LUSI LCLS Ultrafast Science Instruments

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| **ENGINEERING SPECIFICATION DOCUMENT (ESD)** | **Doc. No.**<br>**SP-391-000-84 R0** | **LUSI SUB-SYSTEM**<br>**XPP** |

# LUSI X-Ray Pump Probe (XPP) Instrument Engineering Specification

## DRAFT

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| Revision | Date | Description of Changes | Approved |
|---|---|---|---|
| R0 | | Initial release | |
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## 1. Scope

This document is intended to consolidate all engineering requirements and specifications related to The LCLS-LUSI x-ray pump probe (XPP).

X-ray Pump probe project is managed under LUSI Work Breakdown Schedule (WBS) section 1.2. Only items specifically described in WBS 1.2 will be dealt with in detail.

Elements managed outside of WBS 1.2 will be addressed only insofar as their inclusion provides a more complete understanding of XPP WBS 1.2 requirements.

Numerous documents providing guidance and definition for the design and engineering exist. This ESD is to serve as a “roadmap” to all documents related to the execution of the XPP engineering and design effort. Those supporting documents are referenced in the appropriate section of this document.

## 2. XPP Summary

The X-ray Pump Probe (XPP) instrument is one of the experimental configurations for the LUSI program. XPP combines an optical laser, to excite the atomic structure of a sample, and the X-ray beam to explore the properties of that structure.

XPP is located in Hutch 3 of the NEH approximately 132.5 meters down-beam of the LCLS undulator exit.

The XPP instrument hardware shall have the capability of reconfiguring to enable beam sharing with other experiments.

**XPP beamline “Position 1”** is defined as the configuration with XPP translating hardware located on-axis with the nominal LCLS x-ray beam centerline. At this position the experiment blocks x-ray propagation to the Far Experimental Hall (FEH)

**XPP beamline “Position 2”** is defined as the configuration with XPP translating hardware displaced 0.6 meter horizontally from the nominal beam centerline. At this position x-ray beam is free to enter the FEH for experimental investigations there.

The initial baseline installation of XPP hutch 3 hardware will provide for XPP to be configured to allow X-ray beam to pass through to the FEH. Future upgrades could include the addition of a monochromator x-ray beam-splitter in the up-beam vacuum drift section of XPP hutch 3. This will allow scientific investigation with experimental samples in position 2.

## 3. XPP Major Subsystems

XPP is comprised of five major subsystems:

1. **The up-beam vacuum drift section** is primarily intended for future upgrades to enhance beam sharing between experimental hutches. This area extends up-beam into NEH hutch 2 and includes a small suite of x-ray optic and diagnostic components.

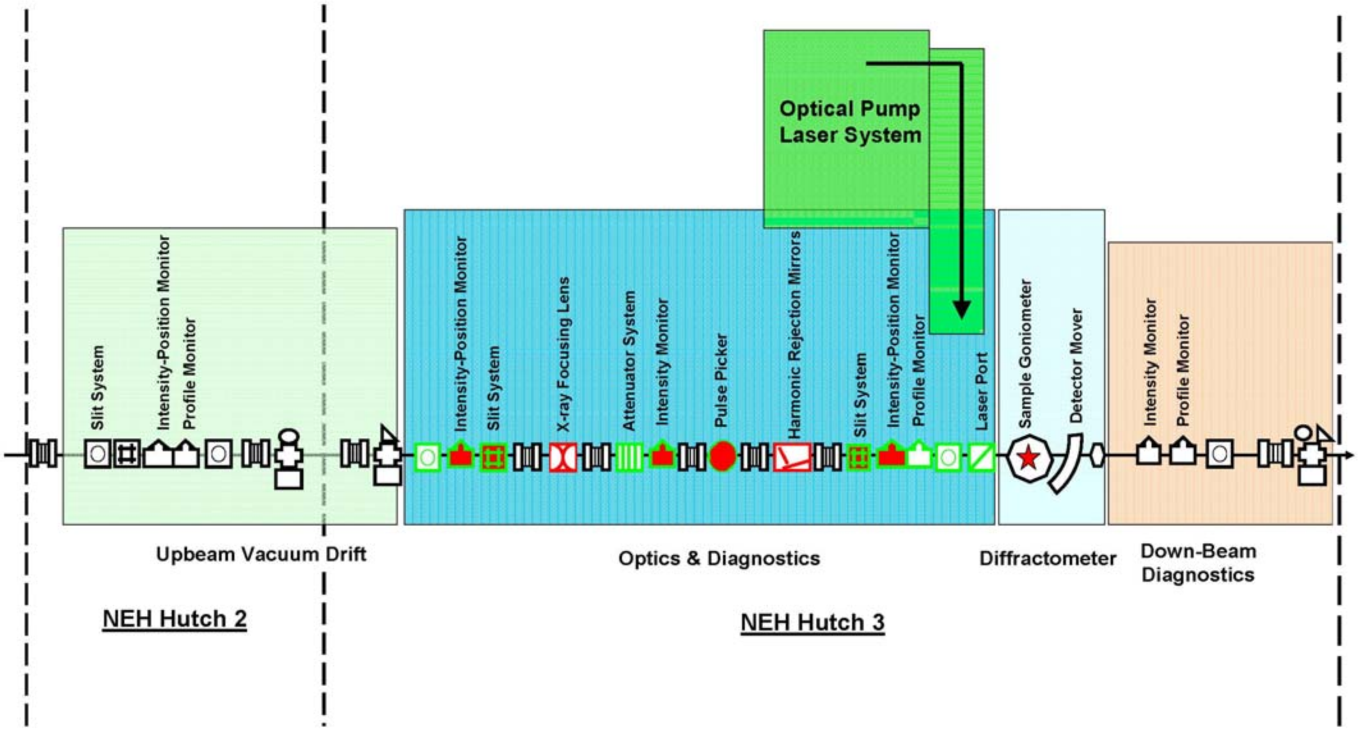
2. **The upbeam x-ray optics-diagnostic suite** for analysis and optimization of x-ray beam properties. This section also provides x-ray vertical steering capabilities for special experiment configurations. This section is designed to translate 0.6 meter (nominal) in "X" to facilitate x-ray beam sharing with other experimental hutches.

3. **The optical pump laser system** used to deliver excitation energy to experimental samples.

4. **The diffractometer system** composed of the sample goniometer ("tilt" and "kappa" goniometer) and the detector mover subsystems. This hardware provides for the positioning and rotation of the experimental sample and the array detector.

5. **The down-beam diagnostic-drift section** used for x-ray beam parameters analysis and diffractometer system alignment. This section also translates 0.6 meter (nominal) in "X", for beam sharing.

## 4. XPP Beamline Schematic



## 5. M.I.E. Interface Control Documents:

The following documents define the interface responsibilities between groups working in support of XPP instrument major items of equipment (MIE).

SP-391-000-05: LUSI to XTOD
SP-391-001-22: XPP Controls
LCLS Doc No. 1.1-509: X-ray End Stations to Conventional Facilities
LCLS Doc No. 1.1-510: Vacuum controls to Vacuum Mechanical

## 6. M.I.E. Physics Requirement Documents

The following documents define the physics requirements for XPP instrument major items of equipment (MIE).

SP-391-000-33: XPP Overall
SP-391-000-13: XPP Diffractometer System
SP-391-000-18: XPP Laser System
SP-391-000-97: XPP 2D Detector

## 7. M.I.E. Engineering Specification Documents

The following documents define the engineering specifications for XPP instrument major items of equipment (MIE).

SP-391-000-57: XPP Sample Goniometer
SP-391-000-62: XPP Detector Mover
SP-391-001-21: XPP Controls

## 8. Supplemental Specifications and Requirements Documents

The following documents define the supplemental specifications and requirements for XPP instrument major items of equipment (MIE).

LCLS Doc No XXX: NEH Hutch 3 Laser System Standard Operating Procedure
LCLS Doc No 1.6-005: Physics Requirements for LCLS / NEH Laser Safety Systems
LCLS Doc No 1.6-001: Physics Requirements for LCLS X-ray End Stations

## 9. Basic Instrument Design Criteria

### 9.1. Hutch PPS Access State Criteria

**With XPP translating hardware in position 1** access into hutch 3 will be permitted contingent on closing a photon shutter upbeam of hutch 3.

**With XPP translating hardware in position 2** access into hutch 3 will be permitted contingent on closing a photon shutter at the upbeam end of the main optics-diagnostics suite. When XPP is configured with translating hardware at position 2, x-ray beam will be permitted to pass through hutch 3 while access is permitted, allowing prescribed PPS conditions are met.

Local shielding, as determined by radiation physics simulations, or other measures, may be required to achieve the above described access states.

## 9.2. Basic Hardware Design Criteria

**The design service life of the XPP hardware is 10 years.**

**Operational hutch temperature is 68 +/-1 degree F**.

XPP hardware will support data acquisition at operational temperature / tolerance.

**Extreme hutch temperature is 68 +/-20 degree F.**

XPP hardware will accommodate extreme temperature / tolerance without permanent damage. All hardware will return to nominal position when hutch temperature returns to operational specifications.

**No extraordinary hutch humidity is anticipated**.

**Nominal experiment duration is one week**. An experiment is defined as use of the hutch 3 hardware during which the hardware configuration is not substantially modified or reconfigured.

All Hardware for XPP will be specified, designed, fabricated and installed in such a way as to provide for function at both hardware positions (position 1 and position 2).

**All XPP systems shall be designed, constructed and installed to support experiment reconfiguration in 8 hours or less**. This includes repositioning of hardware from "position 1" to "position 2", or visa-versa, any x-ray optic or diagnostic element recalibration, diffractometer system and laser system reconfiguration and realignment. Experiment reconfiguration is defined as all tasks required to support the requirements of a given user.

**All tasks to reconfigure the XPP hardware will be within the competency of a typical SLAC mechanical technician**. No specialized expert capabilities, such as alignment engineers, will be required to reconfigure XPP.

## 9.3. X-ray Beam Parameters for Mechanical Design Baseline

**The nominal horizontal spacing between position 1 and position 2 is 0.6 meter (23.622 inches)** .

**The nominal vertical position of the x-ray beam is 1.4 meter above the hutch floor**.

**The actual, nominal, global position of the x-ray beam will known before XPP hardware is installed in the hutch.** Any difference between design beam location and actual beam location will be addressed prior to installation.

**The x-ray beam position will drift to such an extent that repositioning-alignment of XPP hardware will be required at every experiment reconfiguration**. This includes x-ray optical-diagnostic components, sample goniometer and detector mover. Any repositioning will be accomplished using typical SLAC mechanical technicians competency.

**The x-ray beam will maintain precise position throughout the coarse of each experiment** (approx one week) to the extent that realignment during the experiment will not be necessary.

## 9.4. Baseline Instrument Reconfiguration Procedure

Hardware will be design to accommodate the following work flow between experiments.

A. **Complete over-all configuration of beamline hardware**:
  A.1. Hutch PPS state: permitted access
  A.2. Optics – diagnostic sections moved to required position (1 or 2)
    A.2.1. “gold values” selected in control system
  A.3. Configure sample goniometer as required.
    A.3.1. Move to required nominal position (1 or 2)
    A.3.2. Tilt / kappa hardware configuration
    A.3.3. Install x-ray / pump laser fine adjust tooling
  A.4. Configure detector mover
    A.4.1. Move rotation center to required nominal position (1 or 2)
    A.4.2. Install detector attenuator as / if required
  A.5. Complete required pump laser configuration changes
B. **Complete beam based x-ray optical section / pump laser fine adjust.**
  B.1. Hutch PPS state: no access
  B.2. XFLS focus / defocus
  B.3. Insert / retract HR mirrors
  B.4. Configure / align pump laser
  B.5. assume need for special hardware on goniometer or use of dwn-bm diagnostics
C. **Install diffractometer system alignment fixture**
  C.1. Hutch PPS state: permitted access
  C.2. assume hardware different from optic fine adjust fixture
  C.3. assume common fixture for goniometer and detector mover alignment
D. **Complete x-ray beam based diffractometer system alignment**
  D.1. Hutch PPS state: no access
  D.2. Align sample goniometer rotation center to x-ray
  D.3. Align detector mover to sample goniometer rotation center
  D.4. Align diffractometer beam stop to x-ray
  D.5. Align sample positioning camera system to diffractometer system center

**E. Complete sample placement**
  E.1. Hutch PPS state: permitted access
  E.2. Sample aligned in diffractometer with camera system

**F. Start experiment data acquisition**
  F.1. Hutch PPS state: no access
  F.2. Hardware configuration complete
  F.3. Sample change out only required hardware related task during experiment duration

## 10. Optical-Diagnostic Suites Support System Design Criteria

Prioritized design criteria are:

I) **All translating beamline elements must be under positive control** at all times.
  i. All elements will have fixed (immovable) hard stops defining motion extents
  ii. human intervention will not be required to confine elements within their intended range of motion.

II) **Stable relative optical–diag element position** (IE: elements with respect to other).
  i. **Goal: < 5 micron** (+/- 2.5) relative position stability.
  ii. Assumed sources of deviation:
    a. thermal gradients within supports
    b. loads across bellows due to remote commanded component motions
    c. Dynamic response to cyclic input loads

III) **Stable absolute optic-diag suite position** (IE: elements as a unit in global space)
  i. **Goal: < 15 micron** (+/-7.5) with 2 (+/-1) deg F variation
  ii. Assumed sources of deviation:
    a. Gross bulk thermal variation
    b. Dynamic response to cyclic input loads
    c. Unintended redundant loads
  iii. Slits to serve as position datum for optic-diag suite
  iv. Assumes use of invar component fine align supports

IV) **High repeatability of translation hardware** (IE: moving between positions 1 and 2)
  **i. Goal: <25 micron horizontal**
    a. Assumed sources of deviation:
      1. unintended redundant loads
      2. improper restraint load input
      3. hard strike while contacting stop
  **ii. Goal: < 15 micron vertical**
    a. Same as “III” above

V) **Minimize adjacent component** motion due to alignment / bellows / external loads
  **i. Goal: <2 micron**
  ii. Assumed sources of deviation:
    a. Force couples through support structure from remote command motions

VI) **Intuitive** and clearly marked **methods** of traversing beamline components.

VII) **Absolute alignment** of support structure
  **i. Goal: < 200 micron**

## 10.1. Materials

Use of materials with low coefficients of thermal expansion are highly desirable to reduce thermal motion

Use of materials with low thermal diffusivity to limit the displacement effects of short term temperature excursions is highly desirable

## 10.2. Thermal Issues

Due to the long length of the optic-diagnostic suite immediately up beam of the diffractometer system, ~4.6 Meters, if not properly controlled, the effect of small temperature variations can have a large impact on the structural loads and displacement behavior of the support system.

All supports for XPP will have deterministic constraints fully compliant to thermal variations or gradients. Thermal variations or gradients will not create redundant loads on the support system.

## 10.3. Structural Issues

All support system hardware will be engineered to equal or exceed the seismic accelerations or loads prescribed by SLAC directive at the time of design.

**Nominal design load for element support hardware is 10 Lbs / inch of beamline length.**

## 10.4. Precision Motion

Motion control elements will be specified such that the requirements of section 10 are achieved.

Manual control of translation hardware is acceptable (IE: no need for remotely operated motor control).

A high level of repeatability when the optic-diagnostic suite is moved between beamlines is far more important than the absolute position of the support structures. All components to be mounted on the support structures will have their own fine alignment supports.

## 10.5. Alignment / Fiducialization

The x-ray optic-diagnostic support system hardware will not be fiducialized for precision alignment. Support system hardware will be located in the hutch via measurements taken from nominal features / surfaces / edges.

Individual optic-diagnostic components will be fiducialized and precisely aligned after mounted on the support structures.

# 11.Vacuum System Design Criteria

**The average pressure shall be 10-7 Torr.**

All vacuum components shall receive mass spectrometer RGA scans prior to installatin in hutch beamlines. A scan of partial pressures from 1-100 amu should show **no individual peaks above 44 amu, greater than 5E-12 Torr, and the sum of all peaks greater than 44 amu should be less than 1E-11 Torr.**

**Base pressure at vacuum pumps will be consistent with manufactures recommendations for 10 year life expectancy.**

**Peak pressure in some devices (e.g.: monochromator) shall not exceed 10-7 torr**. Components with peak pressure requirements will have said peak pressure identified in it's Engineering Specification Document.

**All seals nominally to atmosphere will be all metal construction.** Non-metallic seals in normally open valves is acceptable. Normally closed (vent / purge) valves will be all metal seal types.

All sections between valves will have a minimum of one gauge set providing pressure sensitivity from atmosphere to 1 nano-Torr.

All sections between valves will have a minimum of one vent / purge valve.

Space permitting, **valve configurations at beamline translation joints will have dual seal vent volume configuration**. The small vent / pump volume can significantly reduce experiment reconfiguration times and limit potential damage due to unintended contamination. One valve at these locations can be manually operated.

All lubricants, cutting fluids, etc., used in manufacturing shall be "sulfur-free". Reference SLAC document No. SC-700-866-47 for a complete list of approved machining 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 they are to be handled only with clean latex or nitrile gloves. All components that cannot be made vacuum tight and purged with dry nitrogen shall be wrapped in SLAC approved lint free paper and Aluminum foil or sealed in a purpose approved vacuum container. Components should only be vented, unwrapped or otherwise exposed in a clean room environment. This includes all piece parts, subassemblies and completed instruments. For storage or transportation, place in clean sealed vacuum grade plastic bag that has been back-filled with nitrogen.

## 12.Schedule

XPP schedule will be created and maintained, throughout the complete project life cycle, under the guidelines established in “LCLS Earned Value Management System Project Schedule Procedure”, LCLS Doc No; PMD 1.1-020.

## 13.Cost Basis-Of-Estimate

XPP cost basis of estimate will be created under the guidelines established in “LCLS Earned Value Management System Cost Estimating Procedure”, LCLS Doc No; PMD 1.1-021 and “LCLS Basis of Estimate Methodology” LCLS doc No. ESD 1.1-100.

## 14.Environmental Safety and Health Design Criteria

All hardware designs will be approved via the LCLS Design Review Guidelines (ref: LCLS Doc No. ESD 1.1-324)

The implementation of the LCLS Project Environment, Safety and Health Plan (LCLS doc No. PMD 1.1-011) will be a key component of the review process. Special attention will be focused on the core functions of the Integrated safety and management System (ISMS) in said design reviews.

## 15.Radiation Shielding Design Criteria

Radiation physics simulations of sources in hutch 3 will be completed. Spot or area shielding will be implemented as required to achieve hutch accessibility to support the requirements of section 9 of this document.

## 16.Inspection, Test and Commissioning

Full inspection of piece parts, for geometric and material property acceptance will be required. Written reports of said inspections will become an element of the component pedigree.

Sub-assembly and component level testing will be conducted to establish compliance with engineering specifications and physics requirements. Testing will include, but not be restricted to, any required motion accuracy and precision, controls hardware (limit switch, position encoders, etc) performance, vacuum performance, support stability and any safety system performance (interlock, safety covers, etc).

Commissioning will be conducted at the system level to validate component level tests and insure seamless integrate at the hutch sight.