LUSI

LCLS Ultrafast Science Instruments

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Primary, Guard, and Monochromatic Slit Systems

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Table of Contents

1. Overview ... 4
2. Applicable Documents, Specifications and Codes ... 5
2.1. Stanford Linear Accelerator Center (SLAC) Specifications ... 5
2.2. Acronyms ... 5
3. General Requirements ... 5
3.1. Location ... 5
3.2. Environment ... 6
3.3. Maintenance, Accessibility and Operations ... 6
4. Optical Requirements ... 7
4.1. Viewport Requirements ... 7
5. Mechanical Requirements ... 7
5.1. Performance Requirements ... 7
5.1.1. Primary and Guard Blade beam degradation requirement. ... 7
5.1.2. Monochromatic Blade beam degradation requirement. ... 7
5.1.3. Scatter requirement. ... 8
5.2. X-ray Transmission Requirements ... 8
5.3. Cyclic Requirements ... 8
5.3.1. Cycle Frequency ... 8
5.3.2. Cycle Speed ... 9
5.4. Mechanical Interfaces ... 9
5.5. Vacuum ... 10
5.6. Materials ... 11
5.6.1. General ... 11
5.6.2. Blade Material and Surface Finish ... 11
5.7. Design Options ... 12
5.8. Thermal Issues ... 13
5.9. Structural Issues ... 13
5.10. Precision Translational Requirements ... 13
5.11. Rotational Requirements ... 13
5.12. Alignment/Fiducialization ... 14
5.13. Stability ... 14
5.14. Kinematics/Supports ... 14
6. Inspections, Test Provisions and Testing ... 14
7. Major Interfaces ... 15
8. Controls ... 15
8.1. Motion Control Requirements ... 15
9. Environmental Safety and Health Requirements ... 15
9.1. Earthquake Safety ... 15
9.2. Radiation Physics ... 15

1. Overview

Slits are required to define the x-ray beam dimensions for the X-ray Pump Probe (XPP) and X-ray Correlation Spectroscopy (XCS) experiments. Slits are also required to cleanup the edges of the beam for the XPP, XCS and Coherent X-ray Imaging (CXI) experiments. The x-ray beam dimension will be tailored to each experiment and thus a variable aperture is needed. This will be achieved with the use of two horizontally opposed and two vertically opposed translating blades. Slits will be used in three different situations.

I. To cut into the main white beam. These are called primary slits.
II. To cut into the halo surrounding the main white beam. These are called guards slits.
III. To cut into the monochromatic beam. These are called monochromatic slits.

The types of slits are defined in SLAC specification No. SP-391-000-14. Depending on the location of the slits, they will have different requirements on the positioning and gap size accuracy.

The coordinate system is defined in Mechanical Design Standards Supplement DS-391-000-36.
(See 2. Applicable Documents, Specifications and Codes section below).

These Slit Devices will be used for the XPP, XCS and CXI instruments and will be compatible with a 10^{-7} Torr pressure environment. See Figure 1.1-1 below for an example of an off the shelf Slit Device.

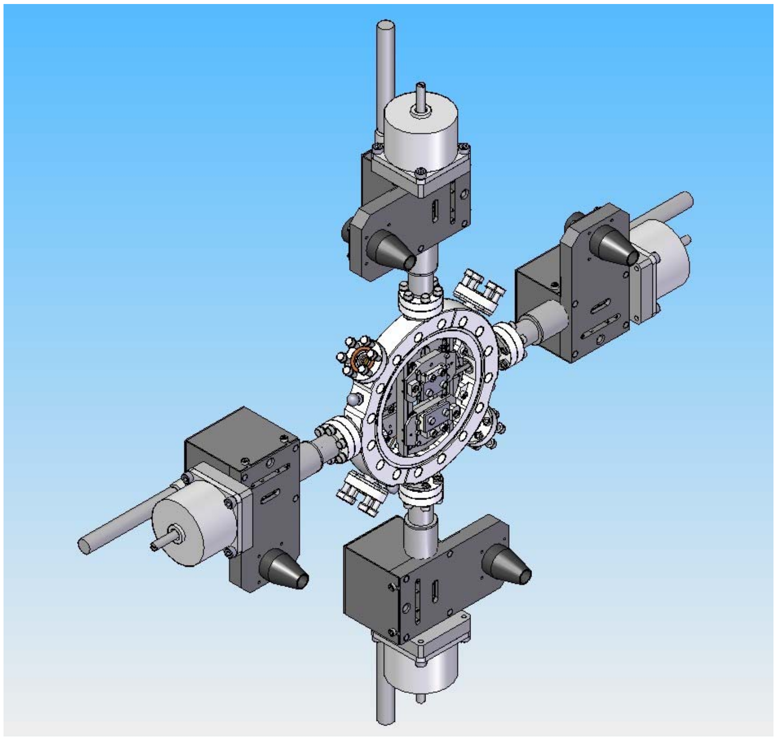

Figure 1.1-1: Example of an "off the shelf" Slit Device.

2. Applicable Documents, Specifications and Codes

2.1. Stanford Linear Accelerator Center (SLAC) Specifications

- SLAC specification No. SP-391-000-14, "Physics Specifications for LUSI Slit System"
- SLAC PRD No. 1.1-014, "LCLS Performance Parameters"
- SLAC drawing No. DS-391-000-36, "Mechanical Design Standards Supplement"
- SLAC drawing No. SC-700-866-47, "Specification KLY & VAC Components Machining Fluids"
- SLAC technical specification No. FP-202-631-14, "FABRICATION OF U.H.V. COMPONENTS"

2.2. Acronyms

CF	Conflat Flange
CXI	Coherent X-Ray Imaging
FEH	Far Experimental Hall
HEDS	High Energy Density instrument
LCLS	Linac Coherent Light Source
LUSI	LCLS Ultrafast Science Instruments
PRD	Physics Requirements Document
NEH	Near Experimental Hall
UHV	Ultra High Vacuum
XCS	X-Ray Correlation Spectroscopy
XPP	X-Ray Pump Probe
XRT	X-Ray Transport Tunnel
XTT	X-Ray Transport Tunnel

3. General Requirements

3.1. Location

These devices will be used in Hutch areas that are highly accessible, such as Hutch 2 and 3 in the NEH and Hutch 4 and 5 in the FEH. There will also be some of the devices in the XTT area. See Table 3.1-1 for a breakdown of locations and quantities.

See Section 5.4 and Figure 5.4-1 for additional information regarding the locations of Slit Devices and the locations relevance to the Max Envelope dimensions of the devices relative to the other nearby beam lines (HEDS and XCS).

Instrument Name	Slit Qty	Slit Location/s	Slit Type/Qty	Beam Type
XPP	4	NEH Hutch 2 NEH Hutch 3 NEH Hutch 3	Coarse Guard - 1 Coarse Guard - 1 Coarse Monochromatic - 2	White beam White beam Monochromatic beam
CXI	4	XRT FEH Hutch 5	Coarse Guard - 2 Coarse Guard - 2	White beam White beam
XCS	7	XRT XRT FEH Hutch 4	Coarse Primary - 2 Coarse Monochromatic - 3 Precise Monochromatic - 2	White beam Monochromatic beam Monochromatic beam

Table 3.1-1: Breakdown of Slit Device locations and quantities.

3.2. Environment

The temperature and relative humidity in the NEH (Hutch 2 and 3) and FEH (Hutches 4, 5 and 6) should be maintained at 72°F +/-1°F (22.2°C +/-0.3°C), and 45% +/-10%, respectively. (Ref.- Doc. 1 9-1038-r2_FEH_Hutch_2.xls)

The temperature and relative humidity in the X-Ray Tunnel (XRT) area will not be controlled. However, the estimation is that they will likely settle (after about one month of full operation) at some equilibrium state of around 74°F +/-5°F (23.3°C +/-1.5°C), and 50% +/-15%, respectively.

All locations of the slit devices are subject to airborne room particulate (especially in the XRT).

3.3. Maintenance, Accessibility and Operations

The maintenance plan goal for the slit devices is that they can be removed from the beam line as a complete assembly. This should only occur occasionally, so no design effort need be put into effect so as to make this removal/replacement extraordinarily fast. (CF flanges are acceptable based on relatively low frequency of flange disassembly).

The accessibility of the areas that these devices are to be located is most typically highly accessible. Therefore the device design should be reasonably elegant, should minimize safety issues (no pinch points, trip hazards, loose cables/hoses, etc) and should be coated/plated and have finishes that reflect high design standards.

Each blade shall be remotely, and independently, operated and controlled along its axis. Additionally, a common design with small modifications should be used to accommodate all types of slits.

4. Optical Requirements

4.1. Viewport Requirements

A viewport is not required on the Slit Device.

5. Mechanical Requirements

5.1. Performance Requirements

5.1.1. Primary and Guard Blade beam degradation requirement.

The goal is for the primary and guard slit blades to withstand the full LCLS flux (white beam) in NEH Hutch 2, across the 2-25 keV spectral range without degradation due to radiation damage given the beam performance parameters listed in PRD No. 1.1-014, which is noted in the Applicable Documents, Specifications and Codes section.

The device will withstand the full LCLS flux (white beam) in NEH Hutch 2, across the 4-25 keV spectral range without degradation due to radiation damage. Attenuation between 2-4keV may be required depending on the material used on the blades. See Table 5.2-1. The energy range where the slits can be used without attenuation is reduced compared to SLAC specification No. SP-391-000-14.

5.1.2. Monochromatic Blade beam degradation requirement.

The goal is for the monochromatic slit blades must withstand the monochromatic beam using a Si(111) monochromator in NEH Hutch 2, across the 2-25 keV spectral range without degradation due to radiation damage given the beam performance parameters listed in PRD No. 1.1-014, which is noted in the Applicable Documents, Specifications and Codes section.

The device will withstand the monochromatic LCLS flux using a diamond(220) monochromator in NEH Hutch 2, across the 4-25 keV spectral range without degradation due to radiation damage. Attenuation between 2-4keV may be required depending on the material used on the blades. If a Si(111) monochromator is used in NEH hutch 2 or 3, then there will be a need to attenuate the LCLS to protect the Si crystals and the required attenuation will be sufficient to protect the slit blades in the 4-25 keV range as well. Again, extra attenuation is expected to be required between 2-4 keV. See Table 5.2-1. The energy range where the slits can be used without attenuation is reduced compared to SLAC specification No. SP-391-000-14.

5.1.3. Scatter requirement.

Parasitic scatter from the slit blades shall be minimized by utilization of cylindrical blades with a very smooth surface finish. Refer to section 5.6.2.

5.2. X-ray Transmission Requirements

The x-ray transmission through a single slit blade is given in Table 5.2-1. Note that the accuracy specifications exceed the requirements stated in SLAC specification No. SP-391-000-14.

Instrument	Name-No.	Transmission at 25 keV	Transmission in 2-8.3 keV range	Positioning Accuracy, Repeatability and Stability (μm)	Radiation Protection
XCS	**Coarse Primary-1** 2 "blades" per linear stage Upstream blade- low Z wt. matl. Downstream blade- high Z wt. matl.	$<10^{-8}$	$<10^{-11}$	2.0	White beam
CXI, XCS, XPP	**Coarse Guard-2** 1 "blade" per linear stage blade- low Z wt. matl.	N/A	$<10^{-9}$	2.0	White beam
CXI, XCS, XPP	**Coarse Monochromatic-3** 1 "blade" per linear stage blade- high Z wt. matl.	$<10^{-8}$	$<10^{-9}$	2.0	Monochromatic beam
XCS	**Precise Monochromatic-4** 1 "blade" per linear stage blade- high Z wt. matl.	$<10^{-8}$	$<10^{-9}$	0.5 (goal) 1.0 (required)	Monochromatic beam

Table 5.2-1: Transmission, resolution for the positioning and radiation protection requirements for the 3 types of slits required. Stability requirements are for short term (a few minutes).

5.3. Cyclic Requirements

5.3.1. Cycle Frequency

Each Slit Blade or Slit Blade pair will be actuated (full stroke travel) 20 times daily, 365 days a year for 20 years (the expected life span of the beam line). This roughly equates to 150,000 cycles over the span of the service life of the device.

5.3.2. Cycle Speed

Speed: Full actuation to occur within 1 min (+/- 30 seconds) from fully opened to fully closed (as defined is section 5.10).

5.4. Mechanical Interfaces

The flanges of the Slit Device shall be 6 in. dia. CF style flanges. It is the design goal that in certain locations Slit Devices may be mounted one to another and the design should allow for this mounting scheme.

The overall Z length of the slit device must be minimized. A design goal for this length, of a single slit device, has been set at 6 inches or less. Both X directions away from the beam centerline (-X and +X) are limited to maximum "envelope" distances of, 13.8 in (350 mm) and 20.8 in (528 mm), respectively. These maximums are primarily due to the geometry constraints at the point along the CXI beamline where the furthest upstream slit device is located. These geometry constraints include the HEDS beam tube, the XCS beam tube, a 1.0 in clearance to those beam tubes, the centerline location of the CXI beamline and its position in between, and relative to, the HEDS and XCS beamlines. No other constraints along the XPP or XCS beamlines result in smaller maximum envelope dimensions than the ones shown in Figure 5.4-1, which shows the stay clear or max envelope dimensions/limits at this first slit device in the CXI beamline.

It is also noted that the centerline to centerline offset distance from the CXI beamline to the XPP and XCS beamlines due to the XPP and XCS Monochromators, is 600 mm.

The –Y dimension should be minimized to fit within the 16 inch (maximum) device space envelope located below the XPP beamline center. The +Y dimension has no limitations but should be in the similar range, at the most, as the –Y dimension. Therefore, smallest of the maximum envelope dimensions (13.8 in) becomes the actual maximum length of any protrusion of the slit body (in the X and Y directions) when the realities of symmetry are taken into account. Meaning that, as long as no "leg" of the slit is longer than 13.8 in there will be no interference between the slit devices and any other beam tubes. Note that care will need to be taken to insure that the slit devices are not located adjacent to other HEDS and/or XCS beamline devices/components.

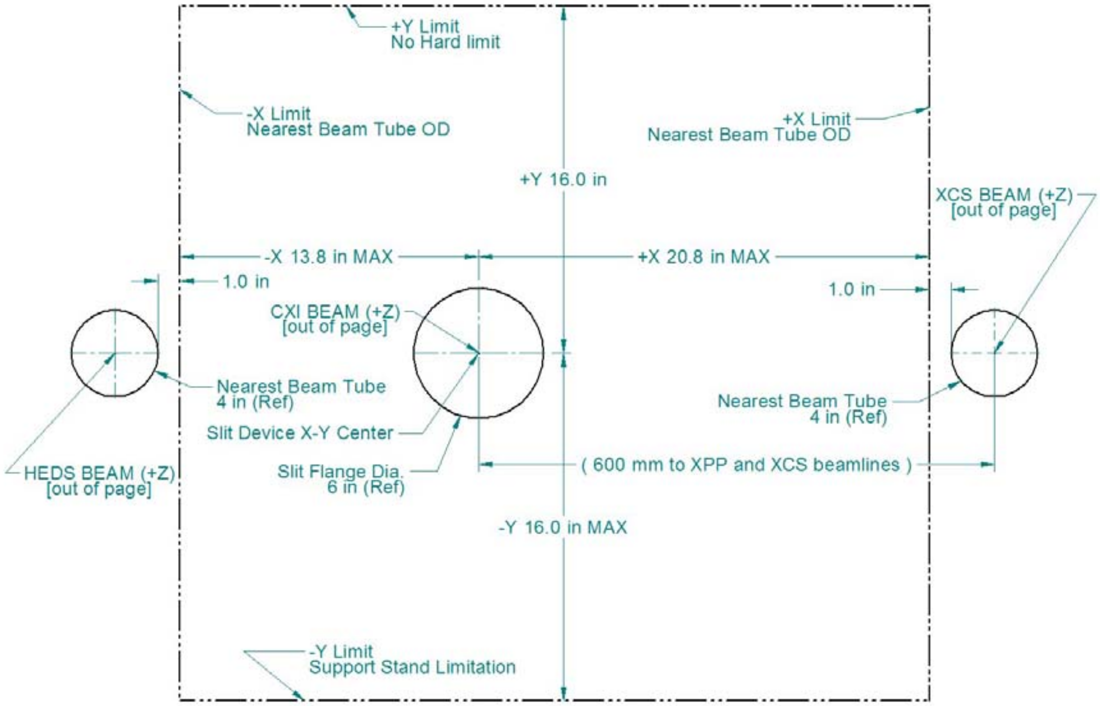

Figure 5.4-1: Slit Stay Clear or Max Envelope dimensions/limitations (at approx. 162.5 m downstream from the START XTT point in mr39175000.par- the Master Beam Line file).

5.5. Vacuum

This Slit Device will be compatible with a 10^{-7} Torr pressure environment, or better, under all operating conditions. The device's vacuum sealing surfaces shall be leak tested as specified in SLAC technical specification No. FP-202-631-14.

All lubricants, cutting fluids, etc., used in manufacturing shall be "sulfur-free". SLAC document No. SC-700-866-47 is a compendium of SLAC approved lubricants. The use of sanding discs, abrasive paper or grinding wheels is typically prohibited. In all circumstances where grinding and polishing are necessary, extra care is required to insure that good vacuum practices and processes are followed. This process shall be reviewed and approved by the engineer for its vacuum compatibility.

All parts and subassemblies shall be cleaned for UHV. Once parts are cleaned for vacuum, handle only with clean latex or nitrile gloves in a clean room with clean work surfaces. This includes all subassemblies. For storage or transportation, place in clean sealed vacuum grade plastic bag that has been back-filled with nitrogen.

5.6. Materials

5.6.1. General

All parts and materials for the device shall be new and compatible with the performance requirements of this specification. Mil source certifications, including heat number and chemical analysis for all materials used in the manufacturing of the device shall be furnished. The device will be used in a radiation environment with a maximum rate of approximately (TBD) kilorad per year, and a total integrated dose of approximately (TBD) rad.

5.6.2. Blade Material and Surface Finish

The scattered radiation produced by the slit blades is a key concern due to the high brightness and coherence of the LCLS beam. To minimize this scattered radiation, very smooth edges have to be realized. A proven solution is the use of cylindrical surfaces since this geometry helps to control the direction of parasitic scatter. The cylinder diameter has to be relatively small to avoid large reflective surfaces that would produce unwanted parasitic scatter. However, other alternatives will need to be considered as well.

To avoid beam damage on blades illuminated by the full white beam, only low atomic number (Z) materials can be used. To obtain the needed attenuation over the entire energy range for the primary slits, a downstream blade from a high Z material is needed. Exposure of this downstream blade to the non-attenuated beam must be strictly avoided. The upstream blade therefore has to act as a guard for the downstream blade. The distance from the beam centerline to each blade surface should differ by a distance of 4µm (with a 1µm accuracy), with the upstream blade being closer to the beam centerline than the downstream blade. Any manufacturing tolerances, build variation, differential thermal expansion, etc, must be allowed for, such that the downstream blade never sees the non-attenuated beam. Alternatively, a dual blade slit design could incorporate the ability to actuate (tilt) the dual blade assembly to assure that the downstream blade remains hidden and therefore, never sees the non-attenuated beam.

The micro-roughness of the slit blade, that is the surface height fluctuations on length scales smaller than 1 mm, shall have a design goal of 0.05 µm [(2.0 µin) or {50 nm}] (R_a) and a requirement that it does not exceed 0.5 µm [(20 µin) or {500 nm}] (R_a).

The figure error of the slit blade, that is the surface height fluctuations on length scales between 1 mm and the total length of the blades, shall have a design goal of 0.5 µm [(20 µin) or {500 nm}] (R_a) and a requirement that it does not exceed 2 µm [(80 µin) or {2000 nm}] (R_a).

Table 5.6.2-1 lists some candidate materials in addition to blade geometry information and surface finish requirements.

Blade Names	Material	Gap	Gap Center Translation	Blade Diameter	Surface Roughness goal (maximum)
Upstream "blade" - used alone in Guard Slits or with Downstream blade in Primary Slits	Silicon Nitride (low Z no./wt.)	-0.1 to 10 mm	+/-5 mm	3 mm	0.05 µm (0.5 µm)
Downstream "blade" - used alone in Monochromatic Slits or with Upstream blade in Primary Slits	Tantalum 90/ Tungsten 10 (high Z no./wt.)	-0.1 to 10 mm	+/-5 mm	3 mm	0.05 µm (0.5 µm)

Table 5.6.2-1: Slit blade specifications.

5.7. Design Options

Figure 5.7-1 shows one Tilting "Dual Blade" design concept under consideration. A Dual Blade option is required in the Primary Slits. The Guard and Monochromatic Slits require only a single blade. The figure shows the blade offset dimension (.004) with the very tight tolerance of one micron (+/-.0005 mm). The intent of this concept is to eliminate this extremely tight one micron tolerance complexity altogether (which is inherent in a rigid, non-tilting, dual blade design) by allowing the Dual Blade Tilt feature to be adjusted, in a controlled fashion, until the proper offset is attained. This is accomplished with the combination of a low power beam, passing through the Slit Device, together with beam imaging analysis.

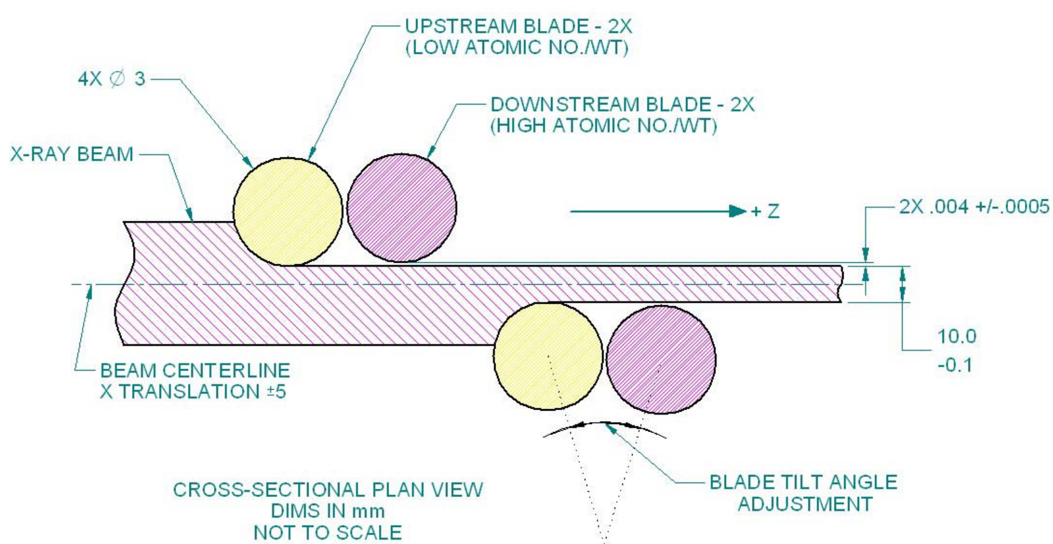

Figure 5.7-1: Tilting "Dual Blade" design concept.

5.8. Thermal Issues

The peak thermal load from the beam is 3.6 x 10^{13} W/cm^2 in the NEH, which correlates to an average thermal load of 438 W/cm^2 for a total load of 0.24 Watts. Blade elongation will occur if/when the blade heats up. The blades must be mounted such that blade elongation will not cause any blade displacement/movement problems.

No thermal degradation on the Slit Blades is allowable based on the average thermal load.

5.9. Structural Issues

See Stability sub-section below.

5.10. Precision Translational Requirements

Four blades, or blade pairs, to actuate independently, minimum blade travel of 15.05 mm. This is a minimum based on the gap width and gap center translation numbers provided in SLAC specification No. SP-391-000-14. Given that these are minimum blade stroke numbers, a nominal blade stroke of 15 mm (+ 1 mm) is recommended to account for coarse alignment while installing the Slit Devices into the beam line. See Figure 5.10-1.

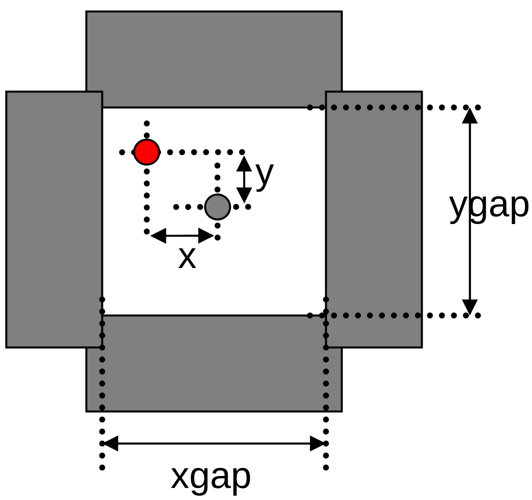

Figure 5.10-1: View down the beam path of the slit system. The grey circle represents the center of the slit aperture. The red circle represents the x-ray beam center. The x and y distances can range from -5.0 mm to 5.0 mm. The xgap and ygap apertures can independently range from -0.1 mm (closed and overlapped) to 10.0 mm (opened).

5.11. Rotational Requirements

No rotational actuation around the nominal beam centerline is required.

5.12. Alignment/Fiducialization

Alignment will be required upon installation. The center of travel of all four blades shall be aligned to the theoretical LCLS beam center line to +/-1.0 mm if the Slit Device is mounted upon its own support stand. If the Slit Device is mounted to adjacent devices, and therefore not on its own support stand, then the Slit Device alignment will be dictated by the alignment of the adjacent device. In this case it shall be a design goal to align the center of travel of all four blades and the theoretical LCLS beam center line to +/-1.0 mm.

Fiducialization of the Slit Device will be required in order to facilitate coarse alignment upon installation. The centers of travel of all actuators shall be fiducialized with tooling balls on the outside of the assembly.

Regardless of the slit device mounting scheme, the y and x axis of the slits must be parallel to the LUSI coordinate system to within +/-1.0 degree (in roll).

5.13. Stability

The Precise Slits utilized in the XCS beamline will need special consideration when it comes to the structural and thermal stability of the support stand in order to keep the Slit Device stable within 8.0 μm (as a design goal) for a period of 12 hours.

5.14. Kinematics/Supports

The Slit Devices will need to be mounted to a 6 degree of freedom mount that allows coarse centering and aligning of the Slit blades to the beam path, either directly to a separate support stand or indirectly to an adjacent device through its own support stand. The design of the support stand of this adjacent device will need to take this into account because it will be supporting the cantilevered weight of the Slit Device (or Slit Device stacked pair).

6. Inspections, Test Provisions and Testing

A functional test of the Slit Device will need to be performed upon receipt of the device, after shipping, to insure that no damage occurred in transit.

Vendor test reports validating the accuracy and repeatability of the blades with respect to the tooling balls are required.

All parts and materials for the device shall be new and compatible with the performance requirements of this specification. Mill source certifications, including heat number and chemical analysis, for all materials used in the manufacturing of the device shall be furnished.

7. Major Interfaces

Throughout LCLS/LUSI, intelligent/integrated actuators/motors are strongly recommended for in-air applications and are suggested for in-vacuum applications, if available.

No shielding will be required to be designed for this Slit Device, however, local shielding may be required after system installation and before operation.

8. Controls

8.1. Motion Control Requirements

The position of the Slit Blades must be known, so incremental encoders are required. Additionally, Stroke/Travel limits switches on all 4 actuators are advised.

If the design allows it, it is preferable but not required that the actuators used are compatible with the Experimental Physics and Industrial Control System (EPICS) software tools and have existing EPICS drivers. The list of EPICS supported hardware is available here http://www.epics.org/.

9. Environmental Safety and Health Requirements

9.1. Earthquake Safety

No special design requirements are necessary for the Slit Devices relative to earthquake safety issues.

9.2. Radiation Physics

Most Slit Devices will be located in radiologically controlled areas so these will have no radiation physics issues and will not require shielding. One Slit Device for the XPP instrument will be in the beam path with personnel in the Hutch. This Slit Device will require radiation physics evaluation/examination (not within the scope of the LUSI Slit System but within the instrument scope). No shielding will be required to be designed for this Slit Device, however, local shielding will be required after system installation and before operation.