Mechanical Design of Secondary Source Slits for Hard X-ray Beamlines at Taiwan Photon Source

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Abstract

The secondary source slits have been developed for specific hard X-ray beamlines at Taiwan Photon Source. Especially for Coherent X-ray Scattering and X-ray Nanoprobe beamlines, severe specifications of the slits are more necessary to define proper beam sizes in horizontal and vertical directions at sample. The opening size of each pair of slits assembled orthogonally is usually needed to range within several microns, so the UHV-compatible piezo-driven stages with closed-loop system were adopted for the purposes of fine adjustment, precise positional accuracy and repeatability. To reduce X-ray scattering effect, the rectangular single-crystal film was bonded on the edge of the slit blade. The machined rotary weak-link structure and piezo-driven actuators were used to slightly adjust parallelism of each pair of the blades with the method of single-slit diffraction. To enhance structural and thermal stability, the granite plinths with specified shape were designed and the precise temperature controlling system will be set up recently. The overall design, mechanical specifications and procedure of testing for secondary source slits will be introduced in this paper.

I. Design of secondary source slits

![Figure 1: Schematic 3-D drawing of secondary source slits.](image1)

Figure 2: On-site view of secondary source slits installed in the Coherent X-ray Scattering beamline at TPS.

![Figure 3: A 3-D model of main mechanism for secondary source slits.](image2)

III. Single-slit diffraction and measurement of parallelism

![Figure 5: Diffraction pattern observed in the test of parallelism for horizontal slit.](image3)

Table 1: The overall specifications of secondary source slits

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Vacuum</td>
<td>≤ 10^-9 mbar</td>
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<tr>
<td>Helium leak rate</td>
<td>≤ 5 × 10^-10 mbar/s</td>
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<tr>
<td>Material</td>
<td>Tungsten carbide (Type WF20: 86.4% WC, 11.5% Co, 2.1% Others) GaAs single crystal</td>
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<tr>
<td>Maximum opening size</td>
<td>13 mm (H) × 13 mm (V)</td>
</tr>
<tr>
<td>Position resolution</td>
<td>≤ 0.006 μm</td>
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<tr>
<td>Position repeatability</td>
<td>≤ 0.018 μm</td>
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<tr>
<td>Positional accuracy</td>
<td>≤ 0.2 μm</td>
</tr>
<tr>
<td>Parallelism between blades</td>
<td>≤ 1 μm</td>
</tr>
<tr>
<td>Range of rotary adjustment</td>
<td>± 0.21 degree</td>
</tr>
</tbody>
</table>

II. Finite-element analysis

![Figure 4: Result of finite-element analysis for rotary weak-link mechanism.](image4)

Figure 6: A compact-type air handling unit for precise temperature controlling system.

IV. Precise temperature controlling system

Equation of Fraunhofer single-slit: $y = \frac{m \lambda D}{a}$

- $y$: Displacement from centreline for minimum intensity
- $m$: Order
- $\lambda$: Wavelength of light
- $a$: Width of slit

Conclusion

The system of mono beam secondary source slits has been designed, fabricated, tested, and installed on the Coherent X-ray Scattering beamline at TPS. UHV-compatible piezo-driven actuators were used to control opening sizes in horizontal and vertical directions and adjustment of parallelism between two blades on each pair of slits respectively. A set of testing procedure based on Single-Slit Diffraction was realized to measure the parallelism between blades, and the design value of parallelism was reached successfully. To reduce the influence of ambient temperature, the precise temperature controlling system will be applied to provide air with constant temperature for enclosed system of secondary source slits. On-site test will be made to acquire more results during the beam time of TPS. According to the results, upgrade will be considered to reach better performance for system of secondary source slits in the future.

Reference