

## THE CALIBRATION OF SSRF BPM

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### Abstract

The test bench of beam position monitor for SSRF, as one of preliminary hardware items, have been completed in the beginning of this year. It was the beam position monitor and test bench. It will be used to test different kind beam position monitor of SSRF. The PC computer controlled test set consists of BERGOZ BPM module, a movable wire to simulate the beam, digital multimeter and programmable logic controller(PLC). Labview Test Executive toolkit has used for controlling and managing test operation in this system. This paper describes this automated test and measurement system and some test result.

### 1 INTRODUCTION

Stability of the closed orbit is essential for stable operation of storage ring of Shanghai Synchrotron Radiation Facility (SSRF). To stabilize the beam orbit, the absolute beam position must be measured. So we must calibrate each beam position monitor to know the location of the electric center and relative to the reference frame of each BPM.

There are several kinds of BPM, 54 BPMs for Booster, 150 BPMs for storage ring, and other 9 BPMs for transport line. These BPMs are different from diameter of chamber, and the BPM head, which are very important to the BPM performance. In order to test characterize, align, and provide data for calibration, a general purpose test stand was designed and constructed. The calibration data acquisition system based on LabVIEW programming toolkits allows for easy development of custom routines for automatic testing and measurement.

### 2 CALIBRATION TEST STAND

#### 2.1 BPM block

The vacuum chamber of SSRF storage ring is ellipsoid, with the 40 mm on the vertical dimension, 70mm on the horizontal dimension. Taking account of the heating problem of the pickup power and the enough sensitivity of beam position, we adopted a small diameter ( $\Phi 15\text{mm}$ ) of the electrode. To reduce the mechanical surveyment for the BPMs with the same vacuum chamber dimensions, we designed the new BPM structure, as shown in figure 1.



Figure 1: The BPM for SSRF storage ring

The BPM is comprised of two halves, opposite to each other in the vacuum chamber on the vertical dimension. The halves are assembled on the vacuum chamber by a flange, assuring gas leak no more than  $1 \times 10^{-10}$  Torr·l/s. There are two electrodes in each halves, with the 25 mm distance between electrodes. The halves are made of stainless steel, isolated the electrodes and feedthroughs with ceramic material. The electrode surface is smoothed with that of the vacuum chamber, so the impedance induced by the electrode may be reduced greatly.

#### 2.2 Test stand

In order to calibrate different BPMs, facilitating mechanical surveyment of BPM and calibration, we designed and constructed a general purpose test stand. The picture of the test stand is shown in Figure 2.

Some methods have been used for electrical calibration of BPMs. To simulate the real beam travelling through the BPM more accurately, we send a continuous 500MHz RF signal down a stretched wire through the BPM. The wire, which diameter is 100  $\mu\text{m}$ , is made of tungsten material and impedance matched on both terminals. The wire is moved by the x-y positioning tables in a grid patten, while the BPM block is fixed by the BPM mounting fixtures.

The x-y positioning tables have a position resolution of 2 $\mu\text{m}$  (half step mode) and  $\pm 0.5\mu\text{m}$  repeatability. The position feedback, running on the PLC, is adopted in this system to guarantee the 2  $\mu\text{m}$  position accuracy. The grating encoders, with the resolution of 1  $\mu\text{m}$ , are incorporated with the x-y position tables, measuring the real movement of the tables. The PLC corrects the

movement of the position stables according to the position value measured by the encoder.



Figure 2: The calibration stand of SSRF BPM

The x-y positioning tables and the BPM mounting fixtures are installed on the same tooling plate that can be adjusted on horizontal plane. The mechanical center of the BPM under test and the accurate knowledge of the reference surfaces with respect to the locating surface are measured by a survey, and the measured data are entered into the calibration program.

### 3 DATA COLLECTION

The 500MHz RF signal, generated by the HP 4400B, is amplified to about 30dBm and delivered to the stretched wire through the coaxial cable. The RF signal on the wire induces signal on the four buttons of the BPM under test. Each button is connected to the BERGOZ's BPM electronics module through four semi-rigid coaxial cables which have the same length and model. The BERGOZ's BPM electronics module can output 7 analog signals, such as X, Y, reflecting the position of the stretched wire in the horizontal dimension and vertical dimension. These signals are then connected to the digital multimeter- KE 2002 to converted into digital signal. In order to increase the measurement accuracy, these digital signals are averaged for 100 times which is implemented by the KE2002.

The BPM calibration program controls the PLC to locate the wire through the RS232 interface, and then collects the position data through a GPIB bus. It also can accept the calibration parameters, such as the range of BPM mapping, the length of the mapping step and data archive. The state of the system can be browsed at the remote place through the network, reducing the influence

caused by operator activity on the measurement. In addition to, we designed a new data collection program running on the VME system through high speed A/D module. It can reduce the calibration time greatly, which is helpful for the result of the BPM calibration.

The BPM of SSRF storage ring has been calibrated with this test stand, a great number of data have been collected under different condition. Figure 3 shows the data acquired when the measurement was made at the 121 mesh points in the central area of  $\pm 5\text{mm}$ (horizontal)  $\times$   $\pm 5\text{mm}$ (vertical) with 1 mm step.

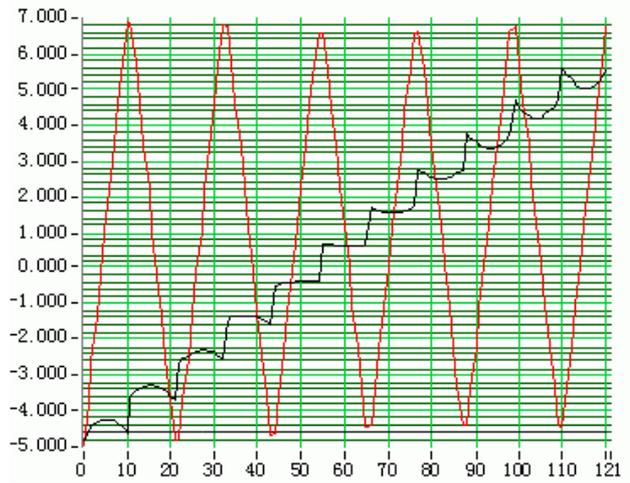


Figure 3: data from SSRF BPM test

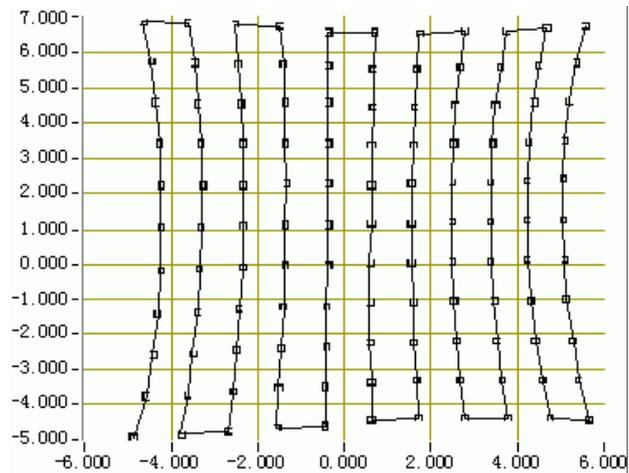


Figure 4: map of SSRF BPM

Figure 4 shows the Y vs. X map from the figure 3's data. The unit of the Y and X axis is voltage. It shows that there is a good linearity in the central area of BPM, while pin cushion distortion appears clearly far from the central.

## 4 ERROR ANALYSIS

After calibration data are obtained, the mapping data are fitted by least-square method to fourth polynomials of

$$\begin{aligned} X &= \sum \{AA_{ij} \cdot H^i \cdot V^j\}, \\ Y &= \sum \{BB_{ij} \cdot H^i \cdot V^j\} \end{aligned}$$

where  $0 \leq i, j \leq 4$ ,  $0 \leq i+j \leq 4$ . In these expression, AA(0,0) and BB(0,0) gives the deviation of the electrical center from the geometrical one, and AA(1,0) and BB(0,1) are the sensitivity of BPM in the x and y direction, respectively.

We calculated these coefficients with the MATHCAD programming tool, and the results are as shown as follow:

$$AA(0,0) = -0.702; \quad BB(0,0) = -0.991;$$

The maximum fitting rms error is found as follows:

$$\sigma_x = \sqrt{\frac{\sum_0^{n-1} (x_{fi} - x_{mi})^2}{n}}$$

$$\sigma_y = \sqrt{\frac{\sum_0^{n-1} (y_{fi} - y_{mi})^2}{n}}$$

Where  $x_{mi}$  and  $y_{mi}$  are the values from the BERGOZ BPM electronics module at the i-th measure point, while  $x_{fi}$  and  $y_{fi}$  are the values calculated by the least-square method. The results of the fitting rms error of data collection of our BPM calibration system are shown as follows:

$$\begin{aligned} \sigma_x &= 5 \times 10^{-3} \text{ mm} \\ \sigma_y &= 8 \times 10^{-3} \text{ mm} \end{aligned}$$

The iterance of the electronics system has been measured. Four channels fixed signals are inputted to BERGOZ BPM electronics module, and the x and y output voltages are measured continually more than 8 hours. The iterances of these results were no more than 3 mV. These results show the accuracy of electronics system is about  $3\mu\text{m}$ .

## 5 SUMMARY AND CONCLUSION

The BPM calibration system has been established and tested by several kinds of BPM. It has a theoretical resolution capability of  $2\mu\text{m}$ , as limited by the step motor used in this system. Although we have not verified to this accuracy, we have obtained the clear BPM mapping using  $2\mu\text{m}$  step of wire movement. The calibration of the BPM system has been shown to be better than the requirements which SSRF BPM system

wants. In addition, we designed a new calibration scheme, measuring the power on each button sequentially by the HP spectrum analyzer, instead of the BERGOZ BPM electronics module. Experiments show that the scheme of BERGOZ BPM electronics module has better position resolution than that of spectrum analyzer, while the latter can calibrate the BPM with current which frequency is adjusted when we need.

## 6 ACKNOWLEDGMENTS

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