ENGINEERING SPECIFICATION DOCUMENT (ESD)	Doc. No. SP-391-000-60 R0	LUSI SUB-SYSTEM Diagnostics

Engineering Specification for the Attenuator Device

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Table of Contents

1. Overview

An attenuator device is required for the LUSI instruments to control the x-ray intensity incident upon the sample. This document describes the specifications of such a device. The attenuator shall meet the requirements for XPP, CXI and XCS.

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-391-000-10	Physics Requirements for the LUSI Attenuator Device
2. SP-391-000-79	Attenuator Device Interface Control Document
3. AD-391-900-00	Attenuator Device Top Assembly
4. TR-391-003-04	Attenuator Device Tech Note, D. Fritz, April 28, 2008
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
XPP	X-Ray Pump Probe
XTOD	X-Ray Transport Optics And Diagnostics
XRT	X-Ray Transport Tunnel

3. General Requirements

3.1. Location

- XPP: The Attenuator will be mounted on a common support with the other optics in this segment in Hutch 3.
- XCS: The Attenuator 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.
- CXI: The Attenuator will be mounted on a common support with the other optics in this segment at the end of the X-ray Transport Tunnel.

3.2. Space Constraints

The volumetric envelope for the Attenuator Device 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.
  - CXI: The X dimension must not interfere with the space which would be occupied by the XCS beam or the future HED beam in either the XRT or Hutch 5.
- Y axis: +Y dimensions are not critical. –Y will be minimized to fit above the raft.
- Z axis: The overall Z length of the Attenuator Device 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 Attenuator Device 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. Temperature stability is not a critical issue for this device. The temperature will vary diurnally in the XRT.

- Humidity: Attenuator shall be capable of operating in 50 +/- 30% relative humidity environment.
- Vibration: The Attenuator 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 5.11) to the raft. In order to avoid interactions with lower frequency and higher amplitude facility vibrations, the Attenuator chamber shall have a fundamental mode of vibration greater than 120 Hz.
- Radiation: Attenuator actuators shall be capable of withstanding 1 Krads/year for their lifetime as defined in Section 3.5.
- Attenuator design shall incorporate covers to protect moving parts including bellows from airborne dust.

3.4. Maintenance, Accessibility and Operations

The filters in the Attenuator Device shall be individually accessible in the field. They may be removed due to damage/degradation, or to be replaced with filters of different thicknesses. Vacuum may be broken to facilitate accessibility.

3.5. Lifetime

The service life of the device shall be 10 years minimum, except for the individual filter elements.

4. Optical Requirements

4.1. Attenuation Levels

- The Attenuator Device consists of 10 filters in series used to attenuate the intensity of X-rays of photon energy from 4 to 25 keV.
- The filters shall be arranged in order of decreasing thickness with the thickest filter located up beam.
- The ten filters shown in Table I, provides 1024 combinations of filter thicknesses from 0 to 20,460 microns in 20 microns increments.
- The Attenuator Device shall attenuate 25 keV photons by a factor of 10^4. This limiting case determines the total thickness of the sum of all the filters (20,460 microns).
- The Attenuator Device shall attenuate 8.3 keV photons by a factor greater than 10^8.
- The Attenuator Device shall provide incremental attenuation of at least 3 steps per decade for all energies greater than 5.7 keV (Reference 4).

- The filters will preserve the transverse coherence of the FEL radiation to the highest extent achievable.

Attenuator Label	Thickness (μm)
Filter 10	10,240
Filter 9	5,120
Filter 8	2,560
Filter 7	1,280
Filter 6	640
Filter 5	320
Filter 4	160
Filter 3	80
Filter 2	40
Filter 1	20

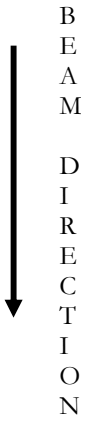

Table I: Attenuator Silicon Filter Thicknesses

4.2. Filter Physical Characteristics

- The filters shall have a 10 mm clear aperture.
- Filter holders shall be designed with an open end such that only the filter material crosses the path of the FEL beam at any time.
- Filter material shall be integrated circuit (IC) quality silicon wafers.
- The filter thicknesses shall be per Table I.

  Note: See http://henke.lbl.gov/optical_constants/filter2.html for filter attenuation properties.
- Surface roughness shall be less than 5 angstroms peak to peak for wafers 100 microns and thicker and less than 20 angstroms peak to peak for wafers less than 100 microns thick. Roughness condition applies over any 1.0 mm distance on the filter.
- Filters shall be polished on both sides.

5. Mechanical Requirements

5.1. Performance Requirements

The FEL beam characteristics including FWHM spot size, energy per pulse and spectral range as defined in Reference 5 shall be used for design purposes.

- Each filter must withstand the full FEL beam flux above 8.5 KeV. Attenuation per Figure 1 is required below 8.5 KeV.
- The XTOD Solid Attenuator will be used for the beam parameters that would cause filter damage. See Section 9.2.

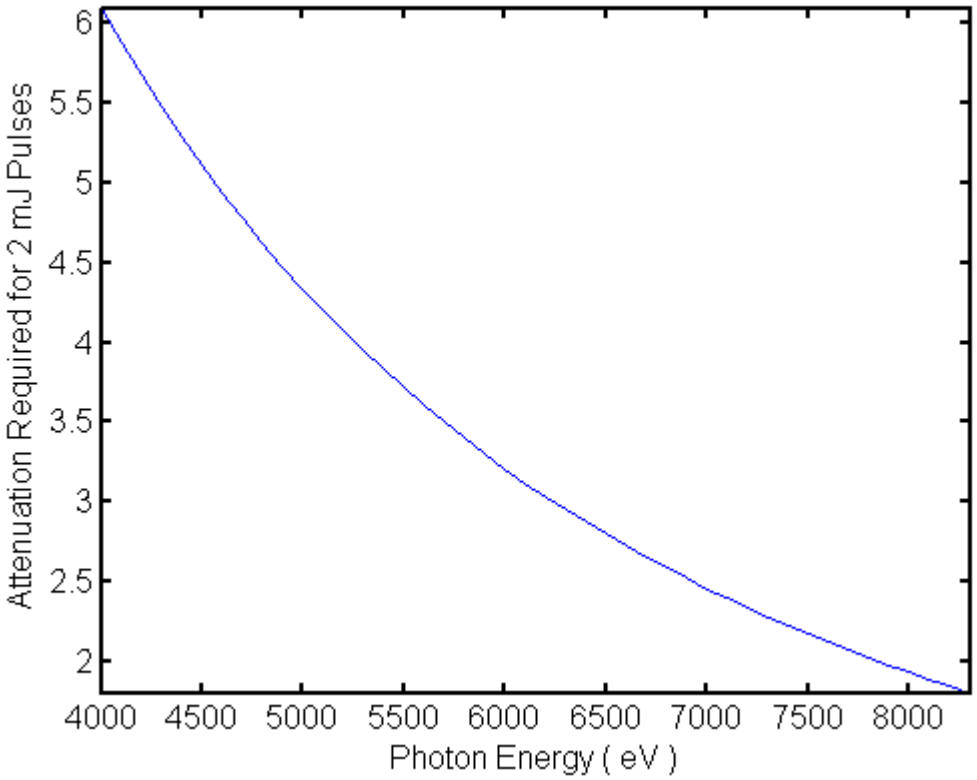

Figure 1: XTOD attenuation levels required to protect LUSI Attenuator filters.

5.2. Positioning Requirements

- Two operating positions are required for each filter: "IN" and "OUT". The following positioning requirements are relative to the theoretical beam centerline in the Attenuator Device as defined in Reference 2. See Section 5.11 for alignment requirements for the entire device.
  - In the "IN" position, each filter shall be centered on the x-ray beam axis within a 1 mm radius.
  - In the "IN" position, the filter surface shall be normal to the theoretical beam centerline within ± 1°.
  - In the "IN" position, a translational repeatability of 100 microns and angular repeatability of 0.1° shall be maintained.

- In the "OUT" position, a minimum stay clear radius of 12.7 mm from the theoretical beam centerline shall be maintained.

- Remote operation:
  - The Attenuator design shall include a remotely operated mechanism for moving the filters to the IN or OUT position without breaking vacuum.
  - The filter shall change state in less than 2 seconds.

5.3. Life Cycle Requirements

Actuators will be cycled up to 3 times daily, 365 days a year for 10 years.

- In situ bake-out: 10 cycles at 300°F and 10^{-5} Torr pressure.
- In / Out cycles: 10,000 cycles at 72 +/-5° F and 10^{-7} Torr pressure.

5.4. Mechanical Interfaces

- The flanges of the vacuum system that connect to the LCLS beamline shall be 6 inch diameter CF flanges, non-rotatable up-beam and rotatable down-beam, per Reference 2.
- The Attenuator shall be supported per Reference 2 and Section 5.11.

5.5. 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.

5.6. 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.
- The use of Teflon is specifically prohibited.

5.7. Thermal Issues

Reserved

5.8. Structural Issues

Reserved

5.9. Alignment/Fiducialization

During installation, the chamber shall be aligned such that the as-measured centerline shall lie along the nominal beam centerline. Chamber position (x, y, z, pitch, roll, yaw) shall be recorded. Fiducialization (likely using tooling balls) shall be performed to ensure compliance with positioning requirements noted in section 5.2.

5.10. Stability

The Attenuators should be stable to the accuracy stated in Section 5.2 over a period of one week.

5.11. Kinematics/Supports

The Attenuator Device will be mounted to a 6 degree of freedom mount that allows precise centering and aligning of theoretical beam centerline of the Attenuator Device to the actual FEL beam path.

6. Electrical Requirement

All motorized degrees of freedom of the Attenuator Device dedicated to each instrument are required to be controlled remotely via the corresponding instrument's control system.

7. Inspections, Test Provisions and Testing

Reserved.

8. Major Interfaces

The Attenuator Device is fixed in position on the Optics raft in Hutch 3 (XPP) and moves with it. All external connections shall be flexible and allow for 1 meter of translation in X.

- There aren't any major interfaces in Hutch 4 or 5.

9. Controls

9.1. Motion Control

Remote operation of the filters is required.

9.2. Feedback

- A status signal that displays the current filter states is required. The status of each filter shall be recorded in the experimental metadata.
- The Attenuator shall provide the required signals when the conditions warrant the use of the XTOD Attenuator as shown in Figure 1, Section 5.1.
- A window to view some of the filters is required.

9.3. Fail Safe

- If pneumatic actuators are used, then they shall default to the 'IN' position in the event of a system fault, as defined in Section 5.2.

10. Quality Assurance

Reserved

11. Environmental Safety and Health Requirements

11.1. Earthquake

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

11.2. Radiation Physics

The Attenuator Device will be located in radiologically controlled areas and there are no radiation physics issues.

11.3. Pressure Vessel/Vacuum Vessel

- Attenuator Device 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.