ISBN: 978-3-95450-249-3 ISSN: 2673-5350 doi: 10.18429/JACoW-IBIC2024-TUP45

THE DESIGN AND ACCURATE CALIBRATION OF HIAF-RING BPM*

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Abstract

Beam Position Monitors (BPM) are the non-destructive monitors used most frequently at nearly all linacs, cyclotrons, and synchrotrons. The most basic function of BPM is to provide the accurate position of the centre of mass of the beam for closed orbit feedback and other demands. However, due to the error of actual processing, the k value and the actual electric center will be different with the ideal k value and electric center of BPM, which requires us to accurately measure the k value and offset value of each set of BPM offline.

There are 79 sets of BPMs in HIAF BRing, SRing & HFRS, with 10 specifications and plate radius ranging from 180 mm to 330 mm, but the shape and size of the front and back pipes connected to bpms are variety during actual installation. Based on theoretical analysis, the k value and offset value of the BPM which electrode plates are too close to the flange are greatly affected by the pipes connected to bpm at both ends, and the measurement error can even reach 9 mm. Therefore, this paper takes HIAF BRing and SRing BPM calibration as examples to explain how to accurately calibrate BPM.

INTRODUCTION

BPM types include capacitive BPM, linear-cut BPM, stripline BPM, and button BPM [1-3]. We will use different types of BPM according to different application scenarios. In the BPM design of HIAF BRing and SRing, combined with the beam profile size at the BPM probe installation position and the vacuum size at both ends, the inner diameter of our BPM plate was finally determined to be 180 mm~330 mm. However, due to the existence of the edge field effect, the k value and offset value of BPM are greatly affected by the shape and size of the pipes on both sides of the plate, and the ring BPM probe is generally only processed by the probe itself due to its huge size, unlike the straight line and other BPM which have its own pipes at both ends during processing, so the longitudinal length is only enough for the design of the plate part of the BPM, it is necessary to pay more attention on calibration, we need to add some short pipe which are consistent with the actual vacuum pipes during calibrating. There are 40 sets of HIAF BRing BPM probes, 4 specifications, 7 different operating conditions during calibration; There are 32 sets of HIAF SRing BPMs, 6 specifications, 29 different operating conditions during calibration, and several examples are used in this article to introduce this theory.

SIMULATION AND DESIGN OF BPM

Initial Simulation Analysis

The initial design version of the HIAF BRing & SRing BPM is shown in Fig. 1. And the main dimensions are: plate inner diameter 200 mm, plate length 178 mm, vacuum pipe inner diameter 274 m, middle individually gnd diameter 264 mm, overall longitudinal length 400 mm.

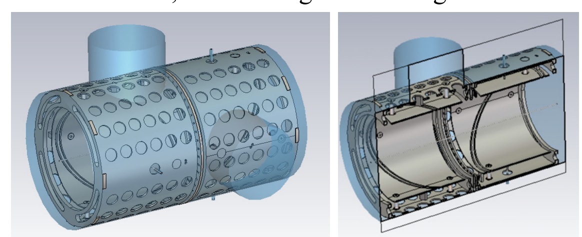

Figure 1: CST simulation model.

CST was used to model and simulate different structural details [4]. For example, whether it needs to add a separated ground structure between the plate and the vacuum tube, the simulation results are shown in Fig. 2. The results show that compared with the structure without the addition of ground, the use of adding separate ground structure and the non-perforated separate ground structure will introduce new resonance points, therefore, the removal of the separate ground structure in this structure. Meanwhile, the removal of the structure greatly simplifies the structure of the BPM itself, and is also more friendly to the vacuum, and brings great benefits to the processing and assembly of large-scale BPM equipment in the later stage. At the same time, the spacing between the plate and the isolation ring structure was simulated and calculated, as shown in Fig. 3. And the size with the highest sensitivity was selected according to the fitting structure of the position information and difference ratio and data.

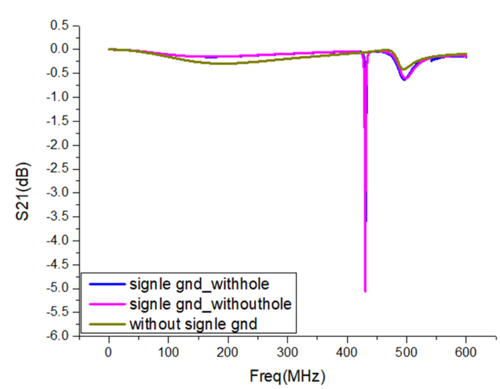

Figure 2: The effect of different individual structures on the resonance point.

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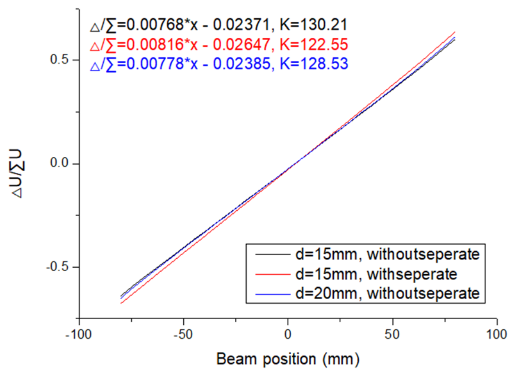

Figure 3: The effect of different individual structures on the resonance point.

Final Structure

Finally, considering the electrical properties of the probe, the requirements of ultra-high vacuum, and the difficulty and consistency of processing, the BPM uses the structure shown in Fig. 4.

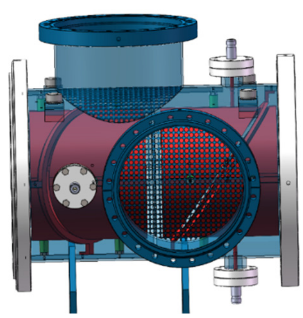

Figure 4: The final BPM structure.

S PARAMETER TEST

The processing prototype is shown in Fig. 5. Figure 6 shows the simulation and measurement results of the resonant point of the monopolar plate, and the results show that there is no resonance point below 300 MHz. Figure 7 shows the simulation and measured results of the isolation between the relative plates, and the results show that the isolation is less than -34 dB below 10 MHz. Figure 8 shows the simulation and measured results of the plate-to-ground capacitance, and the results are about 50 pF. The measured and theoretical design of all electrical parameter test items are in good agreement with the theoretical design.

Figure 5: Processing prototype.

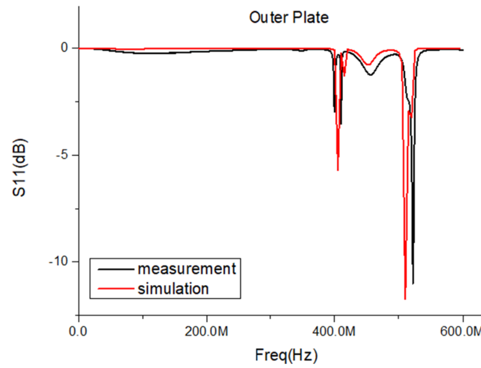

Figure 6: Resonance point test.

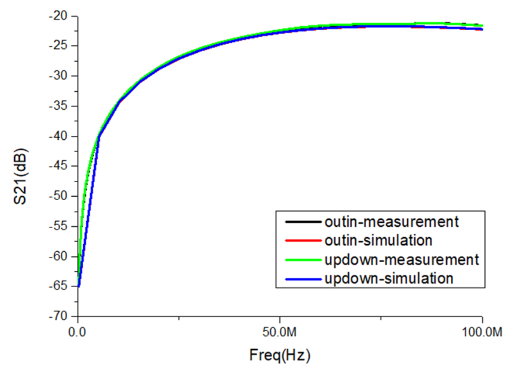

Figure 7: Isolation test.

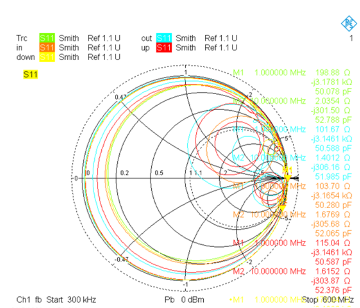

Figure 8: Plate to ground capacitance test.

CALIBRATION OF BPM

With a total of 79 sets of HIAF BRing, SRing and HFRS BPM probes, it is important to build an efficient and accurate calibration system.

Calibration Platform System Construction

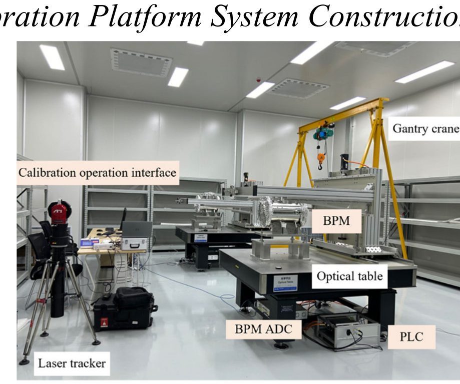

Figure 9: Calibration platform.

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Proc. 13th International Beam Instrumentation Conference,Beijing JACoW Publishing
ISBN: 978-3-95450-249-3 ISSN: 2673-5350 doi: 10.18429/JACoW-IBIC2024-TUP45

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The calibration system consists of a set of standard optical calibration platform, a set of BPM fixed and wire moving mechanical platform, self-developed data acquisition electronics, and a set of self-developed calibration control and automatic data post-processing program, as shown in Fig. 9 below. Among them, the movement of the wire is controlled by a servo stepper motor, and the accuracy is µm level. The accuracy of the calibration platform is within 0.1 mm when the motor travels to the edge position, tested by laser tracker.

Calibration of BPM

The k value and offset value of BPM are simulated and calculated firstly. Figure 10 shows that it is found that the k value and offset values are very different of the bare pipe at both ends of the BPM and the pipe with an inner diameter of 200 are significantly different, as shown in Fig. 11. According to the analysis of the principle, it is caused by the edge field effect formed at both ends of the BPM plate that is too close to the flange.

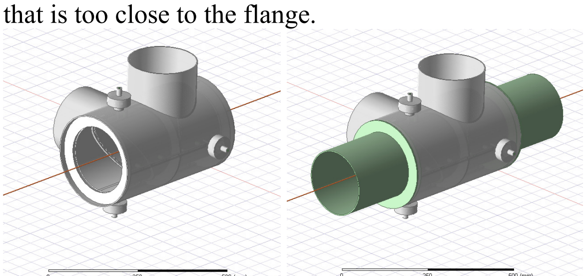

Figure 10: Simulation model.

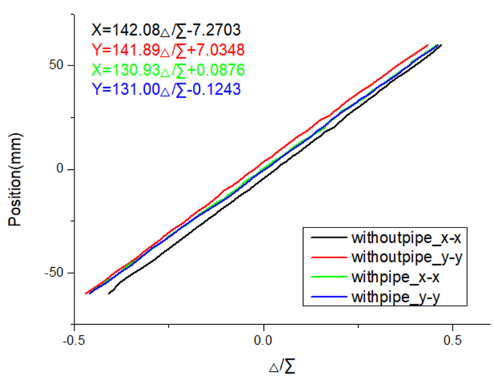

Figure 11: Simulation result.

The conclusion of the above theoretical analysis is tested and verified by the actual working conditions, the test scenario is shown in Fig. 12. Figure 13 shows that the test results, which shows that the actual measurement and theory are unified. It also can be seen that the offline calibration test of BPM must be calibrated in combination with the actual vacuum pipe conditions at both ends.

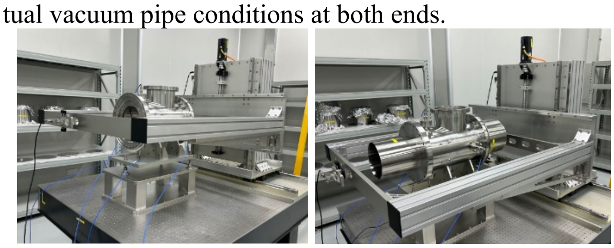

Figure 12: Measured scenarios.

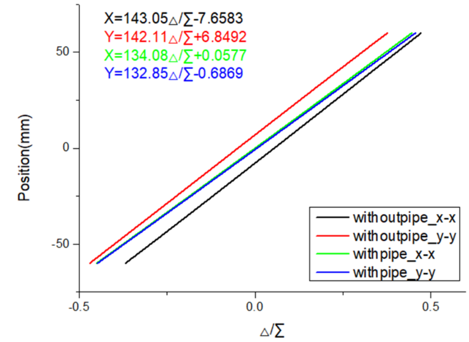

Figure 13: Measurement result.

After determining the calibration method, the overall region of the BPM was mapping, and the result is shown in Fig. 14. It can be seen that the linear region of this type bpm is still very good, and the calibration degree can almost reach about 98 % after a fitting correction.

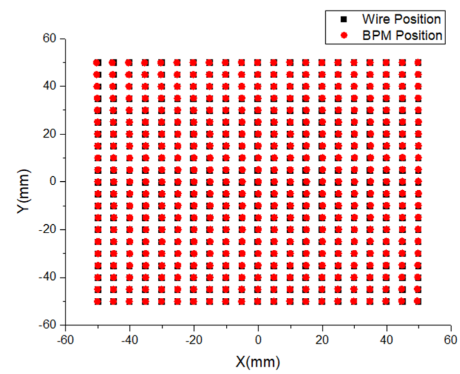

Figure 14: Mapping result (one correction).

CONCLUSION

This article provides a comprehensive overview of the design process and calibration of HIAF Ring BPM. There are a total of 79 sets of BPMs in HIAF BRing, SRing and HFRS, which have complex conditions for vacuum pipes at both ends, including conventional round pipes of different sizes, eccentric round pipes, eccentric rectangular pipes, and even irregular octagonal pipes. When the BPM of the same specification is connected with different pipes, its sensitivity and linear region will change differently, therefore, different tooling needs to be processed to accurately measure the k value and offset value when offline calibrating, and finally the accurate position information can be measured online. At present, HIAF BRing and SRing BPM have been tested offline, installed and launched.

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