LUSI LCLS Ultrafast Science Instruments

ENGINEERING SPECIFICATION DOCUMENT (ESD)	Doc. No. SP-391-000-81 R0	LUSI SUB-SYSTEM Diagnostics

Pop-In Intensity Monitor Mechanical Requirements

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1. Overview

The LCLS X-ray FEL pulses exhibits intrinsic fluctuations in position and transverse intensity profile on a pulse-by-pulse basis. A diagnostic is required to measure the intensity of the X-ray pulses, aiding in the alignment of X-ray optics and diagnostics.

The intensity monitor shall be based on direct X-ray detection, using an X-ray sensor, of the incident X-ray beam.

The coordinate system is defined in Design Standards Supplement DS31100036.

2. Applicable Documents, Specifications and Codes

2.1. Stanford Linear Accelerator Center (SLAC) Specifications

- SLAC drawing No. DS-311-000-36, "Design Standards Supplement"
- SLAC drawing No. SC-700-866-47, "Specification; Machining Lubricants"

3. General Requirements

3.1. Location

A total of 11 Pop-In Intensity Monitors shall be installed, with distribution as follows:

	Shared	XPP	CXI	XCS	Totals
Pop-In Intensity Monitor		2	2	7	11

3.2. Environment

The sensor assembly will operate in vacuum and does not have environmental concerns. The pneumatic actuator or stepper drive will be in ambient air.

Devices installed in the tunnel will generally operate in a hot, dusty environment and must be designed to operate without service for at minimum one year.

The tunnel environment has the characteristics listed in the table below.

Parameter/Condition	Value
Location	Tunnel
Temperature	0°-40° C
Humidity	80% relative
Radiation	10 rad/year
Cleanliness	Airborne dust

Lifetime	20 year

Devices installed in the hutches will operate in a relatively cool, clean environment. It is expected that the devices will operate for several years prior to requiring non-routine maintenance.

Modify above chart for Hutch environment – what are Hutch characteristics?

3.3. Maintenance, Accessibility and Operations

The finished device shall be designed for straightforward installation, alignment, and removal. The sensor may require yearly servicing or replacement. Replacing the sensor shall not require removing the vacuum chamber; it shall be serviceable by unbolting the flange(s) to which it is attached.

3.4. Lifetime

The expected service life of the device is 20 years.

4. Optical and Physics Requirements

Physics requirements (including optical requirements) are set forth in SP-391-000-09 “Physics Requirements for LUSI Pop-in Intensity Monitor”.

5. Mechanical Requirements

5.1. Physical Requirements

- No spare devices shall be built. 11 devices will be built and installed.
- The intensity monitor shall be designed to work for X-ray energies from 6 keV up to 25 keV.
- The intensity monitor will be destructive to incident X-ray beam, but there remains the possibility of residual X-ray transmission especially at higher X-ray energies.
- The design shall incorporate UHV standards and practices for all chambers and all components to be in a vacuum environment. UHV treatment of parts and assemblies shall be observed during cleaning, brazing/welding, handling, and assembly.
- The device shall be designed to mount to standard Conflat knife-edge type flanges with “clearance” type bolt holes.

- The chamber into which this device is installed shall have a 6” non-rotatable flange on the upstream end of the chamber, and a 6” rotatable flange on the downstream end of the chamber.
- Standard flange-to-flange chamber length of 10.62” for off-the-shelf 4, 5, or 6-way crosses shall be considered acceptable. Shorter than this length shall also be considered acceptable.
- Envelope size:
    - -Y distance (center of chamber to top of table) shall be fixed at 16”.
    - +Y dimension shall be 16” or less (soft requirement).
    - –X dimension shall be 13.75” or less.
    - +X dimension shall be 20.75” or less.
    - Z (flange-to-flange) shall be 10.62” or less.
- Design must allow for all bolts to be loaded from inboard of the chamber. Studs and nut plates shall also be acceptable.

5.1.1. Sensor Assembly Requirements

- The design of the intensity monitor shall permit replacement of the sensor in the field.
- Two operating positions are required for the profile monitor: ‘In’ and ‘Out’.
- Numerical position measurement and/or monitoring of the sensor position (or center thereof) shall **not** be a hardware or software requirement. The device shall not measure sensor position to a high degree of accuracy. The device shall not undergo a quality control step to measure sensor position relative to any flanges or chambers (although it shall lie within its permitted tolerance of position and operation).
- The device shall not be used to fine-tune beam position beyond very coarse centering (on the order of 10% of sensor size).
- The intensity monitor state should have the ability to be changed ‘In’ to ‘Out’ and vice-versa within ~3 seconds if feasible.
- An electrical feedthrough with 9 pins shall be utilized to connect necessary wiring from the non-vacuum to vacuum side. An Electronics Engineering Specification Document will detail the wiring, circuitry, and connections of the electrical and electronic components.

- Beam power spec (Yiping)– what does the shielding need to be capable of withstanding? A protective plate capable of sustaining the incident X-ray beam shall be used to cover all materials other than the sensor which could potentially be irradiated by the beam during a mis-steer and shall have a window exposing the clear aperture of the sensor.

- When in the 'In' position, the nominal LCLS beam shall impinge at the center of the sensor to within 10% of the linear dimension of the sensor active area (2 mm) and the surface normal of the sensor shall be aligned the z-axis of the LCLS coordinate system to within ±2°. This can be achieved manually.

- The size of the active area of the X-ray sensor shall be 20x20 mm^2, thus defining the operational range of the monitor accordingly.

- The device shall be designed to have at minimum a clear aperture of 20mm x 20mm for the sensor.

- A translational repeatability of 100 μm and stability of 5 μm, and a rotational repeatability (pitch and yaw) of 1.0° and stability (pitch and yaw) of 0.1° shall be maintained when the sensor is placed in the 'In' position.

- The sensor and its housing shall be electrically insulated from the vacuum can of the monitor. (physics requirements contradict this?)

- The sensor shall be mounted on a metal fixture, which is then attached to the shaft of a translational stage. The shaft shall be stiff enough that motions resulting from mechanical resonances will be less than 50% of the specified spatial resolution of 5 μm.

- A minimum beam stay clear radius of 12.7mm (0.5 inches) shall be maintained when the sensor is in the 'Out' position. The beam shall be assumed to lie down the design centerline of the chamber into which this device is installed.

- The sensor shall default to the 'Out' position in the event of a system fault insofar as it is possible to do so.

    - A system fault is defined as an abnormal state of power, pneumatic pressure, or controls information (either locally or globally).

    - Encountering the full beam while in the 'In' position or while transitioning between states is likely to be damaging to both the sensor and the sensor mount. Therefore, the sensor shall not be permitted to transition from 'Out' to 'In' without verification that the attenuators are in place, and shall immediately transition to the 'Out' state when a loss or potential loss of attenuation is detected (i.e., software or MPS interlocks shall be implemented to protect the sensor and mount from interacting with the full-power beam).

- Should the device fail while blocking the beam, it is highly desirable that the device have a manual retraction strategy. That is, should the motor/pneumatics fail or should power be lost, it is preferred that the device have the ability to be 'backed out' manually.

- For a pneumatic actuator: In the event of a system fault, the pneumatic switch shall default to routing air to retract the pneumatic actuator and remove the sensor from the beamline.

- A failure of pneumatic pressure to (or within) the unit is not considered a common failure mode. Pneumatic failure is expected to occur seldom, if ever, in the 10 year life of the LCLS project. There shall be no "fail safe" consideration for such a failure.

- For a motorized drive: If a motorized drive is used, it shall default to the 'Out' position during a loss of controls input, and shall remain in the 'Out' position indefinitely during a loss of power. However, if power is lost while the device is in the 'In' position or transitioning between states, the device will remain in the position it was in when power was lost. A motorized device will not be able to 'fail safe' in the event of a power failure.

- Mechanical failure is not considered a system fault; any such failure affecting operations would necessitate device repair and/or replacement, and may destroy the beam and/or necessitate venting the system.

5.2. Cyclic Requirements

Bellows for sensor assembly to be designed for 10,000 cycles under vacuum load at 60º C. Stroke will be approximately 1.5 inches and will be specified in the final design. The sensor assembly must be able to structurally withstand 10,000 sensor in/out cycles. Pneumatic actuator or motorized drive shall be capable of 10,000 in/out cycles within mechanical specifications.

5.3. Mechanical Interfaces

The chamber in which this device sits shall be supported from the underlying table by rod ends. The rod ends shall allow adjustability in the x, y, and z directions, and shall allow for roll, pitch, and yaw adjustment.

In every case and in all three instruments (XPP, CXI, XCS), alignment of adjacent chambers shall be driven by the alignment of the Pop-In Intensity Monitor. That is, the upbeam/dowmbeam flanges of the Pop-In Intensity Monitor shall be adjusted to optimize the perpendicularity of the sensor to the beam. The designs of adjacent chambers shall take into account to the limits of the tolerances on the Pop-In Intensity Monitor beamline flanges, and shall have adjustability or permitted misalignment large enough to account for these tolerance limits.

Where the PRD does not specify a location or orientation, this specification shall be considered non-critical. Whereas pitch, yaw, X, and Y of the sensor (and by extension the chamber into which it is mounted) are dictated by requirements of the PRD, roll and Z are not present in the PRD and as such shall be allowed to be variable. This variability will allow for adjacent devices to be optimized. Therefore, if an adjacent device has a roll requirement, the Pop-In Intensity Monitor shall be rolled to meet the spec of the adjacent device.

5.4. Vacuum

This device will be used in an Ultra-High Vacuum (UHV) of 10^{-7} Torr. The device's vacuum sealing surfaces shall be leak tested as specified in section xxx (Nadine – where is the standard spec?).

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 special circumstances good vacuum practices should be followed when grinding and polishing is required. 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/on a clean room/surface. This includes all subassemblies. For storage or transportation, place in clean sealed vacuum grade plastic bag that has been back-filled with nitrogen.

5.5. Materials

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, chemical analysis for all materials used in the manufacturing of the device shall be furnished per Section XX of this specification. The device will be used in a radiation environment with a maximum rate of about XX kilorad per year, and a total integrated dose of xx rad. Use of Teflon is specifically prohibited. (Nadine – need your input for these standards)

5.6. Thermal Issues

Sensor: Thermal load from the beam expected to be a tiny fraction of a watt. Heating of sensor is not expected to be a problem.

Thermal loads on the remainder of the device are not expected to be appreciable in normal operation. Adjacent devices and chambers shall not expect significant heat sourcing or sinking from this device.

5.7. Structural Issues

Rapid cycling or start/stop of pneumatic actuator could cause damage to the sensor. Soft start/stop shall be a design consideration, and testing will be done to ensure appropriate controls are in place to protect the sensor from damage.

Supports for the sensor/actuator assembly and camera/lens assembly shall be sufficiently robust to handle loads applied (vacuum, actuator, torque, cycling, etc). Static and dynamic deflection shall be less than .050". The sensor support shaft shall not resonate when the pneumatic actuator or stepper drive is operating.

5.8. Precision motion

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 alignment requirements.

5.10. Stability

The stability of the chamber is expected to be less than a micron. Small stability changes may occur during state transitions while the actuator is working (any transient issues are expected to die out within a few seconds).

Thermal issues could impact stability. Anything that may cause significant heating (especially cyclic heating) of the device or chamber should be investigated full to determine its impact on device operation.

5.11. Kinematics/Supports

The device shall be designed to meet or exceed the mechanical requirements as assembled. Tolerances shall be adjusted to ensure that the device as bolted together is within specified requirements. Applicable experimental verification, fiducialization, and QC shall be performed to verify compliance. No in-the-field adjustment will be necessary.

The support shall be a 6 degree of freedom strut system utilizing rod ends. Each rod end should have at minimum 0.25 inches of adjustability (plus and minus) from nominal. The distance from the center of the chamber to the table to which the device is mounted shall be designed to be a nominal 16 inches. Mounting system from the rod ends to the table shall also be part of the design of this device.

There shall be 3 rod ends at each end of the chamber. One end of the chamber shall have two Y supports and one X support. The other end of the chamber shall have one each of X, Y, and Z supports. This system allows adjustability of the chamber in all six degrees of freedom (X, Y, Z, roll, pitch, yaw).