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DEVELOPMENT AND APPLICATIONS OF THE WHITE BEAM POSITION MONITOR FOR BENDING MAGNET BEAMLINES

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Abstract

We developed a white beam position monitor to be applied in beamlines with bending magnets. By 0.1 mm light-receiving opening, the beam is split and converted to a photocurrent intensity which can be used to detect the size and position of the beam ≦ 50 mm, and to align the locations of beamline components. A stop-beam measurement method is utilized, so it cannot monitor the beam in real time.

The motorized stage of the monitor has a range of motion up to ± 25 mm with position accuracy of ≦ 1 μm and vacuum capability of ≦ 5 × 10 - 10 Torr, which is compatible with ultra-high vacuum environments. In addition, taking the thermal load 62.89 W of the TPS 02A beamline as an example, the thermal deformation of the analog monitor opening lead to a result that the measured value will have a maximum of 2 μm from the center of the beam.

The monitor is equipped with other components designed by NSRRC colleagues, including a motor control system, a four-channel current amplifier, an EPICS control system, and a GDA data acquisition and analysis software. the whole system has been successfully applied in the TPS 02A beamline. All features are verified and the performance meets the requirements. Besides, the positioning tasks of Slits1 was accomplished and the position variation of the light source was detected by this beam position monitor.

INTRODUCTION

When it comes to monitoring light source and calibration of beamline components, the size and position of the beam are extremely important information, so a beam position monitor with good performance is a necessity. The design of a white beam position monitor is more difficult than a mono beam position monitor, because the thermal load of white light will cause thermal deformation of the material such that the accuracy becomes worse. Moreover, there is more scattered stray light in the white light region than that in the mono beam region. The background value of the white light area is higher, and the scattered stray light passing through different structures may also have an asymmetric spatial distribution. Therefore, a white beam position monitor needs to be designed with an appropriate structure to accurately interpret the beam position signal while limiting the proportion of external stray light entering the detector. These are the key points that must be achieved in the design of the mechanical structure.

The white beam position monitor described in this report is based on various measurement requirements proposed by users, such as calculating the center position of the beam, obtaining the overall beam imaging distribution, analyzing the quality and stability of the beam, and calibrating the zero position of beamline components, and other functions. Because the above requirements are suitable for light-blocking measurement methods, the beam will be completely shielded during measuring. Therefore sample measurements in the experimental station and real-time feedback adjustments of beam position cannot be performed at the same time.

MECHANICAL DESIGN

The white beam position monitor for the beamlines of deflection magnet is shown in Fig. 1. The internal mechanism and accessory design [1] is consisted of (1) cooling water inner and outer pipes (cooling water flows from the outside to the inside of the pipe), (2) fixture (fixing the temperature and electrical current measuring circuits to avoid direct radiation exposure during operation), (3) sapphire sheet (resistivity of 1 × 1011 Ω·cm, excellent electrical insulation property, and good thermal conductivity and mechanical strength performance), (4) tungsten alloy plate (high melting point and good conductivity, as a metal substrate for receiving electron flow), (5) oxygen-free copper (C10100) cover (fixed on the body with a screw lock and ceramic gasket, and insulated from the ground), (6) oxygen-free copper cooling seat body, (7) composed of components such as the lower cover of the oxygen-free copper cooling seat [2].

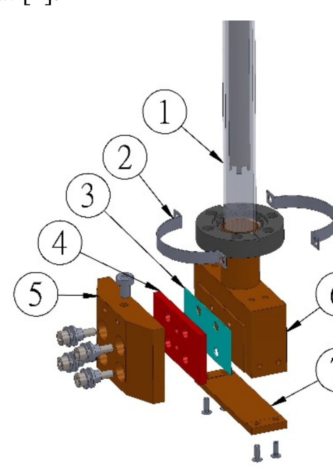

Figure 1: Internal mechanism and accessories of white beam position monitor.

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The white beam position monitor is coated with a light-receiving tungsten alloy plate with oxygen-free copper, as shown in Fig. 2. In order to make the current signal measurement spectrum show the beam distribution as accurately as possible, we need to effectively reduce the luminous flux of scattered stray light and reduce the influence of circuit noise. The size of the light inlet is measured after the current intensity of the TLS beamline is known as a reference. As shown in Fig. 2, the design uses 1/20 of the vertical size of the beam as the short side size of the light inlet. At present the short side size of the beam entrance is 0.1 mm, but this size is extremely difficult to be manufactured. Therefore, two accurate-sized oxygen-free copper blocks are designed, and then the assembled opening is confirmed with a thickness gauge.

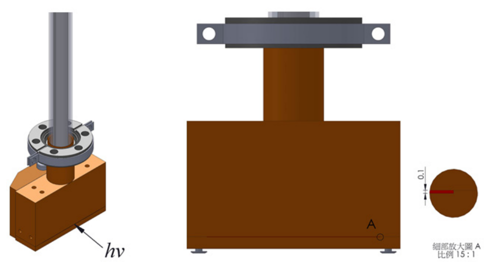

Figure 2: White beam position monitor measurement and beam light entrance size.

THERMAL DESIGN

Simulation is performed to calculate the expansion and deformation of the light inlet due to thermal load [3] and the position error value caused by the deformation. As shown in Fig. 3, the cooling seat bears the temperature distribution of 62.89 W heat load. Due to the cooling water circulation of the main body copper block, the temperature difference on the upper side of the light inlet has a small variation. The lower cover copper block can only transfer heat by the contact area of 5 mm × 15 mm on both sides, so the temperature variation of the lower side of the light inlet is relatively large. In the entire cooling seat, the highest temperature appears at the copper block middle position of the lower cover.

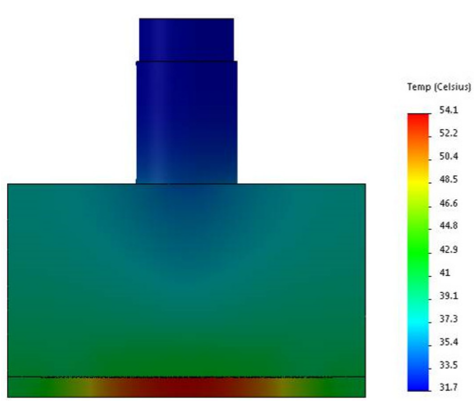

Figure 3: Temperature distribution diagram of the cooling seat under 62.89 W heat load.

As shown in Fig. 4, when the cooling seat is subjected to a 62.89 W thermal load, the maximum stress appears at the ends of the two oxygen-free copper openings. The analysis result shows that the maximum stress is 125 MPa, which is still less than the yield stress of the material itself which is 195 MPa.

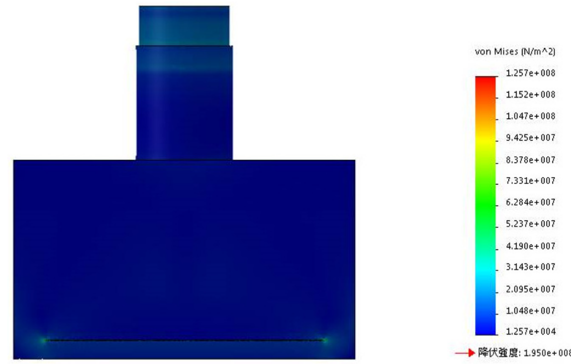

Figure 4: The cooling seat bears the stress distribution of 62.89 W thermal load.

Figure 5 shows that the deformation distribution of the cooling seat in the vertical direction under the heat load of 62.89 W. First, the deformation of the body will also affect the position of the lower cover. Then, the deformation of the cover under the same heating condition is more serious than the body, so the overall The deformation takes on the shape of an open mouth. As shown in Fig. 5 and Fig. 6, the opening-shaped deformation data of the cooling seat in the vertical direction under a heat load of 62.89 W is further captured. The upper side of the light inlet expands downward by 0.0005 mm, the lower side of the light inlet expands downward by 0.004 mm, and the center is calculated. The maximum offset is 0.00175 mm and the full width at half maximum relative to the vertical direction of the beam is 7.25 mm, so its deformation is still within an acceptable range.

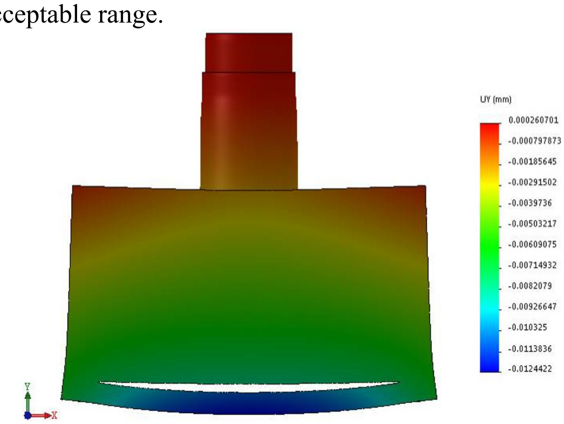

Figure 5: Deformation distribution diagram of the cooling seat in the vertical direction with a heat load of 62.89 W.

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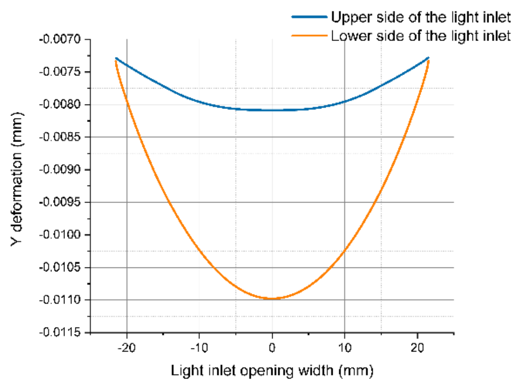

Figure 6: The data graph of the opening deformation of the cooling seat in the vertical direction under the heat load of 62.89 W.

APPLICATIONS

The electric meter used in this report is an integral four-channel current amplifier with a detection current range of 1 nA-100 µA. It can be used with various types of X-ray position monitor to measure the spot position. It also has versatile features such as providing positive or negative bias voltage, RS-232 and Ethernet dual communication interfaces, as well as SD card for data logging and reading data via FTP. The communication specifications include TCP/IP, UDP, and EPICS, which can be easily connected to existing beamline control systems.

This white beam position monitor system has been applied to the commissioning of the TPS 02A beamline, and the simulation results are compared with the measured data to verify the actual performance. After the white beam of the bending magnet interacting with a beamline component, the component motorized stage can be moved and the BPM image can be measured at the same time. When the center of the component and the center of the beam coincide with each other, the calibration is completed.

In addition to directly scanning to observe the distribution of light, it can also be applied to, for example, the calibration of the zero point of each blade in Slits 1. The bpm_x detector is placed in the center of the beam, and the s1t scan data is differentiated and smoothed as shown in Fig. 7. Figure 8 shows that the overall spectrum is approximately Gaussian distribution, and finally s1t is reset to 0 at the above position.

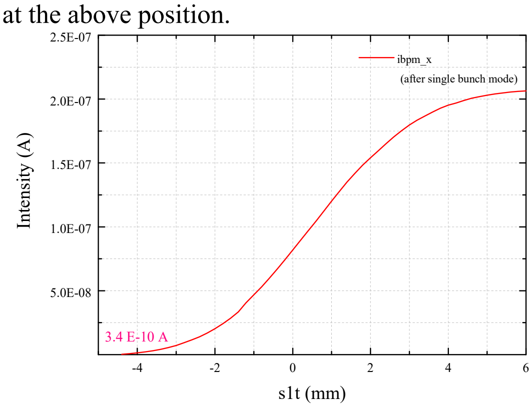

Figure 7: s1t measurement result.

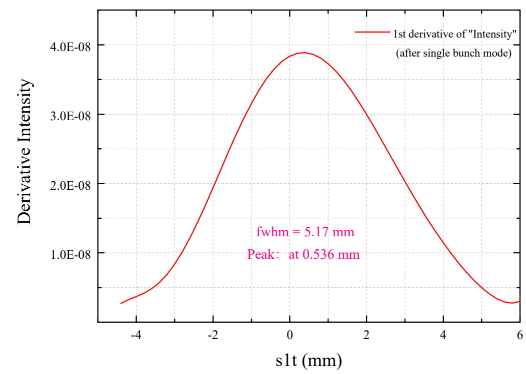

Figure 8: First differential and smoothing of s1t measurement results.

CONCLUSION

A white beam position monitor suitable for bending magnet beamlines is successfully developed Being equipped with a four-channel current amplifier, the system can calculate the center position of the white beam during the test run period of the beamline, and obtain the overall imaging distribution of the white light beam. Furthermore, it provides a complete solution to the needs of analyzing the quality and stability of the beam, and calibrating the zero positions of the beamline components. After the measurement results during the TPS 02A beamline test run was obtained, the data is compared with the theoretical simulation results to verify the accuracy degree. In the future, the composition structure of the white beam position monitor system will be modified based on the above measurement results. The primary goal is to improve the position inaccuracy caused by the asymmetry of the cooling water circuit, clarify the actual impact of various other noises, and seek better solutions.

ACKNOWLEDGEMENT

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