ENGINEERING SPECIFICATION DOCUMENT (ESD)	Doc. No. SP-391-000-80 R0	LUSI SUB-SYSTEM Diagnostics

Intensity-Position Monitor Mechanical Requirements

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1. Overview

The LCLS X-ray FEL pulses will exhibit intrinsic intensity, position, and pointing fluctuations on a pulse-by-pulse basis. A diagnostic is required to measure the intensity and position of the LCLS X-ray beam. This document describes the mechanical requirements of the Intensity-Position Monitor (IPM).

The LCLS coordinate system that defines the global project coordinate system is defined in Section 2.1 Reference 8. Device coordinate systems are defined in Section 2.1 Reference 9

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-391-000-08 Physics Requirements for the LUSI Intensity-Position Monitor
2. SP-391-000-?? Intensity-Position Monitor Interface Control Document
3. AD-391-730-00 Intensity-Position Monitor Top Assembly
4. LCLS PRD 1.1-014 LCLS Beam Parameters PRD
5. LCLS 1.9-1017 LCLS Room Data Sheet, Near Experimental Hall Overall, Revision 2
6. LCLS 1.9-1037 LCLS Room Data Sheet, Far Experimental Hall Overall, Rev. 2
7. LCLS 1.9-1053 X-Ray Transport Tunnel Environment
8. SLAC-TN-05-021 LCLS Undulator Coordinate System
9. DS-391-000-36 Design Standards Supplement
10. FP-202-631-14 Fabrication of UHV Components
11. DS-391-000-36 Design Standards Supplement
12. SC-700-866-47 Specification; Machining Lubricants
13. SLAC-I-730-0A09M-001-R001 SLAC Chronic Beryllium Disease Prevention Program
14. SP-391-001-45 LUSI ICD XPP to DCO

2.2. Acronyms

CXI	Coherent X-Ray Imaging
FEH	Far Experimental Hall
FWHM	Full Width Half Maximum
MEE	Materials under Extreme Environment
IPM	Intensity Position Monitor
MPS	Machine Protection System
NEH	Near Experimental Hall
SASE	Self amplifying spontaneous emission
SLAC	Stanford Linear Accelerator Center
XCS	X-Ray Correlation Spectroscopy
XPP	X-Ray Pump Probe
XRT	X-Ray Transport Tunnel

3. General Requirements

3.1. Location &Distribution

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

	XPP	CXI	XCS	Totals
Intensity-Position Monitor	3	3	5	11

- XPP: The IPM assembly will be mounted on a common support with the other diagnostics in this segment in Hutch 2 and Hutch 3 at the NEH.
- CXI: The IPM assembly will be mounted on a common support with the other diagnostics in this segment. It may be located at the end of the X-Ray Transport Tunnel (XRT), or in Hutch 5 at the FEH.
- XCS: The IPM assembly will be mounted on a common support with the other diagnostics in this segment. It may be at located in the X-Ray Transport Tunnel (XRT), or in Hutch 4 at the FEH.
- Spare sub-assemblies for maintenance will be fabricated under operations budget.

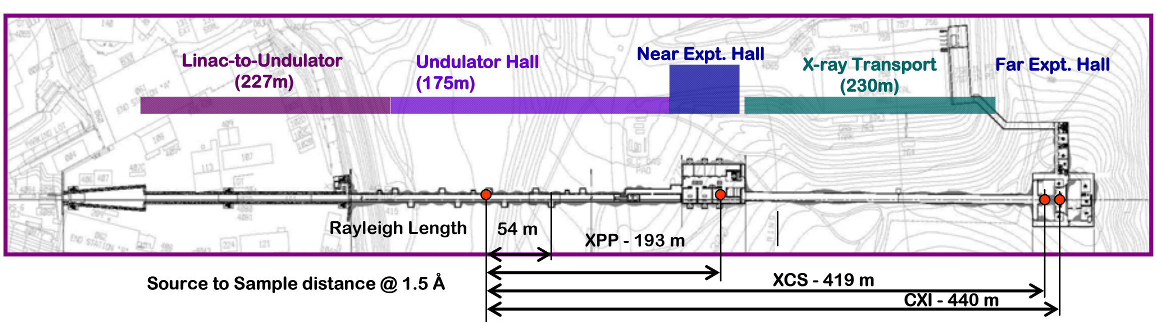

Figure 1. Location of LUSI experiments

3.2. Space Constraints

The volumetric envelope for the IPM assembly 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 location. 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 beamline 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 MEE beamline or the Hutch 5 walls.
- Y axis: The +Y envelope dimension (height) of the IPM is constrained by the facilities environment (ceiling height, cable trays, etc.). The –Y envelope dimension from beam center to the girder mount surface is defined by Reference 14 and will not exceed 16 inches from the beam centerline.
- Z axis: The overall Z length of the IPM assembly will be optimized to a minimal Z length to fit universally in all beam lines.

3.3. Environment

The IPM will be installed in both lab and tunnel environments. The design will be guided by the parameters of the worst case environment, the XRT. The temperature and humidity requirements were derived from Section 2.1 References 5, 6 and 7.

- Temperature: 72°F +/- 5°F.
- Humidity: IPM shall be capable of operating in 50 +/- 30% relative humidity environment.
- Vibration: The IPM 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 IPM chamber shall have a fundamental mode of vibration greater than 100 Hz.
- Radiation: IPM will be capable of withstanding 1 Krads/year for its lifetime as defined in Section 3.5.
- The IPM design will incorporate covers to protect moving parts from airborne dust.

- The IPM diode sensor assembly will operate in vacuum environment as defined in section 5.7.

3.4. Maintenance, Accessibility and Operations

The IPM will be designed for ease of installation, alignment, and removal. The diode assembly will be designed for service and replacement in situ.

The design of the IPM will permit replacement of both the target medium and the diode assembly in the field.

3.5. Lifetime

The designed service life of the IPM is 10 years.

4. Physics Requirements

Physics requirements (including optical requirements) are defined in SP-391-000-08 "Physics Requirements for LUSI Intensity-Position Monitor". The FEL beam characteristics including full width half maximum (FWHM) spot size, energy per pulse and spectral range are defined in Reference 1 and 4.

5. Mechanical Requirements

5.1. Construction

The key components of the IPM target and diode sensor are shown in Figure 2. The IPM consists of an actuator assembly that positions the detection and target elements in the path of the beam. The target medium is down beam of the diode detector assembly.

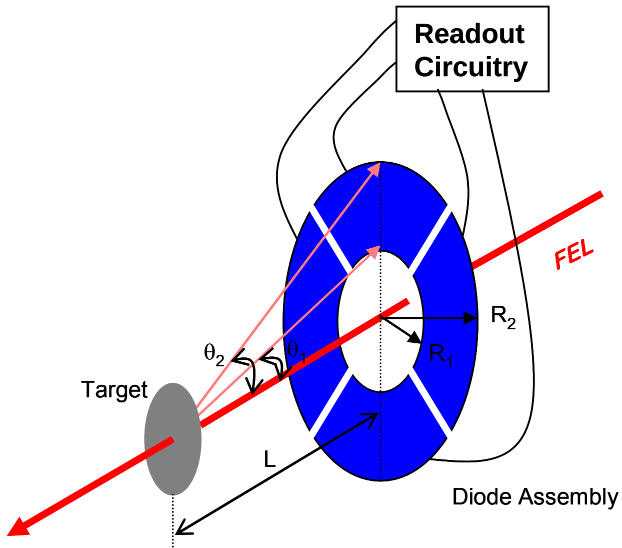

Figure 2 Intensity Position Monitor Schematic

5.2. Performance Requirements

- The IPM will be designed to operate at X-ray energies ranging from 2 keV up to 25 keV.
- The operating region of the IPM monitor will be an area greater than 2 x 2 mm.
- The IPM will be designed to measure the position of the X-ray beam in the XY plane to better than 5 μm in both X and Y directions.
- The intensity-position monitor must withstand the full LCLS flux when focused to an X-ray Gaussian spot size of 50 μm FWHM with 2 mJ pulse energy across the 8-25 keV spectral range without degradation to the monitor due to radiation damage. For energies lower that 8 keV, the focal spot size will produce fluence equal to or less than that of a spot size of 50 um FWHM at 8 keV.

5.3. Positioning Requirements

5.3.1. Target Media Positioning

There are two steps in positioning/aligning the Target Media. First, the entire device is aligned to the theoretical beam centerline per Section 5.11. Second, in operation, the exact center of the target media is found by adjusting the Y position of the target using the target assembly actuator.

Three operating positions are required for the target media (foils): 'Unobstructed' meaning no foil is in operating position, 'IN 1' meaning target 1 is in operating position, and 'IN 2' meaning target 2, and 'IN 3' meaning target 3 is in operating position.

- During target medium movement, the incident X-ray beam will be attenuated to avoid damage to the target assembly.
- The intensity-position monitor will have the ability to change the target media position in ~5 seconds.
- In any "IN" position, the nominal LCLS beam will impinge at the center of the target medium to within 10% of the monitor working range (0.2 mm).
- In any "IN" position, the translational repeatability along the Y axis shall be ≤ 50 μm. The X and Z axis are fixed.
- In any "IN" position, the target medium shall have a stability ≤ 5 μm relative to the device local coordinate system.
- In any "IN" position, the rotational repeatability (pitch and yaw) must be 1.0º relative to the LCLS coordinate system.

- In any "IN" position, angular vibration amplitude (pitch and yaw) of ± 0.1° relative to the LCLS coordinate system shall be maintained for the target medium moved into position. This is required for frequencies greater than 1Hz.
- In the "Unobstructed" position a 0.5 in (12.7 mm) clearance shall be maintained from the beam. The beam shall be assumed to lie down the design centerline of the chamber into which this device is installed.

5.3.2. Sensor Assembly Positioning

There are two steps in positioning/aligning the Diode array. First, the entire device is aligned to the theoretical beam centerline per Section 5.11. In operation, the exact center of the diode assembly is found by adjusting the X and Y position of the assembly using the X and Y axis actuators.

Two operating positions are required for Detection Element: 'IN' meaning sensor is in beam path, and 'OUT' the sensor is clear of the beam path.

- The detector shall change state in less than 30 seconds
- In the "IN" position the beam passes through the detector's hollow center section to within 10% of the monitor working range (0.2 mm).
- In the "IN" position, the intensity-position monitor shall have the ability to be translated ± 5 mm in the Y axis and ± 2 mm in the X axis, with a 5 µm accuracy and repeatability from the nominal beam center.
- In the "IN" position, the surface normal of the sensor shall be aligned to the Y-Z plane of the LCLS coordinate system to within ±1°.
- In the "OUT" position, a 0.5 in (12.7 mm) clearance shall be maintained from the beam. The beam shall be assumed to lie down the design centerline of the chamber into which this device is installed.

	IPM (Sensor)	IPM (target Media)
Vacuum Torr	10^{-7}	10^{-7}
Vibration Amplitude (freq > 1 Hz)	< 1 µm	< 5 µm
Angular Vibration Amplitude (freq > 1 Hz)	±0.1° (pitch, yaw)	±0.1° (pitch, yaw)
Thermal Translational Stability (days)	≤ 5 µm	≤ 5 µm
Static Angular Alignment to theoretical beam	±1° (pitch, yaw)	±1° (pitch, yaw)
Translation range	X: ±2 mm Y: 28mm	Y: 28mm
Translation resolution	5 µm	50 µm
X Translation Repeatability	5 µm	n/a
Y Translation Repeatability	5 µm	50 µm
Z Translation Repeatability	n/a	n/a
Roll Stability	n/a	n/a
Pitch Stability	1°	1°
Yaw Stability	1°	1°
Pitch Adjustability & Resolution	n/a	n/a
Yaw Adjustability & Resolution	n/a	n/a

Figure 3 Positioning requirements summary

5.4. Diode Sensor and Target Assembly Requirements

- The target mount assembly will be designed with a minimum a clear aperture of 10mm x 10mm for the target medium.
- The size of the target assembly clear aperture will be greater than 10mm x 10mm, permitting an active area of 100 mm^2 for full range of monitor operation.
- The mount for the diode sensors will be designed to give a clear aperture through the diode array center of 2x2 mm for beam clearance to the target medium.
- A 9 pin electrical vacuum feedthrough with 9 pins shall be used to connect signal wiring from the non-vacuum to vacuum side. An Electrical Engineering Specification Document will detail the wiring, circuitry, and connections of the electrical and electronic components.
- The diode sensor and its mount assembly will be electrically insulated from the vacuum can of the monitor.

- The diode detector assembly will be rigidly mounted to the actuator shaft. The shaft shall be designed to limit motion amplitude resulting from mechanical resonances to significantly less than 5 μm.

5.5. Cyclic Requirements

The actuators/sensor assembly will be designed for a 1,000 cycle lifetime.

5.6. Mechanical Interfaces

The IPM vacuum chamber will be mounted on an alignment stage that allows 6 axis alignment of the IPM assembly (X, Y, Z, Pitch, Yaw, and Roll).

The IPM will be designed to be aligned and supported independent of any externally applied loads for adjacent devices due to the precision tolerances of position and repeatability for the IPM. The design of beam lines and adjacent devices will account for this requirement.

- The IPM will be designed using standard Conflat (CF) vacuum flanges.
- The IPM vacuum chamber will use 6" rotatable CF flanges with clearance hole on the up beam and down beam chamber Z axes.
- Envelope size:
    - -Y dimension will be 16.0" maximum..
    - +Y dimension is constrained by facilities environment.
    - –X dimension will be 30 cm or less.
    - +X dimension will be 30 cm or less.
    - Z dimension (flange-to-flange) will be designed at minimum possible.

5.7. Vacuum

This IPM has a design operating pressure better than 10^{-7} Torr. The design will adhere to SLAC UHV design and fabrication standards. Manufacturing, cleaning, brazing/welding, handling, storage and leak testing operations shall be per Section 2.1 Reference 10.

5.8. Materials

All parts and materials for the device will be new and compatible with the performance requirements of this specification. Fabricated parts will be inspected for dimensional conformance and inspections reports compiled for all assemblies and components. Vendor part manufacturers will provide certifications for testing of precision and repeatability for

IPM parts and assemblies. Mil source certifications, including heat lot number and chemical analysis for all Vacuum materials used in the manufacturing of the device shall be furnished per Section 2.1 Reference 10 of this specification.

- Use of Teflon is specifically prohibited.

5.9. Thermal Issues

Thermal heating of the sensor is not expected to be an issue.

5.10. Precision motion

The IPM assembly actuators will incorporate stepper motor drives, actuator position encoders, adjustable actuator limit stops and travel end position limit switches.

5.11. Alignment/Fiducialization

The IPM will have tooling balls for external alignment reference. The position of each IPM sensor array (in vacuum) will be mapped dimensionally to the external alignment references during Q.C.

The IPM will be installed and aligned in the LUSI beamline relative to the LCLS coordinate system.

5.12. Stability

The long term dimensional stability will be designed to be less than 0.5 mm due to diurnal and seasonal thermal effects, and long term floor movement.

Short term dimensional stability due to ambient vibration will be on the order of 1-2 microns.

5.13. Kinematics/Supports

The IPM alignment stage will have a 6 degrees of freedom system. Each degree of freedom will have a minimum adjustable range of 10 mm

6. Electrical Requirement

The IPM diode array signal cables will be shielded from EMI.

7. Inspections, Test Provisions and Testing

Each IPM assembly will be serialized, tested, and signed off by engineering and physics prior to installation and again, prior to operation after installation in the beamline.

8. Major Interfaces

The IPM will be integrated into LUSI beamlines and will be designed to fit within the constrained dimensional envelope.

9. Controls

9.1. Motion Control

Motorized motion of the IPM actuators is required to be controlled remotely via the corresponding instrument control system.

9.2. Feedback/Encoders

- The position of each actuator stepper motor will be measured by a rotary motor encoder.
- When servicing the IPM Assemblies or moving to the OUT position, provisions will be made to ensure that the FEL beam does not enter the IPM.

9.3. Fail Safe

- There is no fail safe position required for this device in the event of a system fault.

- During target and sensor array motion, the X-ray beam will be turned off or blocked to avoid damage to the IPM..

10. Quality Assurance

Each production IPM will be calibrated, dimensionally verified, and tested prior to installation and operation. The Q.A. data for these processes will be stored in a database for historical reference.

11. Environmental Safety and Health Requirements

11.1. Earthquake

The IPM will be designed to withstand earthquake acceleration loads of 0.6 g in all axes..

11.2. Radiation Physics

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

The device will be used in a radiation environment with a maximum rate of about 1 kilorad per year, and a total integrated dose of 10 kilorad over the device lifetime. Refer to sections 3.3 and 3.5 for radiation exposure and IPM design lifetime.

11.3. Hazardous Materials

Beryllium shall be handled in accordance with Section 2.1 Reference 12.

11.4. Pressure Vessel/Vacuum Vessel

- The IPM vacuum chamber will be designed for Ultra High Vacuum (UHV) loading with the appropriate safety factors.
- Pressure relief safeguards will be provided at a higher level assembly.