A NOVEL BPM MECHANICAL CENTER CALIBRATION METHOD BASED ON LASER RANGING

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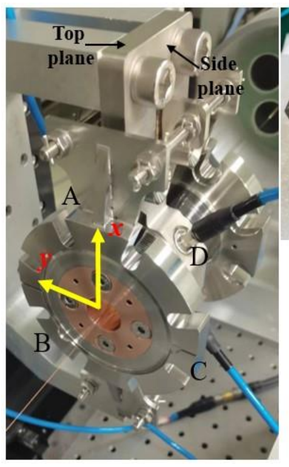
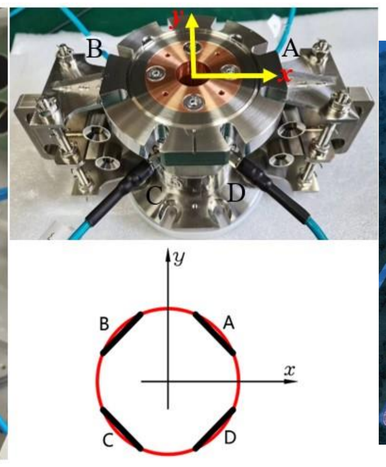
Introduction

- Due to processing errors, the mechanical center and electrical center of BPM do not coincide. Therefore, each BPM is demanded to calibrate before use.
- About 600 BPMs are produced during the construction of High Energy Photon Source (HEPS) project, the calibration task is heavy.
- Finding the mechanical center is extremely difficult, so it is hard to determine and X_{offset} and Y_{offset}.



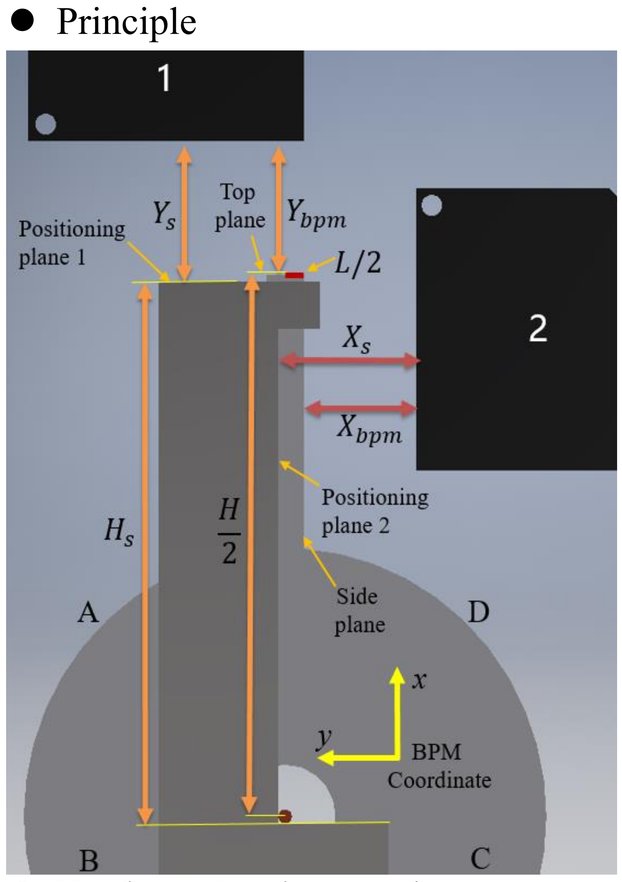


A four button-type BPM of HEPS

The HEPS project located in Beijing

Methods

- Principle



BPM measurement formula

$$x = K_x \frac{V_a + V_d - V_b - V_c}{V_a + V_b + V_c + V_d} + X_{\text{offset}}$$

$$y = K_y \frac{V_a + V_b - V_c - V_d}{V_a + V_b + V_c + V_d} + Y_{\text{offset}}$$

Distance relationship when antenna is located in the BPM mechanical center

$$Y_s + H_s = Y_{bpm} + \frac{H}{2} + r$$

$$X_s = X_{bpm} + \frac{L}{2} + r$$

Two key distances representing BPM mechanical center

$$Y_{bpm\_M} = Y_s + H_s - \frac{H}{2} - r$$

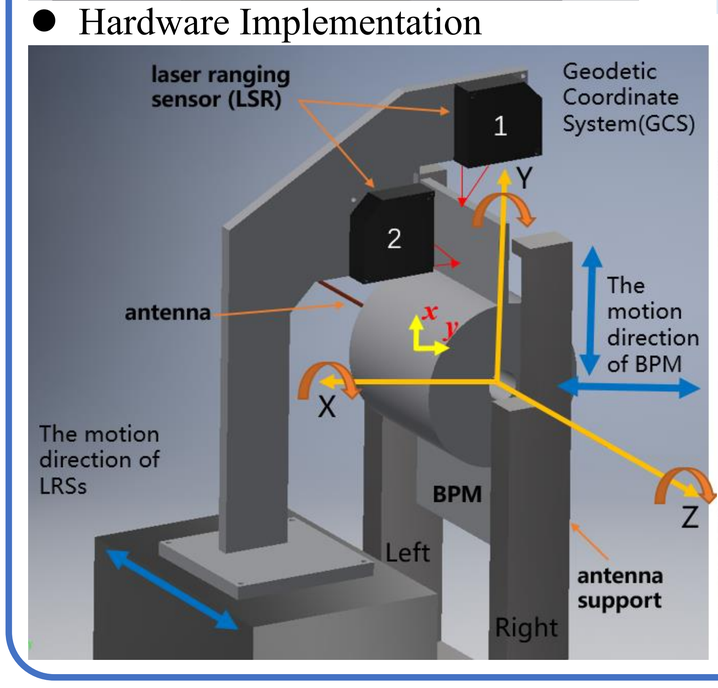
$$X_{bpm\_M} = X_s - \frac{L}{2} - r$$

The formula for calculating electro-mechanical offset

$$X_{\text{offset}} = Y_{bpm\_M} - Y_{bpm\_E}$$

$$Y_{\text{offset}} = X_{bpm\_E} - X_{bpm\_M}$$

- Hardware Implementation



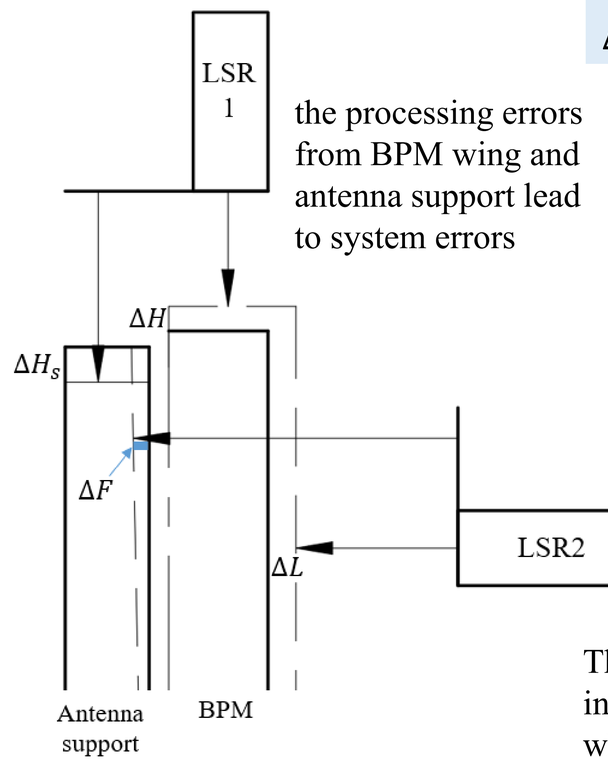
Error analysis

- System error

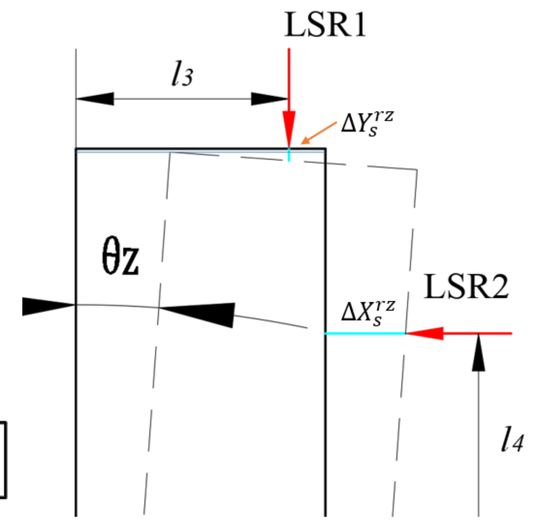
System error evaluation

$$\Delta X^{s}_{\text{offset}} = |\Delta H_s| + |\Delta H| \le 20\mu\text{m}$$

$$\Delta Y^{s}_{\text{offset}} = |\Delta L| + |\Delta F| \le 20\mu\text{m}$$



the processing errors from BPM wing and antenna support lead to system errors



The tiny angle wobble produced by each installation produces random errors, in which the error around the Z-axis is the largest. Because the l_4 is a larger value.

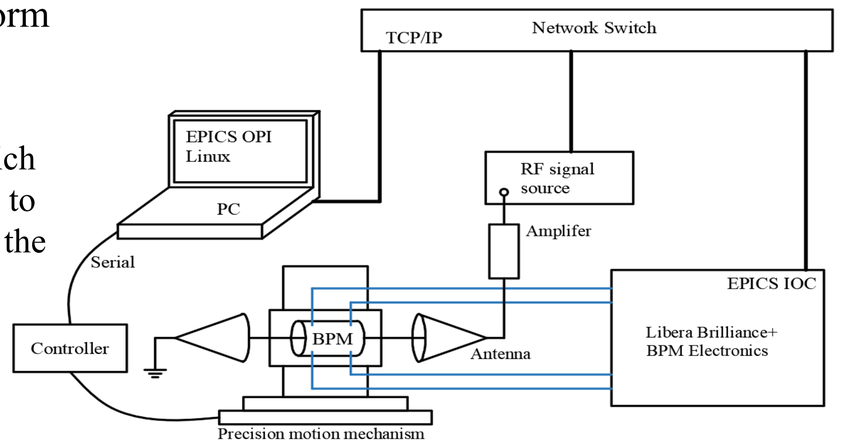
- Random error

Source of random error	symbol	Evaluation method	Hardware elimination	Software elimination
BPM tiny installation angle around GCS X-axis	$\Delta X^{rx}_{bpm\_E}$	\	Tighten the BPM mounting screws using a fixed torque wrench	\
	ΔY_s^{rx}	$l_1\theta_x$		averaging the measured Y_s at multiple positions
BPM tiny installation angle around GCS Y-axis	$\Delta X^{ry}_{bpm\_E}$	\		\
	ΔX_s^{ry}	$l_2\theta_y$		averaging the measured X_s at multiple positions
BPM tiny installation angle around GCS Z-axis	$\Delta X^{rz}_{bpm\_E}$	\		\
	ΔY_s^{rz}	$l_3\theta_z - H\theta_z^2/2$		
	ΔX_s^{rz}	$l_4\theta_z$		

Experiment and discussion

- Experiment platform

The BPM automatic calibration system, which uses *Libera* electronics to position the antenna in the BPM electrical center.



- Experiment data

Base data(mm): $H = 210,\ L = 12, r = 0.105, X_s = 5.820, Y_s = 1.780$

Repeat the experiment 5 times in three different ways and observe the variance.

Measurement operation	σ_{x_offset} / mm	σ_{y_offset} / mm
Repeat installation of BPM only	0.0033	0.0102
Repeat installation of antenna only	0.0081	0.0024
Repeat installation of the antenna and BPM simultaneously	0.0154	0.0122

Change the BPM and antenna simultaneously, with a maximum variance of 15μm

Conclusion and prospect

- Conclusion
  - In order to quickly, low-cost, and high-precision measure the BPM electro-mechanical offset, a new method using precision antenna support and laser ranging sensor is proposed.
  - The measuring platform of the new method is built, and the automatic testing program is designed.
  - The experiment shows that the repetition accuracy of this method is less than 30μm, and the absolute system error is less than 20μm.
- Prospect
  - Update the software and hardware of the calibration platform to accommodate different sizes of BPM.
  - Compare this method with Lambertson method.

Acknowledgements

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