ENGINEERING SPECIFICATION DOCUMENT (ESD)	Doc. No. SP-391-000-58 R0	LUSI SUB-SYSTEM Diagnostics

Engineering Specifications for the X-Ray Focusing Lens System

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1. Overview

The X-ray Lens Focusing System (XFLS) is used to simultaneously reduce the X-ray beam spot size while maximizing the X-ray flux incident on the samples. The XFLS shall meet the requirements for XPP and XCS instruments.

2. Applicable Documents, Specifications and Codes

2.1. Stanford Linear Accelerator Center (SLAC) Specifications

The following documents are cited in this specification by the reference numbers given below.

1. SP-391-000-11 Physics Requirements for the LUSI XFLS
2. SP-391-000-87 XFLS Interface Control Document
3. AD-391-910-00 XFLS Top Assembly
4. SLAC-I-730-0A09M-001-R001 SLAC Chronic Beryllium Disease Prevention Program
5. LCLS PRD 1.1-014 LCLS Beam Parameters PRD
6. LCLS 1.9-1017 LCLS Room Data Sheet, Near Experimental Hall Overall, Revision 2
7. LCLS 1.9-1037 LCLS Room Data Sheet, Far Experimental Hall Overall, Revision 2
8. TBD X-Ray Transport Tunnel Environment
9. DS-391-000-36 Design Standards Supplement
10. FP-202-631-14 Fabrication of UHV Components

2.2. Acronyms

CXI	Coherent X-Ray Imaging
EO	Electro-Optic Monitor
FEH	Far Experimental Hall
FWHM	Full Width Half Max
HED	High Energy Density
MPS	Machine Protection System
NEH	Near Experimental Hall
SASE	Self amplifying spontaneous emission (lasing)
XCS	X-Ray Correlation Spectroscopy
XFLS	X-Ray Focusing Lens System
XRT	X-Ray Transport Tunnel

3. General Requirements

3.1. Location

- XPP: The XFLS will be mounted on a common support with the other optics in this segment in Hutch 3.
- XCS: The XFLS will be mounted on a common support with the other optics in this segment. It may be at located at the end of the X-Ray Transport Tunnel (XRT), or the beginning of Hutch 4.

3.2. Space Constraints

The volumetric envelope for the XFLS is shown in Reference 2. The coordinate system is listed in Reference 9. Additional design considerations are listed below.

- X axis:
  - XPP: The X dimension must fit between the main beam line and the offset beam line when the monochromator is in use. The center-to-center distance between these beam lines is 600 mm, but accommodation must be made for the size of the vacuum chambers, spools, etc. in Hutch 3.
  - XCS: The X dimension must not interfere with the space which would be occupied by the CXI beam in either the XRT or the Hutch 4 walls.
- Y axis: +Y dimensions are not critical. –Y dimensions shall not exceed 16 inches from the beam centerline.
- Z axis: The overall Z length of the XFLS must be minimized. The cumulative length of all the devices on the Optics raft in Hutch 3 must fit between the monochromator and the diffractometer.

3.3. Environment

The XFLS will be installed in both a lab environment and a tunnel environment. The design is driven by the worst case environment, the XRT. The temperature and humidity requirements were derived from References 6, 7 and 8.

- Temperature: 72°F +/- 5°F. The temperature will vary diurnally in the XRT.
- Humidity: XFLS shall be capable of operating in 50 +/- 30% relative humidity environment.
- Vibration: The XFLS vibration environment is a function of how the facility generated vibrations are transmitted through the Optics raft and the 6 degree of freedom mounting (Section 5.12) to the raft. In order to avoid interactions with lower

frequency and higher amplitude facility vibrations, the XFLS chamber shall have a fundamental mode of vibration greater than 120 Hz.

- Radiation: XFLS shall be capable of withstanding 1 Krads/year for its lifetime as defined in Section 3.5.
- XFLS design shall incorporate covers to protect moving parts including bellows from airborne dust.

3.4. Maintenance, Accessibility and Operations

The Lens Cartridges in the XFLS device must be individually accessible in the field. They may be removed due to damage/degradation, or to be replaced with cartridges with different number of lenses. Vacuum will be broken to facilitate accessibility.

3.5. Lifetime

The service life of the device shall be 10 years minimum.

4. Optical Requirements

4.1. X-Ray Spot Size

The FEL beam characteristics used for design purposes including full width half maximum (FWHM) spot size, energy per pulse and spectral range are defined in Reference 5. The X-ray spot size is a function of the number of lenses, their position along the beam line (in Z) and the incoming FEL beam characteristics. These parameters will be selected by the users.

4.2. Lens Physical Characteristics

The lens is made of Beryllium. It is a flat disk with a biconcave center section (core). It is held in a brass washer shaped carrier. This is a purchased part. Appropriate precautions shall be observed for handling Beryllium per Reference 4.

4.3. Spacer Physical Characteristics

Spacer elements are substituted for lenses in order to fill the Cartridge Assembly. These are dimensionally equivalent to empty lens carriers.

5. Mechanical Requirements

5.1. Construction

The key components of the XFLS devices are shown in Reference 3. The XFLS consists of coarse and fine positioners used to locate the Lens Cartridge Mount in the X and Y axes.

There are three Lens Cartridge Assemblies mounted to the Lens Cartridge Mount. Each Lens Cartridge Assembly shall hold 10 lenses and/or spacers. Additionally, for XPP, there is a Z axis stage used to move the entire device along the beam line (Z).

5.2. Performance Requirements

The lenses shall withstand the full FEL beam flux as defined in Reference 5, without degradation to either the lenses or any component of the system itself due to radiation damage.

5.3. Positioning Requirements

5.3.1. Lens Positioning

The centers of all Lenses in a Cartridge Assembly shall be co-axial within 10 μm.

5.3.2. Cartridge Assembly Positioning

There are two steps in aligning the XFLS. First, the entire device is aligned to the theoretical beam centerline per Section 5.10. In operation, the exact center of the lens stack is found by adjusting the X,Y position of the stack using the Cartridge Assembly Mount positioners.

There are four operating positions: "IN 1", :"IN 2", "IN 3" and "OUT", corresponding to the 3 cartridge assemblies in the device. The following positioning requirements are relative to the theoretical beam centerline in the XFLS as defined in Reference 2. See Section 5.11 for alignment requirements for the entire device.

- A Cartridge Assembly in the "IN" position shall be centered (X and Y) on the x-ray beam axis by making adjustments in X and Y within the limits of Table I.
- In the "IN" position, the pitch and yaw of the lens must be less than 0.1° relative to the LCLS coordinate system.
- In the "IN" position, there is not a roll requirement since the lens assembly is not sensitive to this degree of freedom.
- Translational requirements are shown in Table 1.

Motion Axis	Stroke	Resolution	Repeatability	Stability
X	≥ ±5 mm	≤ 2 µm	≤ 2 µm	≤ 0.2 µm
Y	90 mm TBR	≤ 2 µm	≤ 2 µm	≤ 0.2 µm
Z*	≥ ±200 mm	≤ 1 mm	≤ 1 mm	≤ 10 µm

* for XPP only.

Table 1. Translational requirements for the Cartridge Assembly Mount positioner.

- In the "OUT" position, a minimum stay clear radius of 12.7 mm from the Cartridge Assembly to the theoretical beam centerline shall be maintained.
- Remote operation:
  - The XFLS design shall include a remotely operated mechanism for moving each Cartridge Assembly to the IN or OUT positions without breaking vacuum.
  - The Cartridge Assembly state shall change in less than 10 seconds.

5.4. Cyclic Requirements

Actuators will be cycled once daily, 365 days a year for 10 years.

- In situ bake-out: 10 cycles in X, Y and Z (XPP only) at 300°F and ≤10^{-5} Torr pressure.
- X, Y & Z cycles: 3,650 at 72 +/-5° F and ≤10^{-7} Torr pressure.
- A cycle in X is ±5 mm at positions IN 1, IN 2 and IN 3.
- A cycle in Y is the following: OUT position > IN 1 pause> IN 2 pause> IN 3 pause > OUT position.
- A cycle in Z is ±200 mm .

5.5. Mechanical Interfaces

- The flanges of the vacuum system that connect to the LCLS beam line shall be 6 inch diameter CF flanges, non-rotatable up-beam and rotatable down-beam, per Reference 2.
- The XFLS shall be supported per Reference 2 and Section 5.12.
- Access to the Cartridge Assembly is required through the window flange.

5.6. Vacuum

This device will be used in an Ultra-High Vacuum (UHV) of <10^{-7} Torr. Manufacturing, cleaning, handling, storage and leak testing operations shall be per Reference 10.

5.7. Materials

- 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 per Reference 10.
- Use of Teflon is specifically prohibited.

5.8. Thermal Issues

Reserved.

5.9. Structural Issues

Reserved.

5.10. Alignment/Fiducialization

Alignment will be required upon installation. A tolerance of +/-0.5 mm to the alignment features on the assembly (tooling ball sockets) should be sufficient.

In the "IN" position, the pitch and yaw of the lens must be less than 0.1° relative to the LCLS coordinate system. A motorized adjustment of these degrees of freedom is not necessary. An easily accessible manual adjustment of these degrees of freedom should be provided, allowing the metrology group to align the system during its installation on the beam path.

5.11. Stability

The XFLS should be stable to the accuracy stated in section 5.3 over a period of one week.

5.12. Kinematics/Supports

The XFLS devices shall be mounted to a 6 degree of freedom mount that allows coarse centering and aligning of theoretical beam centerline of the XFLS Device, as defined in Reference 2, to the actual FEL beam path.

6. Electrical Requirement

All motorized degrees of freedom of the XFLS dedicated to each instrument is required to be controlled remotely via the corresponding instrument control system (i.e. except for tilt and yaw as described in 5.3.2).

7. Inspections, Test Provisions and Testing

Reserved.

8. Major Interfaces

Reserved.

9. Controls

9.1. Motion Control

- Remote operation of the Lens Cartridge positioning systems is required.

9.2. Feedback/Encoders

- The position of each remotely actuated stage shall be recorded in the experimental metadata.
- When changing between Cartridge Assemblies or moving to the OUT position, provisions will be made to ensure that the FEL beam does not enter the XFLS.
- A window to view the Cartridge Assemblies is required.

9.3. Fail Safe

- The Cartridge Assemblies shall default to the 'OUT' position, as defined in Section 5.2, in the event of a system fault.

10. Quality Assurance

Reserved.

11. Environmental Safety and Health Requirements

11.1. Earthquake

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

11.2. Radiation Physics

The XFLS will be located in radiological controlled areas and there are no radiation physics issues at the device level.

11.3. Hazardous Materials

Beryllium shall be handled in accordance with Reference 4.

11.4. Pressure Vessel/Vacuum Vessel

- The XFLS shall be designed for use in an Ultra High Vacuum (UHV) environment with the appropriate safety factors.

- Pressure relief safe guards will be provided at a higher level assembly.