# Design of Beam Position Monitor of Wuhan Photon Source

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## Abstract

Wuhan Photon Source (WHPS), as a fourth-generation synchronous light source, imposes stringent requirements on the resolution and wakefield impedance of the Beam Position Monitor (BPM). Taking into account the impact of bandwidth, TBT mode and FA mode impose the most stringent demands for position resolution, set at 1 µm and 0.6 µm, respectively. To address the need for beam current monitoring in its 1.5 GeV diffraction-limited storage ring, an optimized design scheme for button BPM is proposed. Additionally, the structure of the BPM feedthrough is enhanced, and a detailed investigation into the impact of various materials on the wakefield impedance of the BPM is conducted. These findings serve as a valuable reference for the future design of similar BPM systems.

## ELECTRODE GEOMETRY

**Table 1:** Main Dimensions of the Electrode

| Geometric dimension | |
|---|---|
| Button radius | 3 mm |
| Button thickness | 2 mm |
| Button gap | 0.3 mm |
| Step-button thickness | 1 mm |

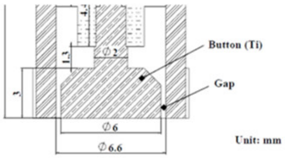


**Figure 1:** Geometry of button BPM electrode

Within this set of geometric parameters, the position gain coefficient (ki) is determined to be 11.5243 mm. Table 2 illustrates that the position resolutions in FA mode and TBT mode are 0.19 µm and 0.61 µm, respectively. Notably, both resolutions satisfy their respective requirements.

**Table 2:** BPM Position Resolution Calculation in FA Mode and TBT Mode

| Mode | Bandwidth | Signal power | Noise | SNR | $\sigma = k_i \cdot \frac{1}{\sqrt{SNR}}$ |
|---|---|---|---|---|---|
| FA | 50 kHz | -12.81 dB | -108.32 dB | 95.51 dB | 0.19 µm |
| TBT | 500 kHz | -12.81 dB | -98.32 dB | 85.51 dB | 0.61 µm |

## WAKEFIELD IMPEDANCE OPTIMIZATION

To optimize beam stability and reduce interference with position signals, it is essential to minimize the peak amplitude of the wakefield impedance while maximizing the frequency of the impedance peak. This optimization involves adjustments in the feedthrough structure and the choice of dielectric material.

(1) Add a step electrode above the button electrode.
(2) Chamfer the edges of the ceramic window and step button.
(3) The wakefield impedance was examined under various electrode materials and ceramic materials. Ultimately, titanium was chosen as the electrode material, while aluminum or aluminum nitride were identified as suitable dielectric material options.
(4) Upon altering the ceramic material, theoretical calculations are conducted for each coaxial segment within the feedthrough to align its impedance with 50 Ω. These outcomes serve as a blueprint for guiding the structural modeling process.

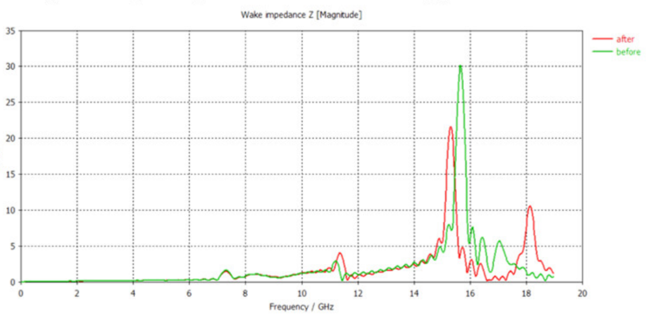


**Figure 2:** Wakefield impedance results before and after optimization

## THERMAL ANALYSIS OF BPM

Our aim is to ensure that the BPM exhibits excellent thermal performance to minimize potential deformation. Examination of Fig. 3 highlights that the superior thermal conductivity of aluminum nitride results in enhanced heat dissipation capabilities. Therefore, the implementation of aluminum nitride as the dielectric material in the BPM is advantageous..

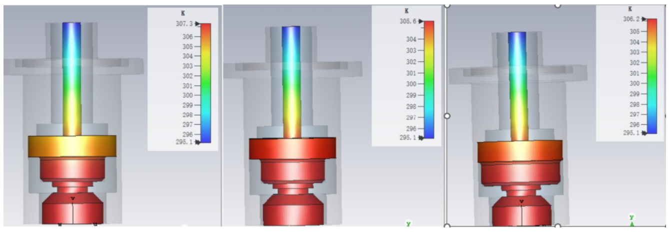

**Figure 3:** BPM thermal simulation results of alumina (left) aluminum nitride (medium) boron nitride (right) as dielectric materials

## MECHANICAL DESIGN

The button BPM package consists of the main chamber (feedthrough with button and inner chamber frame), bellows, support frame and connection flange.

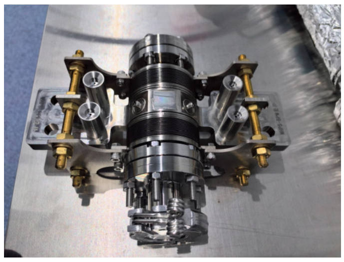

**Figure 4:** Prototype of the whole piece of WHPS button BPM

Considering that positioning and alignment errors can cause deviations in position measurement, the proposed alignment tolerances for the installation between the button BPM assembly and the vacuum box are: 0.2 mm for (x, y, z) indicating the center position of the machine, and 1.5 mrad for the pitch, yaw, and roll angles reflecting the rotation of the three axes.

## Summary

In this research, a refined design approach is introduced for the button BPM within the 1.5 GeV storage ring of the Wuhan Photon Source. The optimization primarily focuses on the structure and material of the button BPM feedthrough. The investigation delves deeply into the impact of diverse electrode materials, ceramic materials, and their respective configurations on wakefield impedance. Following meticulous analysis, titanium emerges as the preferred electrode material. Subsequently, through comprehensive thermal simulations, aluminum nitride is identified as the optimal dielectric material.

It is noteworthy that the structure and shape of the electrodes can significantly influence the wakefield impedance and measurement performance of the BPM. This aspect will be the prime focus of forthcoming research and optimization endeavors.