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**Design of High Heat Load White-Beam Slits
for Wiggler/Undulator Beamlines at the Advanced Photon Source**

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Abstract

A set of horizontal and vertical white-beam slits has been designed for the Advanced Photon Source wiggler/undulator beamlines at Argonne National Laboratory. While this slit set can handle the high heat flux from one APS undulator source, it has large enough aperture to be compatible with a wiggler source also. A grazing-incidence, knife-edge configuration has been used in the design to eliminate downstream X-ray scattering. Enhanced heat transfer technology has been used in the water-cooling system. A unique stepping parallelogram driving structure provides precise vertical slit motion with large optical aperture.

The full design detail is presented in this paper.

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1. Introduction

The 7-GeV Advanced Photon Source (APS) now under construction at Argonne National Laboratory is one of a new generation of synchrotron radiation sources [1], that have presented a multitude of design challenges in the beamline components. One such component is the white-beam slit for insertion device (ID) beamlines, especially for ID beamlines that use both undulator and wiggler sources.

The major design challenge for this slit assembly is that the vertical slits should be able to handle the high heat flux from one APS undulator source, while at the same time it must have a large enough aperture to also be compatible with a wiggler source. To minimize the downstream scattered X-rays from the slits, a novel grazing incidence, knife-edge slit assembly with a unique stepping parallelogram driving structure has been developed for the APS. In this paper, we will discuss the design details of this slit assembly, named L1 in the APS standard components library [2].

2. Design Specifications

At a typical APS undulator/wiggler beamline, L1 slits will be located in the first optics enclosure (FOE) area about 27.5 meters from the undulator source. Using one of the standard APS undulators, called Undulator A [3], the L1 slits will be impinged by a X-ray beam with 3800 watts total power and 400 watts/mm² peak heat flux in the worst case. For wiggler operation, using one of the standard APS wigglers, called wiggler A [4], the L1 slits will have a maximum of 48-mm horizontal slit length to cover about 1.65 mrad of the wiggler beam horizontally (if wiggler A is located at the upstream end of the APS straight section in the worst case). The L1 slit assembly is designed to be able to absorb up to 7200 watts total power from the APS wiggler A source.

As shown in Fig. 1, the L1 undulator/wiggler white-beam slit assembly consists of two pair of slits. The first slit pair, which is located on the upstream side, is called the horizontal slits, and these slits control the beam horizontal size (0 - 48 mm) by moving the slit blades individually. Each horizontal slit blade has a water-cooling length of 100 mm horizontally and a 35-mm motion range. A minimum

horizontal beam acceptance angle of 2.54 mrad has been provided by the horizontal slits to avoid the missteered beam damage to the downstream components.

The vertical slit blade has a 6.8-mm vertical motion range and 12-mm vertical water cooling area. The vertical slits will provide a minimum beam acceptance angle of 0.67 mrad vertically.

Table 1 shows the major design specifications for the undulator/wiggler white beam slits L1.

3. Grazing-Incidence Knife-Edge Configuration

To minimize the downstream X-ray scattering, a knife-edge slit with normal incident surface facing the beam is considered to be the best choice. But, for the L1 slits, this is not possible, because of the high heat flux X-ray impinging on the slit. To solve this problem, the slit front surface was turned around the Y axis by a angle (or around the X axis for the horizontal slits), so that the slit front surface will be impinged by the X-ray beam with a grazing incident angle Θ as shown in Fig. 1.

In order to control the fuzziness of the slit knife-edge in the high energy range, tungsten-based heavy-metal alloy has been chosen as the slit-blade material. To achieve a 0.5-degree real recess angle, the 2.5-degree grazing-incidence angle of the horizontal-slit, knife-edge blade has an 11.3-degree back cutting angle, and the 4-degree grazing-incidence angle of the vertical slit, knife-edge blade has a 7.1-degree back cutting angle. A detailed study about the grazing-incidence, knife-edge fuzziness can be found in reference [5]. Fig. 2 shows the general layout of the L1 undulator/wiggler horizontal and vertical slit assembly.

4. The Parallelogram Driving Structure for Vertical Slits

The design of the L1 vertical slit assembly is based on the use of a large, rigid, parallelogram driving structure that provides continuously independent motion from 0.1 micron to 6.8 mm for each slit blade. The maximum vertical opening of the slit assembly is 8.2 mm, so that they have an overlapping range of plus and minus 2.7 mm.

As shown in Fig. 2, the L1 vertical slit assembly consists of two subassemblies: The upper vertical slit sub-assembly and the lower vertical slit subassembly. The major components of these two subassemblies are the same except that the upper slit blade (1) and the lower slit blade (2) have different profile shapes, as shown in Fig. 1.

There is a coaxial water-cooling tube (3) with enhanced heat transfer mesh [6-7] brazed in the middle of the tungsten alloy blade along the full slit length. The cooling tube is made from a deep-drilled oxygen-free high-quality copper (OFHC) without a water-vacuum joint. The blade has two roller-bearing hinging points (4), which are linked to the vacuum-chamber hinging bases (5) by a pair of link bars (6). To drive the slit blade from outside of the vacuum chamber, the cooling tube has been bent 50 degrees from the slit edge. Welded bellows (7) provide a vacuum feedthrough for the cooling pipe. Near the terminal end of the cooling tube, a linear bearing slide (8) makes the linkage between the cooling tube and a precision, vertical stepping stage (9) to compensate the parallelogram motion. Two compressed springs (10) balance the vacuum force on the stage.

A comprehensive thermal-stresses analysis has been done by T. Nian et.al. [8]. The results show that, the L1 vertical slits will survive when operating under beam either Undulator A or Wiggler A. The maximum thermal distortion on the knife-edge is about 50 microns operating under beam from the Undulator A. This is the worst case, as shown in Fig. 3.

5. The Horizontal Slits

As shown in Fig. 4, the horizontal slit blade (1) is made of a bimetallic plate with a total thickness of 14 mm (3 mm of tungsten and 11 mm of tantalum). A water-cooling tube (2), which is filled by copper mesh for enhanced heat transfer [7], has been soldered to the slit blade on the tantalum side.

The slit blade is clamped to the rigid hollow shaft (3), which is moving along its axis in the horizontal direction. The cooling-water input and output is made through the inner space of the shaft. The supports (4) provide the possibility to have

horizontal and vertical tilting for alignment of the slit-blade knife-edge. The stepping-motor-driven actuator (5) is an APS standard design, called A2-82, which includes a linear encoder with 0.5-micron resolution over a 70-mm travel range.

Because of the space limitation, both horizontal slits are mounted on the same side of the vacuum chamber. Each of the slits has the same design, but they cross the beam from the opposite sides.

6. Conclusion

A set of grazing-incidence, knife-edge, white-beam slits has been developed for the APS undulator/wiggler beamlines. There are several new design concepts applied in this slit set including: a grazing-incidence, knife-edge configuration to minimize the scattering of X-rays downstream, the use of a large, rigid, parallelogram driving structure to provide precision motion and high stability for the vertical slits, and coaxial enhanced heat transfer tubing to provide water cooling.

Mechanical and X-ray tests for the L1 slits are in progress.

7. Acknowledgments

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Figure Captions

Fig. 1, Schematic diagram of the APS L1 undulator/wiggler white-beam horizontal and vertical slit assembly.

Fig. 2, APS L1 undulator/wiggler white-beam horizontal and vertical slits general assembly. (1) upper vertical slit blade, (2) lower vertical slit blade, (3) coaxial water-cooling tube, (4) roller-bearing hinging point, (5) vacuum-chamber hinging base, (6) link bar, (7) Welded bellows, (8) linear bearing slide, (9) vertical stepping stage, (10) compressed spring. (11) vacuum chamber. (12) right horizontal slit. (13) left horizontal slit.

Fig. 3, The maximum thermal distortion on the L1 vertical slit knife-edge.

Fig. 4, Section view of the L1 horizontal slit assembly. (1) horizontal slit blade. (2) water-cooling tube. (3) rigid hollow shaft. (4) supports. (5) stepping-motor-driven actuator.

Design Specifications for L1 Undulator/Wiggler White Beam Slits

- 1, Location : 27.5 m from APS ID Straight Section Center
 - 2, Optical Aperture : Input: 70 mm (H) x 8.2 mm (V)
Output: 0 - 48 mm (H)
0 - 8.2 mm (V)
 - 3, Horizontal Maximum Acceptance : 2.54 mrad (2.18 mrad)
 - 4, Vertical Maximum Acceptance : 0.29 mrad
 - 5, Actuator Maximum Speed : 20 mm/min
 - 6, Input Flange O.D. : 6 inch
 - 7, Output Flange O.D. : 6 inch
 - 8, Vertical Slit Grazing Incidence Angle : 4 degree
Horizontal Slit Grazing Incidence Angle : 2.5 degree
 - 9, Slits Material : TZM or Heavy Metal with OFHC Cooling Base
 - 10, Water Cooling : Mesh-filled or Micro-channel
 - 11, Vertical Slits Motion Structure : Stepping Parallelogram
 - 12, Vertical Slits Motion Resolution : 0.2 μm
 - 13, Horizontal Slits Motion Resolution : 0.5 μm
 - 14, Device Flange to Flange Length : 1750 mm
 - 16, Vacuum : UHV Compatible
 - 17, Maximum Total Power : 3800 W (U) 7200 W (W)
-

Fig. 1

Fig. 2

Displacement Uz
 Contour (mm)
 SMN = -.058328
 SMX = .050865

█	-.057475
█	-.051504
█	-.045532
█	-.039561
█	-.033589
█	-.027618
█	-.021646
█	-.015675
█	-.009703
█	-.003731
█	.00224
█	.008212
█	.014183
█	.020155
█	.026126
█	.032098
█	.038069
█	.044041
█	.050865

Fig. 3

FIG. 4