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Development of the Screen Monitor for TPS Beamlines

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Abstract. The screen system described in this article is designed to meet the needs of a synchrotron radiation beamline at Taiwan Photon Source (TPS). In the design of the mechanical structure, we combined a square chamber and a coaxial cooling tube for spatial efficiency. The coaxial cooling tube with a fluorescent plate is controlled with a cylinder or motor. The fluorescent materials, diamond and YAG:Ce, are excited with synchrotron radiation to produce a fluorescent image captured with the CCD. With image processing, the beam profile and position are confirmed. This screen monitor is widely used at the TPS beamlines.

DESIGN OF A WHITE-BEAM SCREEN SYSTEM

The designs of screens for X-ray beamline diagnostics are divided into two kinds: a white-beam screen and a mono-beam screen. In the white-beam screen, the key component is a diamond plate made by chemical vapor deposition (CVD); it has the advantages of a small rate of outgassing, a high fluorescence output, a large thermal conductivity and a small atomic mass. On considering the issues of heat load and reflected light from the synchrotron radiation, a design of a rear-projection module with coaxial cooling was adopted, shown in Fig.1. The cooling part consists of a cooling head of copper (1), a conflat (CF) flange (2)for thermocouple feed-through, a bellows(Travel length 20mm) (3), a stainless-steel tube (4)and fittings (Swagelok)(5). The assembly of a bellows and a CF flange is used to separate the vacuum from the atmosphere so that a water circuit with its coaxial cooling (4,5) on the atmosphere side does not damage the vacuum of the beamline.

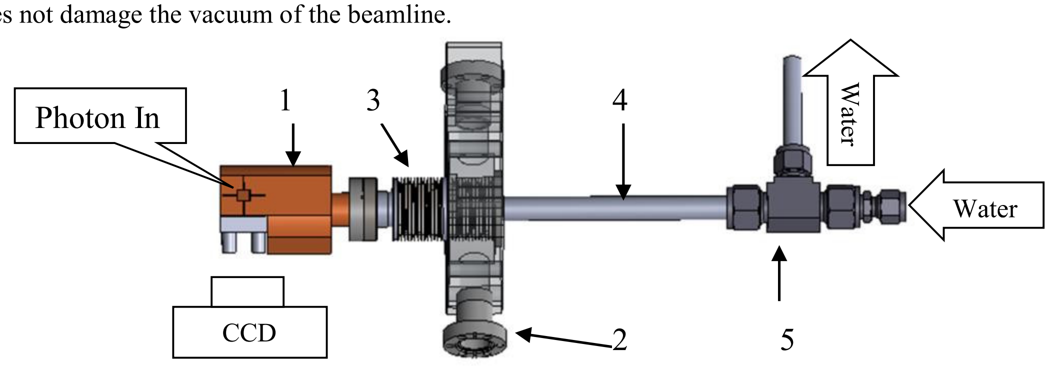

FIGURE 1. Design of the rear-projection module with coaxial cooling

A diamond plate with a nickel film (500 nm) is mounted on an oxygen-free copper block with coaxial cooling, shown in Fig. 2 and 3. The CCD camera and incident beam are at angle 90^{o} to one another to capture the fluorescent image with rear projection; in this manner influencing the quality of the image by the reflection of the synchrotron

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radiation (SR) can be avoided [1]. The CCD-captured fluorescence image is magnified twice because the diamond plate is located at a 30° angle to the incident beam.

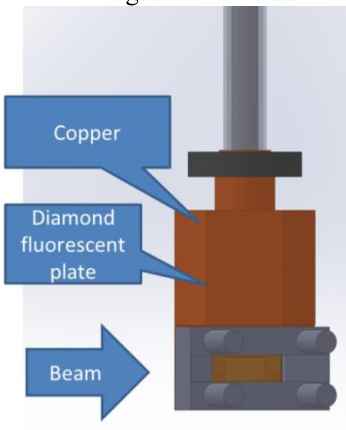


FIGURE 2. Oxygen-free copper block, side view

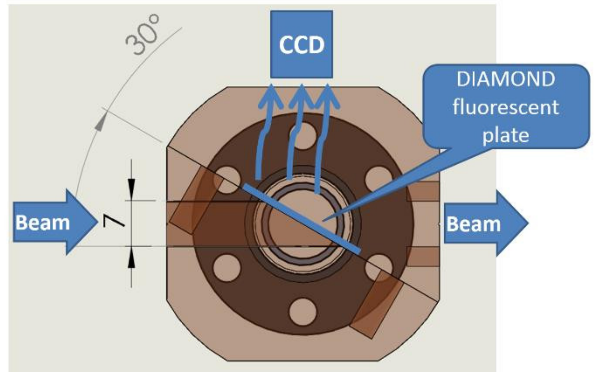


FIGURE 3. Oxygen-free copper block, bottom view

THERMAL ANALYSIS

To verify the cooling effect of the white-beam fluorescent plate, the incident beam of TPS was used at maximum power 120 W; the power density on the diamond screen module was calculated to be 17.4 W/mm^2. Software (SolidWorks) for finite-element analysis was used to simulate the temperature and thermal stress of the diamond screen. The parameters of the cooling water are water temperature 25 °C and flow rate 2 L/min,

The results of the simulation show that the highest temperature is only 56.7 °C at the center of the diamond fluorescence plate and there is no overheating, shown in Fig. 4a. The maximum stress is 63.8 Mpa, which is much less than the tensile strength of diamond, 1200 Mpa, shown in Fig. 4b. The result shows that the screen system can operate normally under a white beam with a high power density.

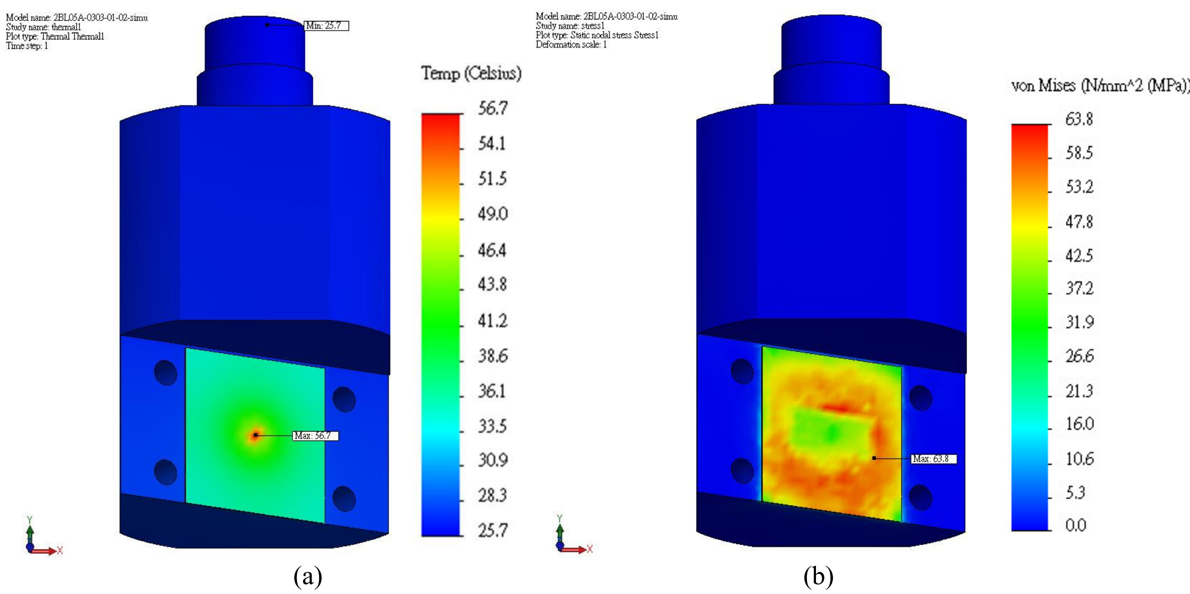


FIGURE 4. (a) Temperature of the cold head and fluorescent plate assembly and (b) distribution of thermal stress

DESIGN OF A MONO-BEAM SCREEN SYSTEM

Figure 5 shows the design of a mono-beam screen system. The CCD is mounted on the view-port at 90º to the incident beam. The assembly of the screen head consists of four parts. The yellow triangular block is a prism; the brown triangular block is an aluminum block; the red plate is YAG:Ce [2], and the semi-transparent part is an aluminum holder with a one-piece processed structure. The oblique projection causes image distortion. The fluorescent image at an oblique angle is larger than the image from a perpendicular direction, shown in Fig. 7a. Here we use a right-angle prism that reflects the fluorescence to maintain the image size. Using the aluminum block with a prism shape, the position of the CCD camera can be varied according to the optical design and the spatial requirements.

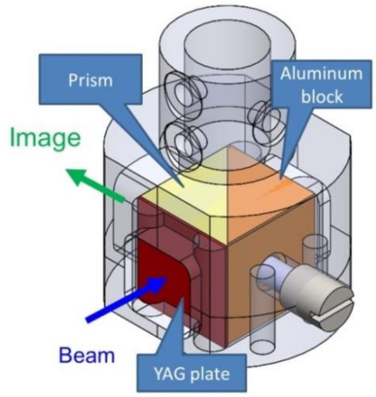
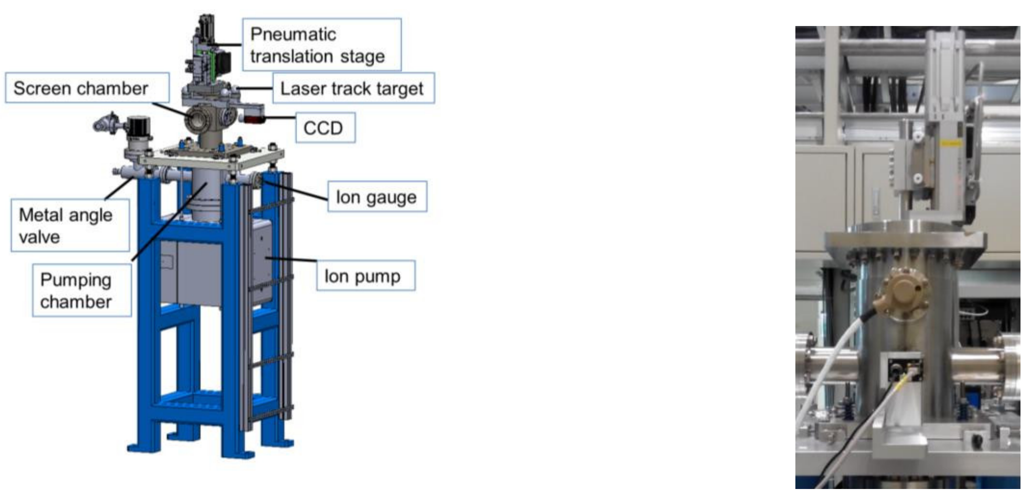


FIGURE 5. Design of a YAG:Ce plate holder module

OVERALL DESIGN

Figure 6 shows the overall design of the architecture considering the low manufacturing cost and a requirement for rapid maintenance; the chamber and the support of the screen system are symmetrically designed to decrease the manufacturing costs and the fabrication errors. In addition, the position and orientation of the CCD camera and the translation stage can be altered because of spatial constraints and user requirements. The screen system is equipped with an ion pump, which forms a closed vacuum system with vacuum equipment upstream and downstream, and which is responsible to achieve an ultra-high vacuum. It also protects the beamline in the event of a pressure or power failure [3][4].



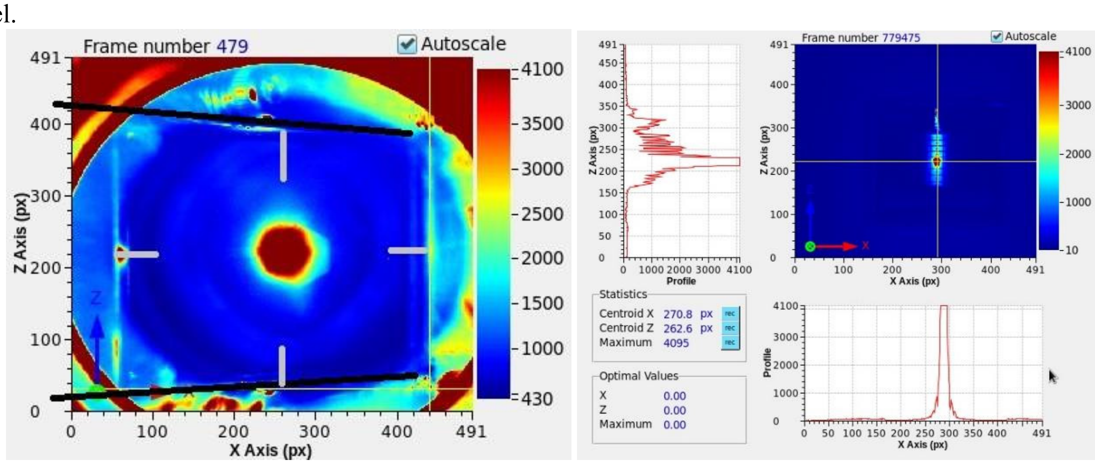
(a) **(b)**

FIGURE 6. (a) Overall structure of the screen system, **(b)** Vacuum chamber variable according to user requirement

APPLICATION

The control program of the beamline is designed with software of the Experimental Physics and Industrial Control System (EPICS). The users can adjust optical components for beamline alignment with a fluorescent image and the adjusted parameters of the optical components on the display of the computer of the beamline [5].

A pre-drawn line on the fluorescent plate retains the actual size. A spatial resolution of one pixel is obtainable with the length of the pre-drawn line compared with the pixel value of its display on the screen. Fig. 7a is a fluorescent image taken from the white-beam screen; a grey line denotes the reticles, and black lines show that the left side of the diamond plate is larger than the right side. This image distortion is caused by the depth of the field. The reticle of the diamond plate is as a 5-mm, grey line; the spatial resolution is 0.1 mm/pixel. Fig. 7b shows a fluorescent image taken from the mono-beam screen. The interval on the grid line of the YAG:Ce plate is 1 mm; the spatial resolution is 0.077 mm/pixel.



(a) (b)

FIGURE 7. Design of the screen system with EPICS.

(a) Fluorescent image on the diamond plate, (b) Fluorescent image on the YAG:Ce plate.

CONCLUSION

The design of the white-beam module with rear projection avoids radiation damage and the influence from visible light. The design of the mono-beam module with a prism avoids distortion of the image. These screens can show the beam size and the beam position to diagnose the beamline situation. They have been successfully used at TPS beamlines and have also become standard instruments.

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