DEVELOPING WHITE BEAM COMPONENTS OF TPS BEAMLINE 24A

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Abstract

The TPS 24A, Soft X-ray Tomography (SXT) beamline, is one of the beamlines in the second construction phase at the Taiwan Photon Source (TPS). This bending magnet (BM) beamline has high flux in the range between 260 eV and 2600 eV. It is designed for transmission full-field imaging of frozen-hydrated biological samples. At the exit slit, the beam flux optimized in 520 eV is 2.82×10^{11} photons/second with resolving power 2000, the beam size is 50×60 μm^2 (V×H, FWHM) and the beam divergence is 1.73×1.57 mrad^2 (V×H, FWHM). By contributions of the generic beamline components project in recent years, modular mechanisms would be used in this beamline such as mask, X-ray beam position monitor (XBPM), photon absorber (PAB), and screens. However, these beamline components were designed for ID beamlines, so they should be redesigned for BM beamlines. This paper generally introduce these beamline components decided and redesigned for the TPS 24A. They will play important roles at the BM beamlines in the future.

BEAMLINE LAYOUT

Figure 1 shows the layout of the SXT beamline.

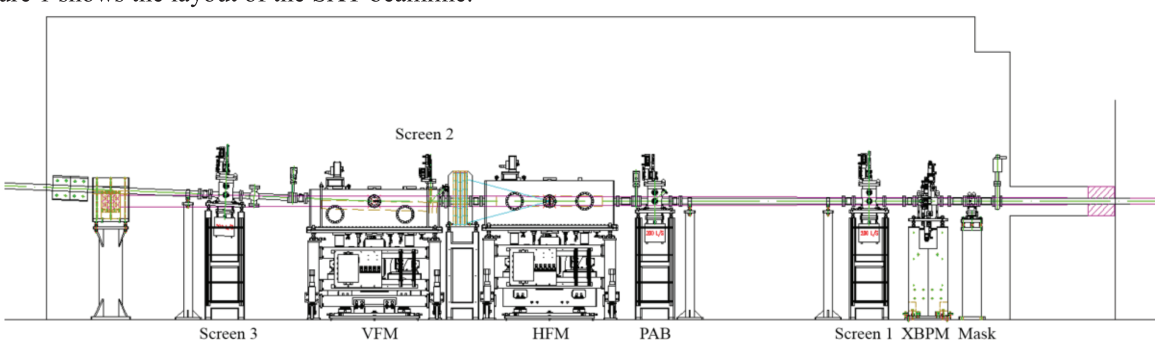

Figure 1: White beam components layout of the SXT beamline.

MASK

The mask as shown in Figure 2 is used to confine the beam size of 21 mm (H) × 20 mm (V) with small range adjustment. Due to the much larger beam size and lower heat load of BM beamlines, we cancelled the tungsten blades used in ID beamlines and simplified the route of cooling water in the chamber of the mask. The entrance and exit ports were also changed from 2.75 inch to 4.5 inch CF flanges. Furthermore, a local shielding which contains of lead and Polyethylene (PE) was added to the mask to prevent the bremsstrahlung radiation.

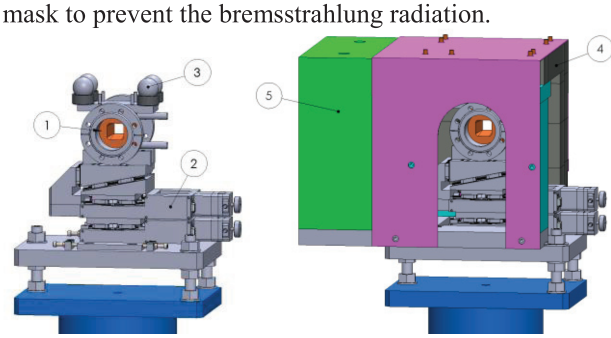

Figure 2: The schematic drawing of the mask and local shielding.

1. UHV water-cooling chamber, 2. Motorized XZ stage, 3. Laser tracker target, 4. Lead, 5. PE.

XBPM

The XBPM with high precision and current detecting function is used to confine the beam size and observe the beam fluctuation. Four tungsten blades moved by linear stages are used to confine the beam size. The stroke of the linear stages and bellows was changed from 10 mm to 30 mm to make sure that the blades travel longer than the beam size. The beam could fully pass through when the blades are opened, and would be cut off when the blades are closed. Optionally, eight M16 × 2.0 screw holes made on the granite stand could be used if a bremsstrahlung stopper is needed. Figure 3 shows the schematic drawing of the XBPM.

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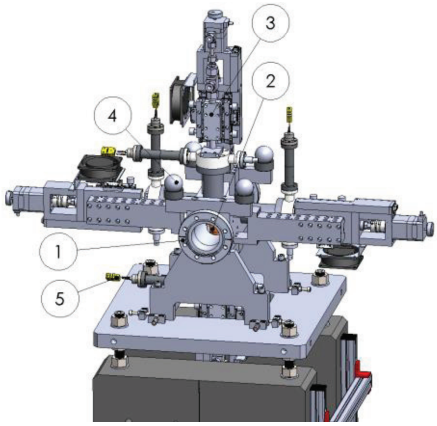

Figure 3: The schematic drawing of the XBPM. 1. UHV chamber, 2. Blades with cooling unit, 3. Motorized linear stage, 4. Laser tracker target, 5. Thermocouple.

WHITE BEAM SCREEN

The screen as shown in Figure 4 is designed to observe the beam size and position. There are five screens in the TPS 24A and three of them were used for white beam. In the generic beamline components project, a small type of chamber and liner stage module is used for the screen while a large one is used for the PAB. Modules of the screen 1 and 3 in the TPS 24A were changed to the PAB type because of the much larger beam size of BM beamlines. Linear stage of the screen 2 is still the typical small type so it could be put into a narrow space in the VFM chamber. Finally, the stroke of the three linear stages and bellows was changed to 30 mm, too.

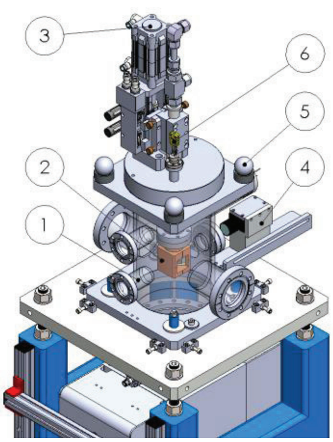

Figure 4: The schematic drawing of the screen 1. 1. UHV chamber, 2. Screen with cooling unit, 3. Linear stage, 4. CCD, 5. Laser tracker target, 6. Thermocouple.

PAB

The PAB as shown in Figure 5 is used to block the beam temporarily when user need. Reticules were made on an oxygen-free high thermal conductivity copper (OFHC) which was coated with fluorescent material to observe the beam position roughly. The stroke of the linear stages and bellows was also changed to 30 mm. A tungsten local shielding could be added into the chamber if it is needed.

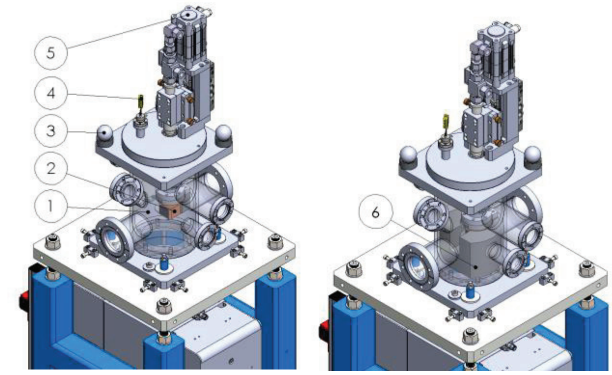

Figure 5: The schematic drawing of the PAB and local shielding.
1. UHV chamber, 2. OFHC with cooling unit, 3. Laser tracker target, 4. Thermocouple, 5. Linear stage, 6. Tungsten shielding.

FLOW RATE OF COOLING WATER

For flow in a pipe or tube, the Reynolds number is generally defined as: [1]

$$\mathrm{Re} = \frac{\rho v D_H}{\mu} = \frac{v D_H}{\upsilon} \tag{1}$$

where:
D_H = hydraulic diameter of the pipe (m)
v = mean velocity of the fluid (m/s)
μ = dynamic viscosity of the fluid (Pa·s)
ν (nu) = kinematic viscosity (m^2/s)
ρ = density of the fluid (kg/m^3)

If Re is under 2300, the behavior of the fluid is laminar; turbulent flow occurs when Re is over 2300 and gets fully developed after Re is over 4000. Turbulent flow takes more heat away than laminar but brings vibration, so the minimum flow rate of cooling water was determined by Re = 4000 in generally condition. Minimum flow rate of the beamline components which got less concern about vibration than heat issue was determined to Re = 2300. A table of minimum flow rate of the generic beamline components is listed in Table 1:

Table 1: Minimum Flow Rate of Cooling Water.

	Mask	PAB/Screen	XBPM
D_H (m)	0.0075	0.0053	0.0027
Re	4000	4000	2300
Flow Rate (L/min)	5.2	5.2	1.9

THERMAL SIMULATION

Thermal Simulations were done to calculate the temperature and thermal stress of the white beam components by SOLIDWORKS Simulation. Since the beam is Gaussian distribution in vertical direction, the power load used in simulation was divided to five area according to the proportion of Gaussian distribution. The power loads and simulation results are listed in Table 2 and the simulation results are shown in Figure 6 to 9:

Table 2: Power Load of White Beam Components.

	Mask	PAB	Screen	XBPM
Power Load (W)	23.8	100	67.1	100

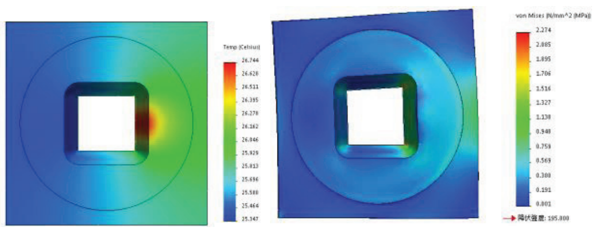

Figure 6: Temperature and thermal stress of the mask.

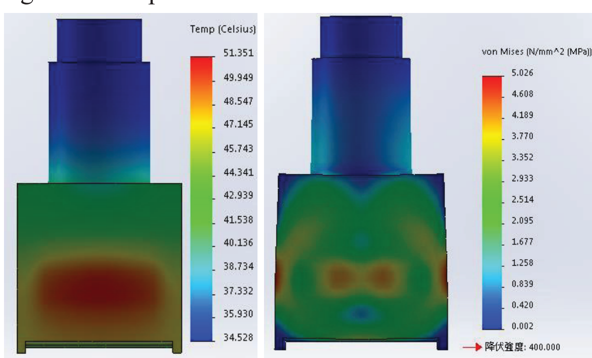

Figure 7: Temperature and thermal stress of the XBPM.

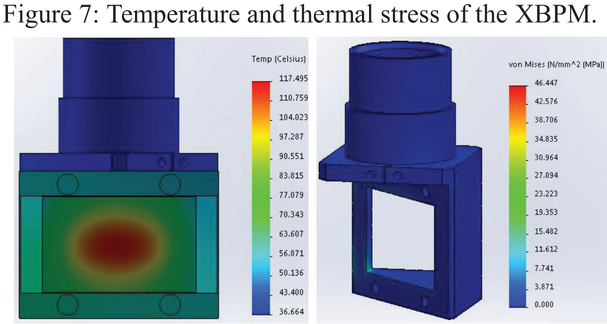

Figure 8: Temperature and thermal stress of the screen.

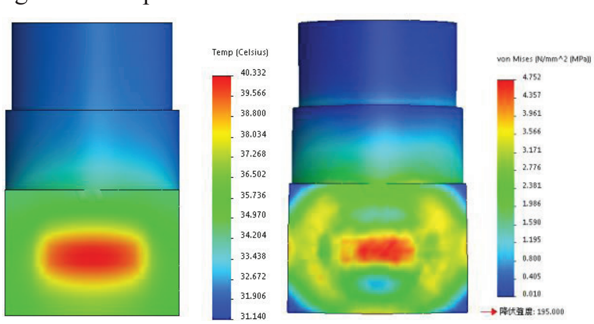

Figure 9: Temperature and thermal stress of the PAB.

CONCLUSION

- All these white beam components have not been tested online and the test is scheduled in October, 2016.
- The bremsstrahlung radiation of the mask and the PAB is needed to be observed continuously.
- 30 mm is the maximum beam size due to the chamber inner space of generic beamline components, bigger chambers should be designed for larger beam size.
- We would keep developing the design for getting more accurate beam size and position.
- To determine the flow rate of cooling water needs more experiments and data, especially the pressure loss of long pipe.

ACKNOWLEDGEMENT

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REFERENCES

[1] The Engineering Toolbox, http://goo.gl/ByO7Wj