled precisely. We can also put the amplified pickup signal directly into the spectrum analyzer through the switch to look at the longitudinal or transverse spectrum, the ramping process and to do the Schottky noise analysis.

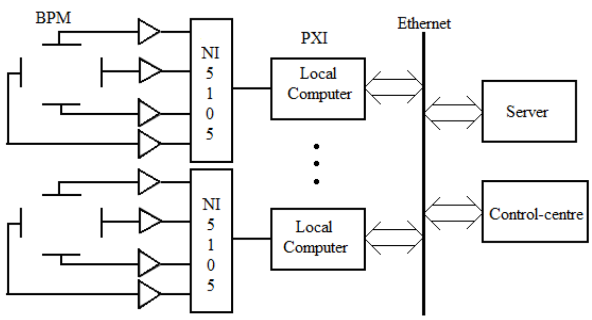

Figure 3: BPM processing system setup.

BEAM MEASUREMENT RESULTS

The BPM system played a vital role during the commissioning of the HIRFL-CSR. As mentioned above, we use the broadband processing system, so the single bunch can be monitored, turn-by-turn [3]. Figure 4 is the stored beam signal of C^{6+}- 6.89MeV/u from a BPM at the beginning of the CSRm commissioning. In this case the RF system of the CSRm wasn't used, thus the bunched beam from the cyclotron SFC would become as a costing beam gradually after the single-turn stripping injection, and the beam signal from BPM also became weak turn by turn. At the 20th turn the beam signal had already become very weak. Figure 5 is the BPM signals measured from a C^{6+} beam with the energy of 600MeV/u in CSRe. The four channels from up to down correspond to the signals from four electrodes of one pickup: left side and right side for horizontal measurement, upside and downside for vertical measurement. From that we can see that there was an oscillation in the vertical direction. The interval between the two signals is 0.557µs and that was the right revolution time of the beam at that energy in the CSRe.

Figures 6 and 7 are the longitudinal and transverse Schottky spectrum measurement in CSRe done by the LABVIEW software. From the results we got that the momentum dispersion was 2.39E-4, the tune value in x plane was 2.5177 and in y plane it was 2.5239. The designed tune value is 2.5300 in horizontal plane and 2.5258 in vertical plane. In Fig 7 there are 4 sidebands in each plane. But two of them are real transverse sidebands and the other two are the coupled signals from the other plane. We judged that by adjusting the corresponding quadruple magnet, if we adjust the quadruple strength in horizontal direction, then the horizontal sidebands would move, so from that we could distinguish them.

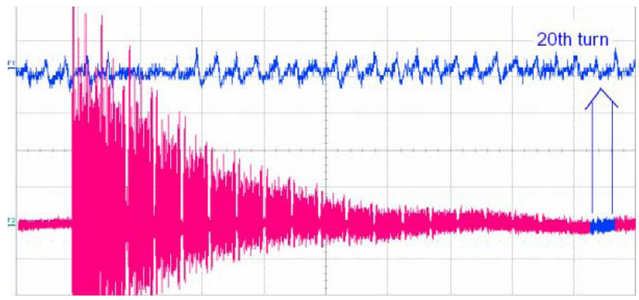

Figure 4: The stored beam signal from BPM in CSRm.

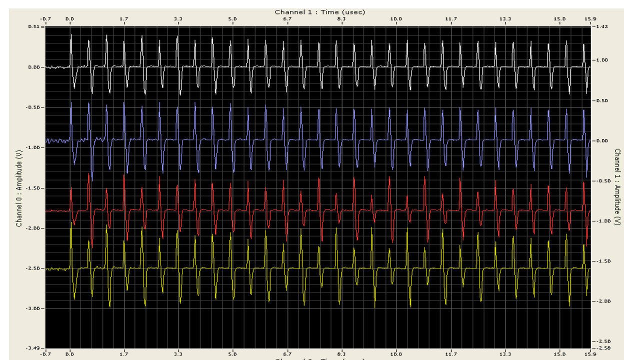

Figure 5: BPM signal from CSRe.

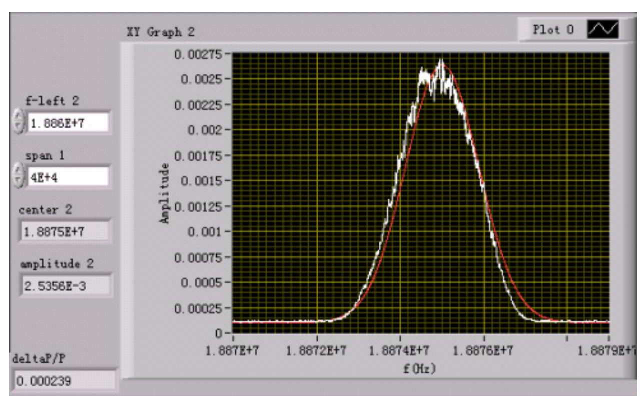

Figure 6: Momentum dispersion measurement in CSRe.

The closed-orbit measurement and correction were also done with the BPM system. Figure 8 is one of the closed-orbit measurement results in horizontal and vertical plane of CSRm. Furthermore, the BPM system can give the information about betatron and synchrotron oscillations, transfer functions, betatron amplitudes, and many other static and dynamic beam parameters.

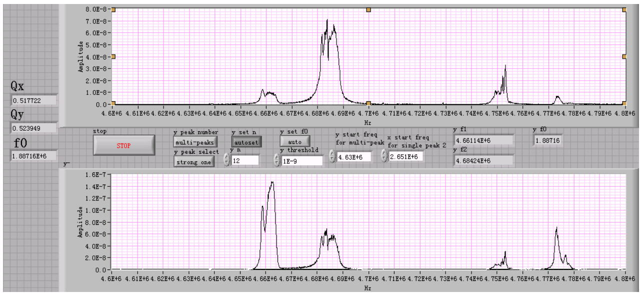

Figure 7: Tune measurement in CSRe.

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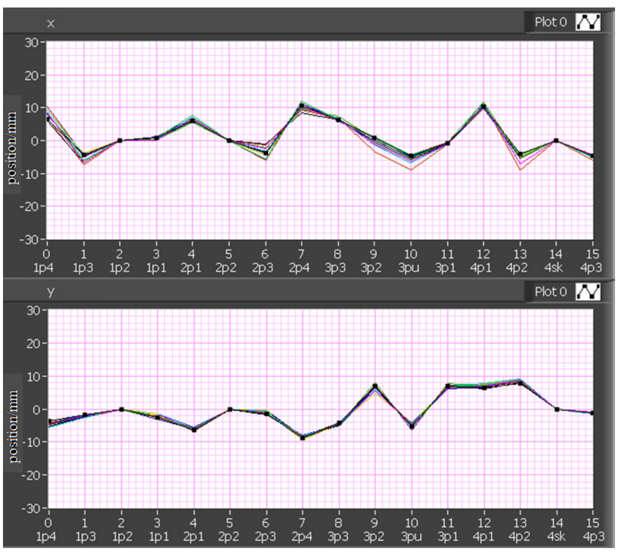

Figure 8: Closed orbit measurement of CSRm.

CONCLUSION

So far the BPM system has been successfully used in HIRFL-CSR. But for very weak beam or single particle measurement, it is impossible because the sensitivity is too low and the noise is too large. Now we are doing a resonant pickup to measure the very weak beam or single particle.

REFERENCES

[1] J.W. Xia et al, “Construction and commissioning of the HIRFL-CSR”, APAC’04, Indore, India, Feb. 2007, THXMA03, p. 534.

[2] Peter Fork, “Lecture Notes on Beam Instrumentation and Diagnostics”, Joint University Accelerator School, January – March 2008.

[3] G. Vismara, “The comparison of signal processing systems for beam position monitors”, DIPAC 1999, Chester, UK, p.12.