# HIGH HEAT LOAD SLITS FOR THE PLS MULTI-POLE WIGGLER*

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*Abstract*

The HFMX (High Flux Macromolecular X-ray crystallography) beamline under commissioning at the Pohang Accelerator Laboratory uses beams from a multi-pole wiggler. Two horizontal and vertical slits relevant to high heat load are installed at its front-end. In order to treat high heat load with reducing beam scattering, the horizontal slit has two GlidCop blocks with 10° of turned-grazing inclination. The blocks adjust each gap of the slits by being translated, by two actuating bars, on slides fixed to a support, respectively. Water through channels machined along the actuating bars cools down the heat load of both blocks. The vertical slit has the same structure as the horizontal slit except its installation direction with respect to a vacuum chamber and its inclination angle. The installed slits show stable operation performance and no alignment for the blocks is required by virtue of a pair of blocks translating on slides. The cooling performance of the two slits has been also shown to be acceptable. In this paper, the details of the design and manufacture of the two slits are presented and its cooling performance is reported.


## INTRODUCTION

The synchrotron radiation source of the HFMX beamline at the PLS (Pohang Light Source) is a multi-pole wiggler of which the number of poles is 28. The outer portion of the synchrotron radiation that has entered the front-end is excluded by vertical and horizontal fixed masks before going into a collimating mirror. Horizontal and vertical slits define subsequently the size of the cross-section of synchrotron radiation necessary for a specific experiment. At the moment, scattered beams must be excluded not to go into the collimating mirror.

At the front-end of the PLS ID beamlines, the length from the exit port of a storage ring vacuum chamber to its concrete wall is 5.8 m. The optics design of the HFMX beamline that adds an 1.4 m long collimating mirror chamber to its front-end makes space for other components of the front-end more limited. Thus, since the inclination angles of cooling components including slits for the multi-pole wiggler are not unrestricted, it is required to take a deep consideration about the heat load from the multi-pole wiggler and the cooling performance of the slits at the design stage of the slits.

It is fundamental to adopt turned-grazing inclination for scattered beams not to go into the downstream experimental region [1-2]. Generally, two blade blocks of slits with turned-grazing inclination are usually made into respective assemblies, which are independently installed and controlled [1-2]. At this development of slits, we have developed a suitable-sized slit system with a new compact structure for PLS multi-pole wigglers which can drive two blade blocks from a main flange side by arranging them into one assembly with turned-grazing inclination adopted.

This paper discusses the principal and structural details of the design of these slits.

## DEVELOPMENT OF SLITS

### Calculation of Heat Loads on Slits

The total power of the multi-pole wiggler reaches 9.5 kW and its peak power density is 3.6 kW/mrad$^2$. The peak surface power density $W_{xy}$ (W/mm$^2$) on the blade blocks of slits may be calculated by following equation [3]:

$$W_{xy} = 1.076 \times 10^{-2} B_0 E^4 IN / l^2 \quad (1)$$

where $B_0$ (T) is the magnetic field, $E$ (GeV) is the storage ring energy, $I$ (mA) is the storage ring current, $N$ is the number of poles, and $l$ (m) is a distance from the multi-pole wiggler center.

Calculating by Eq. 1 when the operating condition of the storage ring is 2.5 GeV and 300 mA, peak surface power densities of 30.6 W/mm$^2$ and 29.4 W/mm$^2$ are obtained for a horizontal slit and a vertical slit positioned at distances of 10.8 m and 11.0 m, respectively, away from the multi-pole wiggler center. On the other hand, the total power to be absorbed by both slits amounts to 3.18 kW when the opening angles of the horizontal and vertical slits are $\pm 0.75$ mrad and $\pm 0.12$ mrad, respectively, which are their normal opening angles.

### Description of Slit Design

Fig. 1 shows the general assembly of the horizontal slit. Two GlidCop blade blocks (1) and (2) are arranged parallel with the synchrotron radiation centerline. Two linear slides (3) are bolted on the bottom edges of both blade blocks and contact two opposite long linear slides (4) attached on a setting plate (5). The setting plate is assembled with a support (6) bolted to a main flange (7). The two blade blocks are vacuum-brazed on the surface of cooling channels with stainless steel connecting plates (8) and (9), respectively. Both connecting plates are also connected to reducing nipples (10) via special 2.75” flanges at the ends of actuating bars (11) TIG-welded to themselves. The upper 4.5” flanges of the reducing nipples are bolted to two z-stages (12) and can be driven by two stepping motors connected to those stages with two worms, respectively. A photograph of the assembled horizontal slit is shown in Fig. 2.

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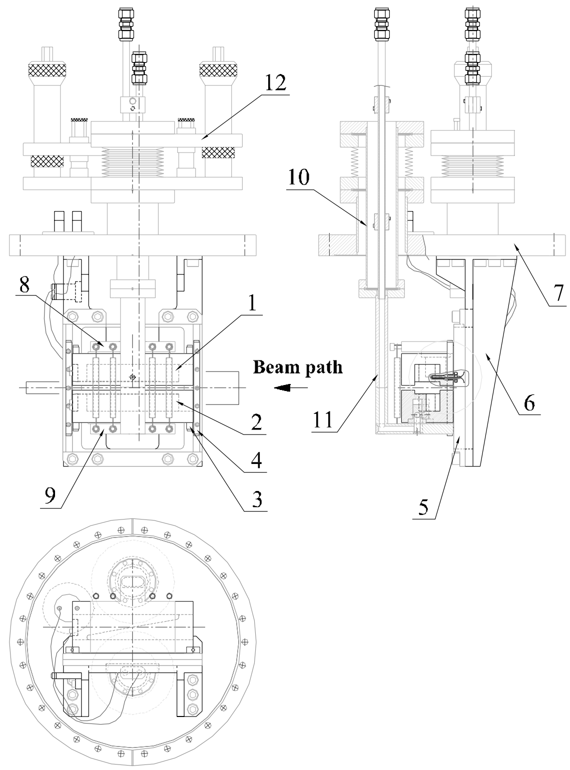


Figure 1: Horizontal slit general assembly.

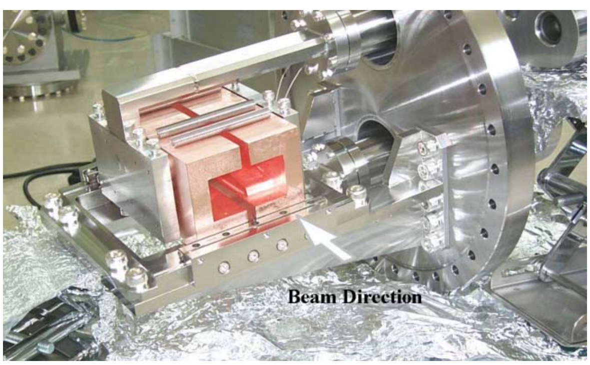


Figure 2: Assembled horizontal slit.

Solid models of a blade block and a connecting plate of the horizontal slit are shown in Fig. 3. The surface of the turned-grazing inclination on which beams impinge are inclined by 10° for the horizontal slit to reduce beam power density. The vertical slit is installed behind the horizontal slit and admits beams of which the width has been reduced by the horizontal slit. But the maximum width of the beams which pass the horizontal slit reaches 20.5 mm. Thus, the inclination angle of the blade block of the vertical slit has been determined to be 15° to cover the incident beams and to standardize the structures and the dimensions of its parts with the horizontal slit. Therefore, the peak surface power densities become 5.31 W/mm$^2$ and 7.61 W/mm$^2$, respectively.

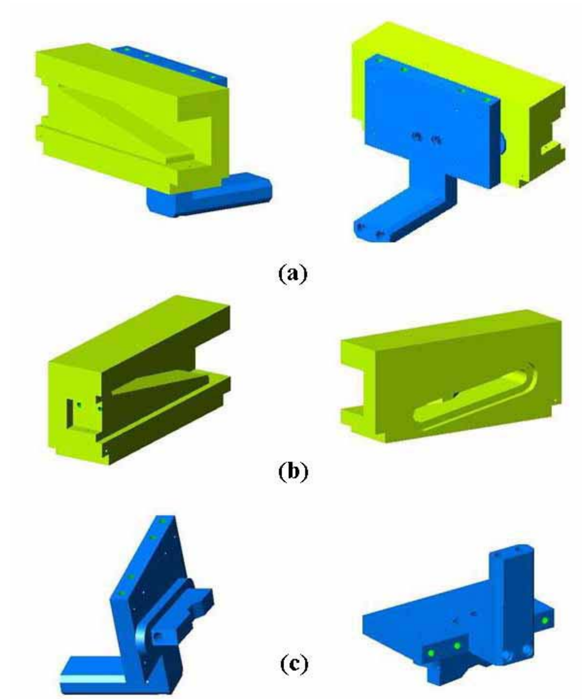


Figure 3: Solid models of the inner blade block and its corresponding connecting plate of the horizontal slit.

It is expected that the beams impinging on the valley of turned-grazing inclination with such a structure as that of Fig. 3 are confined within the valley without scattering into downstream components. On the backside of the blade block, a 12 mm wide cooling channel is milled parallel with the surface of inclination. The connecting plate corresponding to the cooling channel is put into the slot and the assembled body is vacuum-brazed.

The connecting plate is made of 304L stainless steel. The connecting plate takes a role of the intermediate path of cooling water for the blade block and a role to supply displacements to the blade block.

## TEMPERATURE MEASUREMENT AND DISCUSSIONS

The horizontal and vertical slits have each own K-type thermocouple to measure their temperature rises resulted from beams. The thermocouples are attached to the blade blocks near to their main flange. Fig. 4 shows the thermocouple attached to the horizontal slit. To avoid a short of thermocouple wires and to press the thermocouple tip against the end of the screw hole, two ceramic rods and a screw with a central hole are used as shown in Fig. 4.

The temperatures of the horizontal and vertical slits measured by the thermocouples are plotted as a function of storage ring current in Fig. 5. The temperature of the horizontal slit increases by about 12 ℃ per 100 mA. And the temperature of the vertical slit shows a rise rate of

2.6 ℃ per 100 mA. It is shown that the beam add little heat load on the vertical slit at the present gap status.

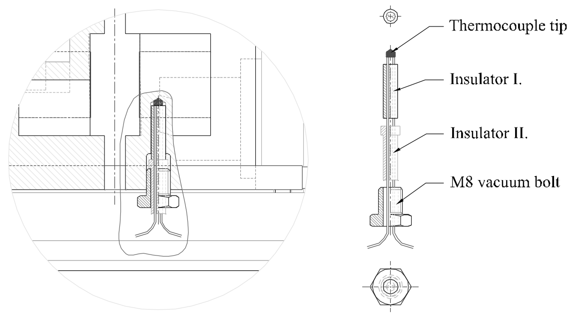


Figure 4: Thermocouple attachment and its parts.

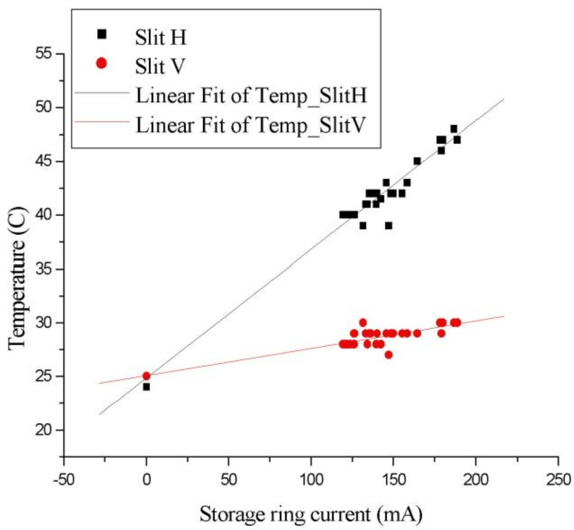


Figure 5: Blade block temperatures of the horizontal and vertical slits vs. storage ring current.

To approximate the temperature of the surface impinged by beams, the one-dimensional heat-conduction equation is used:

$$\Delta T = \int_0^x \frac{q}{kA(x)} dx \qquad (2)$$

Brief calculation using equation (2) yields $\Delta T \cong 65$ ℃. As $T_{surf} \cong \Delta T + T_{thermocouple}$, a surface temperature of the horizontal slit blade block of about 113 ℃ can be estimated for a storage ring current of 200 mA. This is well below 300 ℃, which is the maximum endurable surface temperature of GlidCop [4].

Fig. 6 shows a beam profile observed at the third screen monitor of the HFMX beamline after passing a focusing mirror. Since the screens are inclined by 30° with respect to incident beams, the images displayed on the screens are magnified two times horizontally. The beam profile shape of Fig. 6 changed to a crescent as the beam starts to be focused by the focusing mirror.

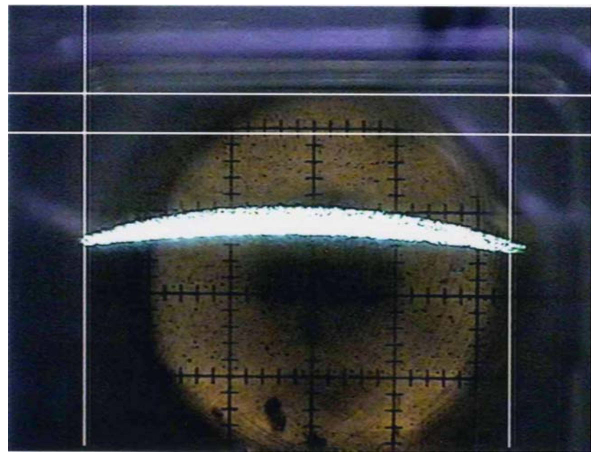

Figure 6: Beam profile on the 3rd screen monitor.

## CONCLUSIONS

We have developed a suitable-sized compact slit system by arranging two blade blocks on linear slides with turned-grazing inclination adopted and by designing so that driving of two blade blocks from a main flange adjusts slit gap.

Since both blade blocks of the slits have angles of turned-grazing inclination relevant to the power density of the PLS multi-pole wiggler, the slits not only have the length of the blade blocks not too long but also intercept scattered beams effectively. Furthermore, the translations of the blade blocks are stably performed by virtue of the guidance of slides so that vibration-resistant characteristics required to slits can be expected.

The measured temperatures of the blade blocks showed that the designed and manufactured slits had effective cooling capacity for the beams from the PLS multi-pole wiggler. The compact structure of the horizontal slit was identically applied to the vertical slit.

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