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A ROTATION METHOD TO CALIBRATE BPM ELECTRIC OFFSETS

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Abstract

Beam position monitor is a key instrument for machine commissioning. To measure beam position accurately, offline calibrations to acquire the sensitivity and offsets of the BPM are essential prerequisites. A new method to calibrate the BPM electric offset is proposed in this paper. By measuring the location variation of the BPM electric center after rotating the BPM 180 degrees, the BPM offset can be derived. The method is more convenient, universal and accurate than the traditional methods. The method is successfully applied to calibrate the button BPM of Xi'an Proton Application Facility. The repetitive measurement error is $20.8\mu m$.

INTRODUCTION

Beam Position Monitor (BPM) is a key instrument to observe beam positions along beam transport line. The output data from the BPM system shows the orbit position relative to the BPM electric center, rather than the BPM geometrical center. For an ideal BPM, the electric center coincides with the geometrical center. However, due to machining and assembling errors, the BPM electric center is decentered in reality. To measure absolute beam position accurately, BPM should be calibrated offline before installation. Wire method is the mostly used BPM calibration method. A thin wire is driven at appropriate rf frequency to simulate beam and provide output signals. It can not only calibrate the BPM sensitivity and nonlinearity, but also the BPM offsets with known wire position relative to the BPM geometrical center. Usually, special mechanical toolings, such as microscope and ball head pin [1], survey and locating pin [2], micrometer and dowel pin [3], fiducials and laser tracker [4], are used to locate the wire position relative to the BPM geometrical center. These methods have some common drawbacks, like complex measurement procedures and not universal. Relocating is necessary when calibrate a new BPM, and every type of BPM needs particular mechanical toolings. This paper proposed a new method to calibrate the BPM offset by rotating BPM. Compared with the traditional method, the new method is simpler, more accurate and versatile.

METHOD

The new method is adapted from a magnetic center measurement method [5]. It is using a wire driven at 325 MHz frequency to simulate beam. When the wire is located at the center of the BPM, output signal amplitudes of the opposite electrodes are equal. The working principle of the method is shown in Fig. 1. Firstly, move the wire to the BPM electrical center. Then, rotate the BPM 180 degrees. Due to the offsets among the BPM electric center, the BPM geometrical center and the center of rotation. Position of the BPM changes, and the wire is no longer located at electric center of the BPM. Move the BPM to make the output signals the same, that is, the wire is located at the BPM electric center again. In the measurement, the wire is always fixed. And the BPM electric center is coincident with the wire in the step 1 and step 3, that is, the BPM is actually rotated about the BPM electric center.Therefore, the BPM electric center relative to the BPM geometric center is just half of BPM position variation, that is , $(d_2 - d_1)/2$. More detailed derivatives are as followings. Denote the offset between the BPM geometrical center and the center of rotation as O_1, the offset between the BPM electric center and the BPM geometrical center as O_2 and the offset between the BPM electric center and the center of rotation as O_3. Obviously

$$O_3 = O_1 + O_2 \quad (1)$$

At the moment, distance from the BPM to rangefinder is d_1. After rotating the BPM about the center of rotation 180 degrees, the distance from the rangefinder to the BPM is $d_1 - 2O_1$, and the distance needed to move the BPM electric center to the wire location is $2O_3$. Therefore, the distance from the final BPM location to the rangefinder is

$$d_2 = d_1 - 2O_1 + 2O_3 \quad (2)$$

Substituting Eq. 1 into Eq. 2, we obtain

$$d_2 - d_1 = 2O_2 \quad (3)$$

The measurement is irrelevant to the center of rotation, that is, BPM installation location can be arbitrary. The method does not need any special mechanical toolings for positioning. Hence, the method is universal, it is applicable for different type of BPMs.

TEST BENCH

A test bench was constructed to test the method. Picture of the test bench is shown in Fig. 2. A 0.19 mm diameter copper wire, used to simulate beam, is secured at the SMA

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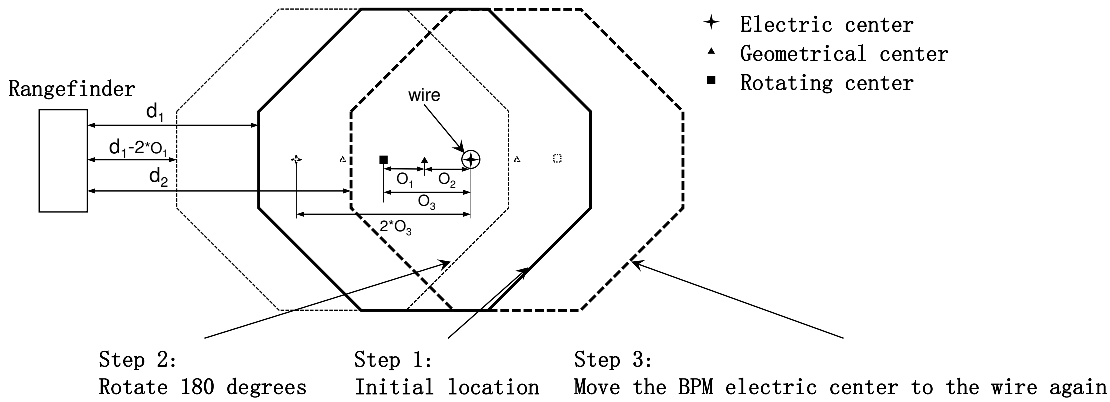

Figure 1: Schematic diagram of the method.

rf connector at both ends. The upper port is connected to a rf signal generator. The lower port is ended with a matching load and a counter weight. The whole lower end sinks into dielectric oil to retard the vibration of the wire. BPM output signals are processed by Libera Single Pass H [6] to obtain the wire position. The test bench includes three motors, two linear motors are used to achieve movement in x-y planes, the other is a rotary motor, whose range is larger than 180 degrees. A laser displacement sensor (Panasonic HL-G105-S-J) is used to measure movement of the BPM to be tested. The detailed procedures to perform the measurement are as followings:
1) Install the BPM to be tested and fix it with screws;
2) Rotate the BPM until the reflected light coincides with the incident light spot of the laser sensor, that is, the measurement direction of the laser sensor coincides with the BPM horizontal direction;
3) Move the BPM until the copper wire located at the electric center of the BPM;
4) set the laser sensor to zero;
5) Rotate the BPM 180 degrees, then move the BPM electric center to the wire again;
6) The BPM horizontal offset is just half of the current readings of the laser sensor;
7) Rotate the BPM 90 degrees, then repeat 3)~6) to obtain the BPM vertical offset.

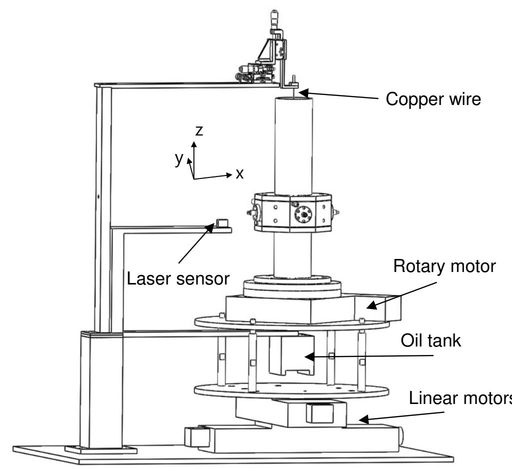

Figure 2: Picture of the test bench.

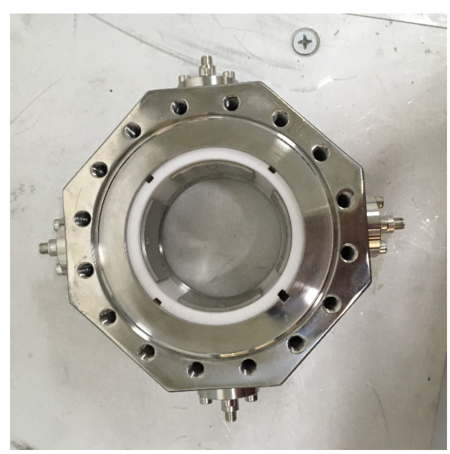

Figure 3: Picture of the XiPAF button BPM.

TEST RESULTS

The method is used to measure the offsets of Xi'an Proton Application Facility (XiPAF) button BPMs [7]. Picture of XiPAF button BPM is shown as Fig. 3. The BPM has an octagonal structure, the mechanical center is defined as the center of the opposite planes. Although diameter of the copper wire is as large as $0.19mm$, the measurement error of the wire position is lower than $\pm 2\mu m$. The measurement error of the laser sensor is better than $\pm 10\mu m$ in the preliminary tests. Therefore, the measurement accuracy is expected to better than $\pm 12\mu m$. The repeated measurement results are shown in Fig. 4. The rms error of multiple times measurements is $20.8\mu m$. The measurement repetitive error is a bit larger than the expected value,which is caused by some outliers that is much larger than the average value. The geometric fiducials of the BPMs are four $54mm \times 48mm$ planes, due

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to the large area, the planeness error of the plane may be the origin of the strange measurement points. More detailed measures of the fiducial planes on the coordinate measuring machine are planned. If we eliminate the strange points, the measurement accuracy is $\pm 11 \mu m$, which agrees with the expected value.

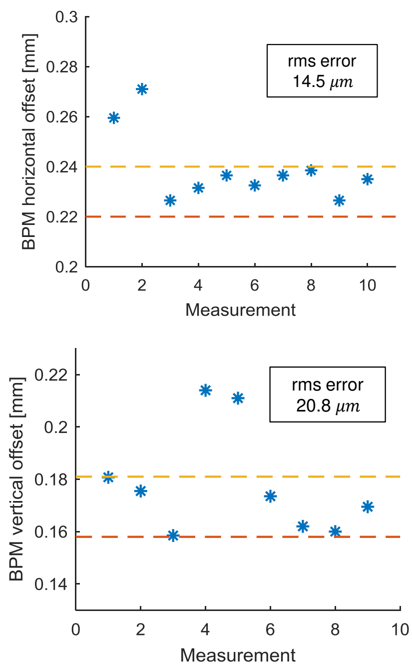

Figure 4: Measured electric offsets of the button BPM.

CONCLUSION

A new method to measure the BPM offsets based on rotating BPM is proposed in this paper. Compared to the traditional methods, the new method is more accurate and convenient. The precision of the method is mainly dependent on the measurement accuracy of the laser sensor. At XiPAF, the measurement repeating precision is $20.8 \mu m$.The method is versatile, especially suiting for calibrating multiple types of BPMs.

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