

ENGINEERING SPECIFICATION DOCUMENT (ESD)	Doc. No. SP-391-000-57 R1	LUSI SUB-SYSTEM XPP DIFFRACTOMETER
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LUSI XPP Sample Goniometer Engineering Specification

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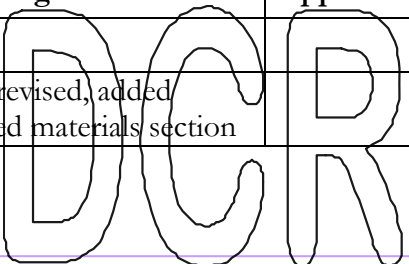
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R0	8-10-08	Initial release	
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Table of Contents

1. Scope:	3
2. Sample Goniometer Summary:	3
3. Glossary / Definitions:	3
4. Applicable Documents, Specifications and Codes:	4
4.1. SLAC Documents:	4
4.2. SLAC Specifications:	4
4.3. Industry Specifications and Codes:	4
5. General Area / Adjacent Equipment Description:	4
5.1. LCLS / LUSI overview:	4
5.2. XPP Instrument Overview:	5
5.3. Hutch 3 / XPP Hardware Layout:	5
5.4. Coherent X-ray beam:	6
5.5. Detector Mover System:	7
6. Sample Goniometer Coordinate System:	8
7. Goniometer Basic Performance Requirements:	8
7.1. Overall dimensions:	8
7.2. Sphere of Confusion:	8
7.3. Load Capacity:	9
7.3.1. Sample Translation Platform:	9
7.3.2. Kappa Goniometer:	9
7.4. Goniometer Element Interface Requirements:	9
7.5. Translation and Rotation Specifications Evaluation:	10
7.6. Translations and Rotations Hard Stops:	10
8. Mounting Base Requirements:	10
9. Interaction Point Translation Requirements:	11
10. Goniometer Common Rotations Requirement:	12
11. Sample Translation Requirements:	13
12. Kappa Goniometer Requirements:	14
13. Sample Mount Requirements:	15
13.1. Tilt Platform Sample Mount:	15
13.2. Kappa Goniometer Sample Mount:	15
14. Alignment Fixture Interface:	16
14.1. Tilt Platform Alignment Fixtures:	16
14.2. Kappa Goniometer Alignment Fixtures:	16
15. Motion Control Requirement:	17
15.1. Motor Specifications and Requirements:	17
15.2. Encoder Specifications and Requirements:	17
15.3. Limit Switches:	18
16. Cable Management:	18
17. Power and Data Cable Requirements / Interface:	18
17.1. Power Cabling Requirement / Interface:	18
17.2. Control Cabling Requirement / Interface:	19
18. X-ray Stop Stay Clear Requirements:	19
19. Lifting Features:	19
20. Environmental Safety and Health Requirements:	20
21. Supplemental System Requirements:	20

1. Scope:

This document describes and defines the engineering requirements for a system to precisely support, translate and rotate experimental samples in the LUSI X-ray Pump Probe (XPP) instrument. This device will subsequently be known as the “sample goniometer”.

2. Sample Goniometer Summary:

The LCLS-LUSI XPP sample goniometer will be used to precisely control the physical location and orientation of a sample. The nature of the LCLS-LUSI machine requires an extraordinary level of flexibility and accuracy from the diffractometer system. The diffractometer consists of two major components, the sample goniometer (subject of this document) and the detector mover. The sample goniometer must have the ability to position the sample within two widely separated interaction point regions. Two different goniometer configurations (“sample translation” and “Kappa”) are required to accommodate a wide range of experimental objectives. The system must incorporate features to enable the use of future sample vacuum environments, cryostat or cryostream. Features to accommodate alignment fixtures for sample goniometer and detector mover must be integral to the overall design to achieve desired levels of accuracy. Goniometer design must enable rapid reconfiguration to maximize science output.

3. Glossary / Definitions:

Accuracy: Defines the ability to establish location or angle to a predetermined value, with respect to a fixed coordinate system.

Detector: Transduction Hardware

Detector Mover: Hardware designed to position and translate a detector

Diffractometer system: Hardware system employed to position and translate both sample and detector

Experiment Sphere of Confusion: Uncertainty in absolute location of the intersection of x-ray beam, pump laser and sample feature

FEH: Far Experimental Hall

FEL: Free Electron Laser

Goniometer Foundation: Surface providing attachment for goniometer mount base.

IP: Interaction point, the intersection of x-ray, pump laser and sample

Kappa Goniometer: Hardware employed to position and rotate a sample feature

LCLS: Linac Coherent Light Source

LUSI: LCLS Ultrafast Science Instruments

Mechanical Sphere of Confusion: Uncertainty in absolute position of sample goniometer center of rotation.

NEH: Near Experimental Hall

Pitch: Rotation about the X-axis

Range: The total available limit(s) of motion with respect to a fixed coordinate system origin or axis

Repeatability: Defines the ability to successively reestablish a desired location or angle, with respect to a fixed coordinate system.

Resolution: Defines the uncertainty of a measurement of location or angle with respect to a fixed coordinate system. Also defines the minimum measurable difference between two dissimilar values.

Roll: Rotation about the Z-Axis

Sample Translation Goniometer: Hardware employed to position and rotate a sample. Also known as “Tilt Platform”

SLAC: Stanford Linear Accelerator Center

Stability: Defines accuracy for a specified time

XPP: X-ray Pump Probe

Yaw: Rotation about the Y-axis

4. Applicable Documents, Specifications and Codes:

4.1. SLAC Documents:

GP-391-300-00:	“Hutch 3 - XPP Arrangement”
GP-391-750-14:	“Hutch 3 - XPP Sub-system Stay Clear Definitive Lay-out”
ID-391-300-10:	“XPP- Sample Goniometer Installation”
ID-391-320-07:	“Mounting Base Installation”
SA-391-320-09:	“Mounting Base Weld and Machine”
SA-391-320-10:	“X-ray Beam Stop Assembly and Stay Clear”
SA-391-320-14:	“Cable Carrier Assembly and Stay Clear”
SC-391-320-03:	“Interaction Point Translation Specification Control”
SC-391-320-04:	“Goniometer Common Rotations Specification Control”
SC-391-320-05:	“Sample Translation Specification Control”
SC-391-320-06:	“Kappa Goniometer Specification Control”
SC-391-320-11:	“Elements Interface Specification Control”
SC-391-320-12:	“Mount Base to IP Trans Element Specification Control”

4.2. SLAC Specifications:

SP-391-000-84:	“LUSI XPP Instrument Engineering Specification”
AP-391-000-59:	“Engineering Review Guidelines”
DS-391-000-36:	“Design Standards Supplement”
SLAC-I-720-0A24E-002:	“Specification for Seismic Design of.....at the Stanford Linear Accelerator”

4.3. Industry Specifications and Codes:

NEC, NFPA 70:	“National Electric Code,”
NEC, NFPA 70E:	“Electrical safety in the Workplace”
CBC 2007:	“California Building Code, 2007”

5. General Area / Adjacent Equipment Description:

5.1. LCLS / LUSI overview:

The Linac Coherent Light Source (LCLS) is a machine for the production of coherent hard x-rays (IE: x-ray laser light). The overall length of the LCLS machine is approximately 1.8 km.

The LCLS Ultra-fast Science Instruments (LUSI) program consists of a suite of x-ray instruments for exploiting the scientific capability of the LCLS. These instruments will be housed in experimental hutches located down-beam of the LCLS in a Near Experimental Hall (NEH) and a Far Experimental Hall (FEH).

The linear architecture of the LCLS complex (as compared to previous storage ring light sources), and the stringent requirements necessary to maintain the coherent x-ray beam properties, coupled with the need to maximize user scientific productivity, determine unique requirements for the LUSI instruments.

5.2. XPP Instrument Overview:

The X-ray Pump Probe (XPP) instrument is one of the experimental configurations for the LUSI program. XPP combines an optical “pump” laser, to excite the atomic structure of a sample, and the X-ray beam to “probe” the properties of that structure. **The major XPP subsystems and locations are shown in GP-391-300-00.**

XPP is located in Hutch 3 of the NEH.

Due to the linear architecture of LCLS, the XPP instrument hardware must have the capability of reconfiguring to enable beam sharing with other experiments.

XPP configured for data taking at “Position 1” blocks X-ray beam from propagating to the FEH.

XPP configured for data taking at “Position 2” permits X-ray beam to propagate through to the FEH.

To maximize scientific output, all XPP systems will be designed, constructed and installed to support hardware reconfiguration, realignment and recalibration in 8 hours or less. This includes hardware repositioning from position 1 to position 2, or visa-versa.

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

5.3. Hutch 3 / XPP Hardware Layout:

The XPP hutch 3 floor plan consists of a main experimenter area and a down-beam alcove.

Overall **hutch 3 dimensions are shown in figure 1.**

A master coordinate system, to define locations of hardware in hutch 3, is also defined in this figure. The master coordinate system is right handed Cartesian with its origin nominally 1.4

meters above the floor and the Z+ axis in the nominal direction of X-ray beam propagation, parallel to the floor. The X+ axis is in the horizontal plane and Y+ axis is vertically up.

An interaction point is defined as the location where the x-ray beam and optical pump laser intersect the sample. XPP will have two nominal interaction point locations (IP1 and IP2), also shown in **figure 1**. IP1 is actively defined when XPP is in “straight ahead” mode, blocking x-ray propagation to the FEH. IP2 is actively defined when XPP is using monochromatic offset x-ray beam. **The nominal separation between IP1 and IP2 is 0.60 meter.**

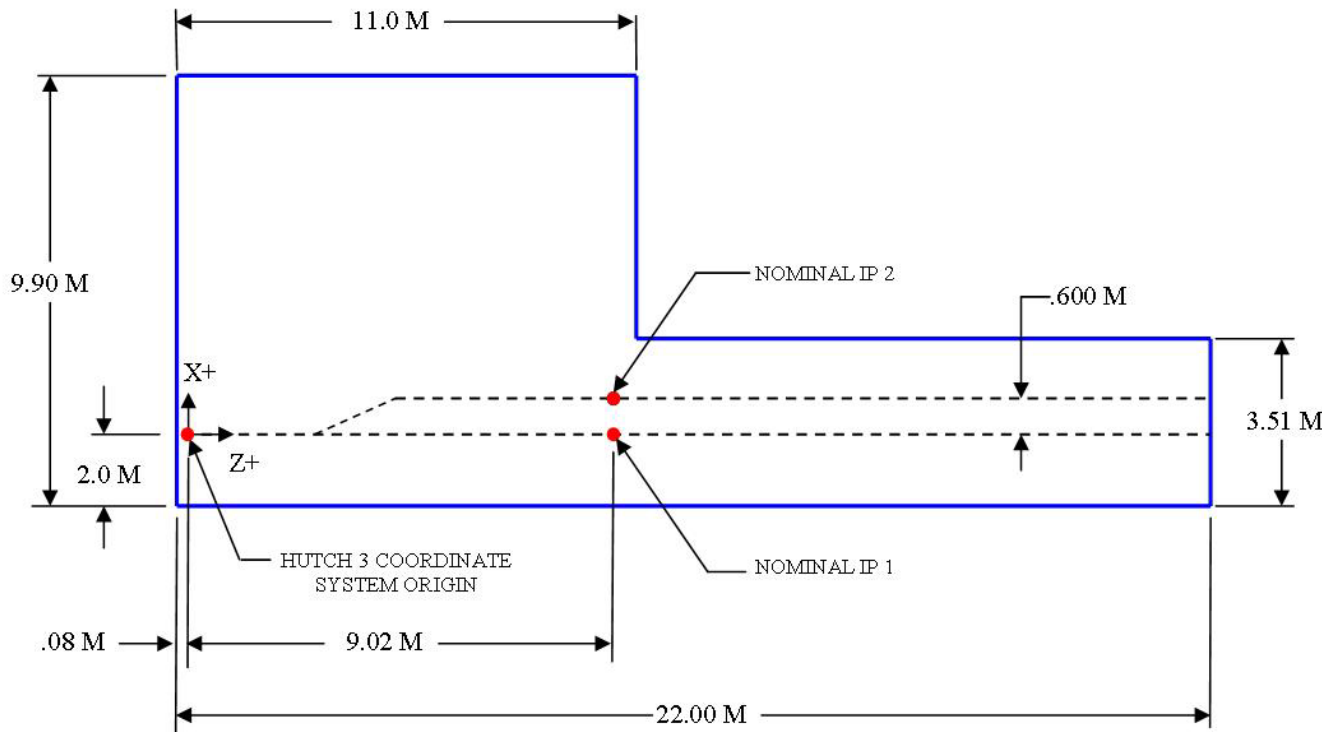


Figure 1
Hutch 3 – XPP Floor Plan

5.4. Coherent X-ray beam:

Up-beam optical transport elements can have a significant effect on the position of the x-ray beam entering hutch 3.

The active interaction point and subsequently **the true, aligned, location of the diffractometer system rotation center can vary by up to 4 mm (+/- 2 mm tol) from nominal.**

Some classes of XPP experiments will require the x-ray beam to have a down angle at the sample surface interface (IE: active interaction point). Elements in the optics-diagnostic section will be employed to steer the x-ray beam to the desired down angle. This down angle translates to a vertical offset of the active interaction point.

The maximum vertical offset of the active interaction point, and subsequently **the true, aligned, vertical location of the diffractometer system rotation center can vary by up to 30 mm from nominal.**

The horizontal and vertical extents (“X” and “Y”) of possible true interaction points, and therefore, diffractometer rotation center locations, with respect to the nominal locations, is shown in **figure 2**. The view is shown with the X-ray beam into the page. **Sample goniometer hardware will be constructed to allow the rotation center to be aligned within these two zones.**

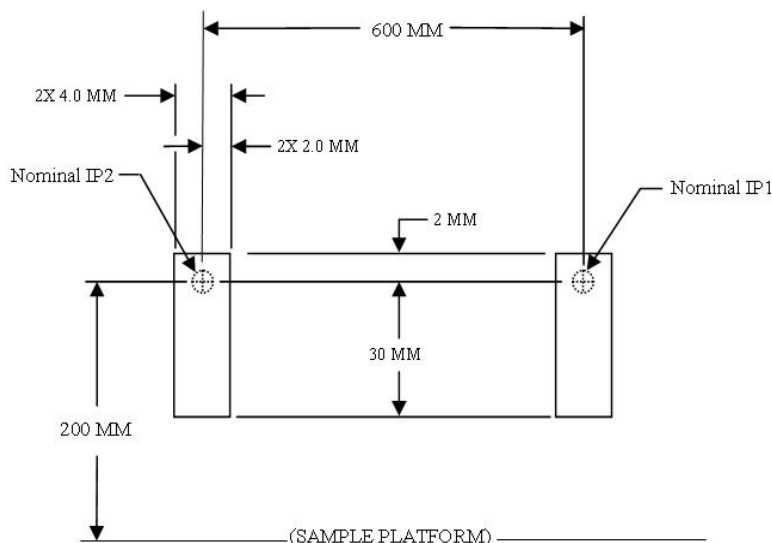


Figure 2
Diffractometer Rotation Center Zones

5.5. Detector Mover System:

The Detector Mover is used to position a custom, large area detector (1024 x 1024 pixels, approx. 200mm square) about a pre-defined diffractometer rotation center, coincident with the sample goniometer coordinate system origin. The detector will be moved over spherical surfaces with radii ranging from 10–100 centimeter. To insure maximum accuracy and stability of the diffractometer system, the detector mover system will be physically (structurally) isolated from the sample goniometer.

6. Sample Goniometer Coordinate System:

The sample goniometer will have a coordinate system defined to establish relative position and angle with respect to the x-ray beam (i.e.: active interaction point), adjacent equipment and hutch. This coordinate system will exist independent of the configuration of the sample goniometer.

The goniometer coordinate system will, by definition, be a right hand Cartesian system with its origin located at the center of axis rotation of the active hardware configuration. The Z+ axis is the nominal direction of X-ray beam propagation, parallel to the floor. The X+ axis is in the horizontal plane and Y+ axis is vertically up.

All subsequent coordinate directions indicated in this document are referenced per this coordinate system.

7. Goniometer Basic Performance Requirements:

7.1. Overall dimensions:

The complete sample goniometer system shall be designed to accommodate an X-ray beam nominally located 1.40 meters above the goniometer foundation (floor).

7.2. Sphere of Confusion:

The minimum diameter spherical volume that is required to include x-ray beam, pump laser and sample feature is the “experimental sphere of confusion”. The coincidence (overlap) of these elements cannot be guaranteed for a volume smaller than this defined region. The value of the experimental sphere of confusion defines the lower limit on the certainty of the absolute location of the interaction point.

The final achievable value for experimental sphere of confusion is effected by aspects of the x-ray beam, pump laser and sample goniometer. Determination of the specifications for the sample goniometer hardware are directly related to, and determined by, the desire to minimize the experiment sphere of confusion.

The “mechanical sphere of confusion” is defined as the uncertainty of location of the sample goniometer center of rotation. The mechanical sphere of confusion is determined by the variation of the measured location of the goniometer center of rotation as all rotation axis are translated through their full range of travel. **The measured value of the mechanical sphere of confusion is with respect to the hutch master coordinate system (IE: the floor), defined per section 5.3.**

The LUSI-XPP sample goniometer will have a mechanical sphere of confusion less than 30 microns. This value applies independent of goniometer configuration and with loading as defined in section 7.3.

7.3. Load Capacity:

7.3.1. Sample Translation Platform:

The sample translation platform configuration shall maintain the specified mechanical sphere of confusion, per section 7.2, with a 225 Lb (~100 kg) payload mounted with center of mass up to 1.97 inches (~50 mm), in any direction, from the goniometer rotation center.

7.3.2. Kappa Goniometer:

The kappa goniometer configuration will maintain the specified mechanical sphere of confusion, per section 7.2, with a 2.2 Lb (~1.0 kg) payload mounted with center of mass up to 0.24 inches (~6.0 mm), in any direction, from the goniometer rotation center.

7.4. Goniometer Element Interface Requirements:

The goniometer elements described in sections 8 through 12 are each consider **individual, unique, elements of the complete goniometer**. Under no circumstance will the elements, as defined in sections 8 through 12, be subdivided further than as described in those sections.

XPP system requires maximum operational flexibility and reconfigurability from the goniometer.

To achieve this end, **it is a distinct advantage to have a single interface configuration compatible between as many elements as possible.**

Elements sharing a compatible interface configuration shall be capable of assembly without other modification.

All interfaces require mate-demate rigidity and durability. Any element mating interface shall have the rigidity required to simultaneously achieve the sphere of confusion (section 7.2) and load capacity (section 7.3) requirements.

Each interface must achieve a minimum five hundred (500) mate-demate cycles without requiring overhaul or component replacement.

Due to the nature of the XPP experiment, repeatability between mate-demate cycles is not a stringent requirement.

Mate-demate element interface alignment repeatability shall be 50 microns (maximum).

Detailed definition of all mating surface parameters: flatness, bolt pattern, bolt size, alignment interface, bolt torque, etc, are defined in SC-391-320-11 and SC-391-320-12 for mount base to IP translation element interface.

7.5. Translation and Rotation Specifications Evaluation:

All translation and rotation specifications established in this document shall be evaluated in the context of the fully assembled sample goniometer.

The datum from which all translation and rotation measurements shall be evaluated will be the interface surface between the mounting base (section 8) and the interaction point translation element (section 9). All requirements for accuracy, repeatability and stability shall be evaluated with respect to, and shall be measured at, the sample goniometer center of rotation.

Interaction point translations (ref section 9) and goniometer common rotations requirements for accuracy, repeatability, resolution and stability shall apply in either “sample translation platform” or “kappa goniometer” configurations.

7.6. Translations and Rotations Hard Stops:

All translation and rotation elements shall be provided with adjustable hard stops where applicable. Rotation elements with motion range requirements of “continuous” are not required to have hard stops.

8. Mounting Base Requirements:

The sample goniometer translation elements are attached to, and statically aligned via, the mounting base assembly and its interface with the goniometer foundation.

The mounting base will not be repositioned, or otherwise adjusted, on an experiment by experiment basis.

The mounting base shall have the ability for realignment under extreme circumstances (eq: significant seismic ground displacement). Therefore the mounting base will not be grouted in place or otherwise permanently restricted from being repositioned with respect to the goniometer foundation.

Static alignment accuracy of the mounting base defines the absolute orientation of the common rotations vertical axis with respect to the hutch master coordinate system.

The mounting base provides the surface upon which the sample goniometer translation and rotation components (sections 9 through 12) are placed.

The main mount surface of the base element shall be mateable to the lower surface of the interaction point translation element described in section 9, as specified in section 7.4.

Mount Base Alignment Specification

Direction	Range	Accuracy	Repeatability
Y	12 mm (+/-6)	50 micron (+/-25)	N/A
X, Z	12 mm (+/-6)	150 micron (+/-75)	
Roll, Pitch	N/A	<0.10 mRad (<+/-0.25)	
Yaw	N/A	<0.26 mRad (<+/-0.13)	

The mounting base shall be designed to:

- 1) Have the main mount surface located at Y = -1182 mm, +/-0.5mm.
- 2) Have a main mount surface minimum X length of 1244 mm (centered on nominal IPs 1 & 2).
- 3) Have a main mount surface minimum Z width of 450 mm (centered on nominal IPs 1 & 2)
- 4) Have a main mount surface flatness of 25 micron.
- 5) Have main mount surface attachment features as shown in SC-391-320-12.
- 6) Have auxiliary mount surfaces:
 - a) located at Y = -1073 mm, +/- 0.5 mm.
 - b) having X length of 1244 mm (centered on nominal IPs 1 and 2).
 - c) located from Z = +286 to +435 mm and Z = -286 to -435 mm.
- 6) Accommodate a goniometer foundation elevation variation of 45 mm (+/-22 mm). This variation is distinct from the alignment specification. This variation can be addressed by in situ spacers adjustments, machined to as measured thickness, or other means.

SLAC is situated in an active seismic zone. All hardware exceeding a weight of 300 Lbs. and / or mounted greater than 4 feet above the floor will be reviewed by a SLAC “citizen safety committee” for seismic loading resistance. Applicable loads and structural behavior will be evaluated for compliance to the 2007 version of the California building code and SLAC publication SLAC-I-720-0A24E-002: “Specification for Seismic Design of Buildings, Structures, Equipment, and Systems at the Stanford Linear Accelerator”.

9. Interaction Point Translation Requirements:

The interaction point translation element’s purpose is to position the sample goniometer center of rotation at the intersection of the x-ray beam and the optical pump laser.

This positioning defines the absolute location of the active interaction point.

The sample goniometer rotation center will, by definition, be located within either of two zones as defined in section 5.4, figure 2.

It is desirable to have total X travel range beyond the explicitly defined 604 mm to allow for base mounting alignment tolerances.

Fine X adjustment is required at both nominal interaction point locations.

The lower mating surface of the interaction translation point element shall be located 1182 mm, +/-0.5 mm, below the nominal goniometer rotation center (IE: 218 mm, +/-0.5mm, above the goniometer foundation). This dimension is based on, and includes, the asymmetric “Y” range specification.

Interaction Point Translation Specification

Direction	Range (mm)	Accuracy (micron)	Repeatability (micron)	Resolution (micron)	Stability (micron / hour)
X coarse	604 min	1000 (+/-500)	<10 (+/-5)	<10 (+/-5)	N/A
X fine (Note 1)	4.0 (+/-2.0)	5.0 (+/-2.5)	1.0 (+/-0.5)	<1.0 (+/-0.5)	<1.0
Y (Note 2)	32 min (+2.0 / -30.0)	5.0 (+/-2.5)	1.0 (+/-0.5)	<1.0 (+/-0.5)	<1.0

Note 1: “X fine” values are applied two times, singularly centered at each nominal interaction point

Note 2: “Y” range tolerance applied asymmetrically to accommodate active interaction point zones (figure 2).

All translations shall be motor driven and encoded per section 15. Cable management shall be per section 16.

The lower surface of the interaction point translation element shall be mateable to the upper surface of the mounting base element (section 8), as specified in section 7.4.

The upper surface of the interaction point translation element shall be mateable to the lower surface of the common rotations element (section 10) as specified in section 7.4.

Interaction point translation nominal acceptable configuration geometry is defined in SLAC document number SC-391-320-03.

10.Goniometer Common Rotations Requirement:

The common rotations element is the primary element of the sample translation goniometer. It establishes and defines the rotations of the sample when the goniometer is configured as a “tilt platform”. The common rotations element supports the kappa element when so configured. The accuracy of the rotation axis intersections establishes the lower limit achievable for the mechanical sphere of confusion. When the sample goniometer is in the kappa configuration the common rotations vertical axis may be used to establish incremental rotations.

The common rotations element shall have the center of rotation located 460.0 mm, +/-1.0 mm above the upper mating surface. (IE: upper mating surface at Y = -460 mm +/-1.0 mm)

Goniometer Common Rotations Specification

Direction	Symbol	Range (degree)	Accuracy (arc-sec)	Repeatability (arc-sec)	Resolution (arc-sec)	Stability (arc-sec / hour)
Roll	C	10 (+/-5)	30 (+/-15)	6 (+/-3)	<3 (+/-3)	<6
Pitch	w	10 (+/-5)	30 (+/-15)	6 (+/-3)	<3 (+/-3)	<6
Yaw	m	360 (continuous)	30 (+/-15)	6 (+/-3)	<3 (+/-3)	<6

All rotation axis shall be motor driven and encoded per section 15. Cable management shall be per section 16.

The lower surface of the common rotations element shall be mateable to the upper surface of the interaction point translation element (section 9), as specified in section 7.4.

The upper surface of the common rotations element shall be mateable to the lower surfaces of the sample translation and kappa goniometer elements (sections 11 and 12), as specified in section 7.4.

Goniometer common rotations nominal acceptable configuration geometry is defined in SLAC document number SC-391-320-04.

11. Sample Translation Requirements:

The sample translation element establishes the platform for mounting of experimental samples and special sample environments. It also serves as the mounting platform for goniometer and detector mover alignment fixtures (section 14).

The sample translation element will typically be mounted atop the common rotations assembly.

The sample translation element shall provide motion in the X, Y and Z directions for accurate centering of mounted components to the goniometer rotation center.

Sample Translation Specification

Direction	range (mm)	accuracy (micron)	repeatability (micron)	resolution (micron)	Stability (micron / hour)
X, Z	50 min	5.0 (+/2.5)	1.0 (+/-0.5)	<1.0 (+/-0.5)	<1.0
Y	20 min	5.0 (+/-2.5)	1.0 (+/-0.5)	<1.0 (+/-0.5)	<1.0

All translations shall be motor driven and encoded per section 15. Cable management shall be per section 16.

The sample translation element upper mounting surface shall:

- 1) Have transverse (X,Z) dimension of 0.39 meter on a side minimum (0.15 M²).
- 2) Have the upper mounting surface 200 millimeter, +/-0.5 millimeter, below the goniometer rotation center (IE: Y = -200 mm) when “Y” translation range is at its median value.

The lower surface of the sample translation element shall be mateable to the upper surface of the common rotations element (section 10), as specified in section 7.4.

The lower surface of the sample translation element shall have identical mating features as the kappa goniometer element mounting interface (section 12).

Sample translation element nominal acceptable configuration geometry is defined in SLAC document number SC-391-320-05.

12.Kappa Goniometer Requirements:

The kappa goniometer element establishes and defines rotations of the sample distinct from those provided by the common rotations element. The accuracy of the kappa rotation axis intersections establishes the achievable lower limit for the mechanical sphere of confusion when so configured.

The kappa goniometer element shall:

- 1) Have “eta” axis nominally oriented in the diffractometer coordinate system X-Z plane.
- 2) Have “kappa” axis oriented at 50 to 60 degrees (54.5 degree preferred) with respect to the eta axis.
- 3) Have “phi” axis parallel to “eta” axis when “kappa” value nominally zero.
- 5) Have lower mating surface 460 mm, +/-0.5 mm below rotation center (IE: Y = - 460 mm).
- 6) Have lower mounting surface parallel, +/-0.2 degrees, with respect to “eta” axis.
- 7) Provide 70 millimeter minimum radial clearance, rotation center to “phi” rotation mounting surface.

Kappa Rotation Specification

Rotation Direction	Symbol	range (degree)	accuracy (arc-sec)	repeatability (arc-sec)	resolution (arc-sec)	Stability (arc-sec / hour)
Eta	h	360 deg (continuous)	30 (+/-15)	6.0 (+/-3.0)	<3 (+/-1.5)	<6.0
Kappa	k	360 deg (continuous)	2.0 (+/-1.0)	1.0 (+/-0.5)	<1 (+/-0.5)	<6.0
Phi	φ	360 deg (continuous)	2.0 (+/-1.0)	1.0 (+/-0.5)	<1 (+/-0.5)	<6.0

All rotation axis shall be motor driven and encoded per section 15. **Open loop control (IE: “counting steps”)** per section 15.2 is acceptable. Cable management shall be per section 16.

Fine adjustment of the kappa element rotation axis orientation, with respect to the hutch master coordinate system, shall be accomplished using the common rotation element's pitch and roll translations.

The lower surface of the kappa goniometer element shall be mateable to the upper surface of the common rotations element (section 10), as specified in section 7.4.

The kappa element lower mounting interface shall be identical to the sample translation element mounting interface (section 11).

Kappa goniometer element nominal acceptable configuration geometry is defined in SLAC document number SC-391-320-06.

13. Sample Mount Requirements:

13.1. Tilt Platform Sample Mount:

All sample mount hardware for the tilt platform configuration shall:

- 1) Have lower interface configuration identical to that employed to mate the sample translation element (section 11) to the common rotations element (section 10).
- 2) Have 200 mm dimension from lower mount interface to goniometer rotation center.
- 3) All mounts, including special environment (IE: vacuum, cryostat, cyrostream) shall use identical lower interface configurations.

Additionally a specialized rotation element, required for some tilt platform sample mounting, shall:

- A) Provide continuous rotation in the X-Z plane (IE: axis parallel to the horizontal plane, normal to the "Y" plane)
- B) Have 200 mm dimension from lower mount interface to rotation center.
- C) Rotation shall be motor driven per section 15.1.
- D) Open loop control shall be acceptable per section 15.2.
- E) Have cable management per section 16.
- F) Provide for attachment of kappa sample mount per section 13.2.

Specific sample mounting methods and hardware details will be confirmed on an experiment by experiment basis.

13.2. Kappa Goniometer Sample Mount:

Attachment of samples to the kappa goniometer configuration shall be accomplished via a translation / rotation stage assembly. The sample mount positioning stage shall accurately locate the sample feature at the rotation center of the kappa goniometer.

The stage assembly will have a minimum of five degrees of freedom ("sample X", "sample Y", "sample Z", "sample tip" and "sample tilt").

Kappa Sample Mount Translation Specification

Direction	range	accuracy	repeatability	resolution	Stability
“sample X” “sample Y”	5 mm, min	20.0 micron (+/-10.0)	5.0 micron (+/-2.5)	<2.0 micron	<1.0 (micron / hour)
“sample Z”	10 mm, min	20.0 micron (+/-10.0)	5.0 micron (+/-2.5)	<2.0 micron	<1.0 (micron / hour)
“sample Tip” “sample Tilt”	3 degree, min	Not Applicable	Not Applicable	Not Applicable	<0.6 (micron / hour)

All translation axis (sample “X”, “Y” & “Z”) shall be motor driven and encoded. Motor and encoder shall be per section 15 as space permits. **Open loop control (IE: “counting steps”) per section 15.2 is acceptable.** Cable management shall be per section 16 as space permits.

All rotation axis (sample “Tip”, “Tilt”) shall be manually control via finger knob or other equivalent mechanism.

The sample mount positioning stage shall mount to the kappa “phi” rotation axis element.

In addition to sample support, the stage assembly shall serve to control alignment indicators to accurately position the kappa goniometer rotation center at the intersection of the x-ray beam and optical pump laser, thereby defining the location of the active interaction point.

14.Alignment Fixture Interface:

Due to the nature of the sample goniometer, the fabrication accuracy of alignment fixtures is not critical. The diffractometer alignment procedures will address, via the numerous translation degrees of freedom, any inaccuracies inherent in the alignment hardware.

14.1. Tilt Platform Alignment Fixtures:

All fixtures intended for mounting on the sample translation element (section 11) shall have a mating interface configuration identical to that used for sample mounts (section 13.1). The sample translation element shall provide the positioning of the alignment fiducials with respect to the rotation center. The nominal distance from mating interface to alignment fiducials shall be 200 mm, +/-0.5mm.

14.2. Kappa Goniometer Alignment Fixtures:

Hardware intended for alignment of the kappa goniometer rotation center shall mount directly to the kappa sample mount assembly (section 13.2).

Sample mount assembly translations shall provide positioning of alignment fixture fiducials to the rotation center when so configured.

15. Motion Control Requirement:

15.1. Motor Specifications and Requirements:

Motors shall be Intelligent Motion Systems, Inc. MDrive™ motion control version (MDI3CRL-XXX) “smart motors” using MDrive Plus™ and Expanded PLUS2™ Control.

Sample Goniometer Motor Count

Element	Axis	Motor Qty	ESD Ref.	Comments
IP Translation	beamline "X" & "Y"	2	sec. 9	
Common Rotations	Roll, Pitch, Yaw	3	sec. 10	
Sample Trans	X, Y, Z	3	sec. 11	Not req'd with kappa config
Kappa	Eta, Kappa, Phi	3	sec. 12	Not req'd in sample trans Config
Tilt Sample Mount	sample pitch	1	sec 13.1	Only req'd with special rotation element
Kappa Sample mount	Sample X,Y,Z,	3	sec 13.2	May also be used with sample trans special rotation element (section 13.1)

Sample goniometer motor count is:

- i) Gross total motor quantity is 15.
- ii) Net total motor quantity is 12 maximum.

Sample translation and kappa elements motors will not be installed simultaneously.

15.2. Encoder Specifications and Requirements:

Translations and rotation axis requiring external encoding shall use hardware compatible with the requirements specified for closed loop-external connection for the Intelligent Motion Systems, Inc. MDrive™ motion control version (MDI3CRL-XXX) “smart motors” using MDrive Plus™ and Expanded PLUS2™ Control.

Translations and rotation axis not compatible with external encoding shall employ closed loop internal encoding specified for the Intelligent Motion Systems, Inc. MDrive™ motion control version (MDI3CRL-XXX) “smart motors” using MDrive Plus™ and Expanded PLUS2™ Control or open loop control.

15.3. Limit Switches:

All translation and rotation elements shall be provided with adjustable limit switches. Adjustability shall be provided such that the limit switch can be positioned to change state at the point of contact with the hard stop (section 7.6)

16. Cable Management:

All cabling shall be located, configured and labeled to provide rapid and intuitive reconfiguration of the sample goniometer.

All power and data cabling shall be routed and strain relieved in a manner such that:

- 1) All translation directions and rotation axis can achieve full range capability, plus 10% of full range, without load on cable, connector or diffractometer hardware.
- 2) Rotation axis with a range specification of “360 degree continuous” shall be capable of plus/minus >180 degree of rotation, from nominal “zero” without load on cable, connector or diffractometer hardware.

An industry standard approved flexible cable carrier shall be mounted at the “-Z” (IE: up beam side) of the sample goniometer between the mounting base element (section 8) and the interaction point translation element (section 9).

The flexible cable carrier shall fit within a stay clear volume located at:

- a) Y= -800mm to -1173 mm
- b) X length of 1244 mm (centered on nominal IPs 1 & 2)
- c) Z = -350mm to -500mm

Reference SLAC document no. SA-391-320-14 for cable carrier nominal hardware configuration and stay clear volume.

A DIN rail interface shall be located on the mounting base element (section 8) within 300 mm of the end of the flexible cable carrier.

A DIN block shall be provided for each connector of each motor. (IE: one to one cable mapping).

The nominal mounting location for the DIN rail is shown on SLAC document no. ID-391-320-07.

17. Power and Data Cable Requirements / Interface:

17.1. Power Cabling Requirement / Interface:

Power cable gauge size shall be the maximum size applicable to the given motor frame. Power cabling shall be of sufficient length to terminate at DIN block, located per section 16.

All motors associated with interaction point translation (section 9), common rotations (section 10), sample translation (section 11) and kappa goniometer (section 12) shall be connected with a individual “home run” cable to the power supply (via DIN block interface per section 16).

Motors associated with sample mounts (section 13) may be “daisy chain” wired if space and range requirements demand.

The sample translation and kappa goniometer elements will not be installed simultaneously. Motor power cabling may be shared between these elements. If cable is shared between these elements said cable must be clearly identified to ensure accurate and rapid reconfiguration of goniometer elements.

17.2. Control Cabling Requirement / Interface:

Control cabling shall be consistent with the requirements and specifications of Intelligent Motion Systems, Inc. MDrive™ motion control version (MDI3CRL-XXX) “smart motors” using MDrive Plus™ and Expanded PLUS2™ Control.

Motor controller to serial port server shall use RS-422/485 protocol. Communications port connector at motor shall be 10-pin friction lock wire crimp (style RL)

All control communications cabling shall be of sufficient length to terminate at DIN block, located per section 16.

18.X-ray Stop Stay Clear Requirements:

Hardware will be required to protect elements down beam of the sample goniometer from the intense x-ray beam. The beam stop will need to be positioned as close to the sample as possible to maximize its effectiveness.

A stay clear volume will be defined to insure interface clearance and compatibility between sample goniometer hardware and the beam stop.

The x-ray stop stay clear volume will:

- 1) Have elevation extents of $Y = -200$ mm to $Y = -1073$ mm.
- 2) Have X length of 752 mm (centered on nominal IPs 1 & 2).
- 3) Extend from $Z = +286$ mm to $Z = +435$ mm.

Reference SLAC document SA-391-320-10 for x-ray stop nominal hardware configuration and stay clear volume.

19.Lifting Features:

All components with a mass greater than 15 Kg (~33 Lb weight) shall have clearly defined lifting features and instructions.

20.Environmental Safety and Health Requirements:

All hardware will be subject to SLAC review and approval for compliance to SLAC ES&H standards. Reviews will be conducted in accordance with SLAC document number AP-391-000-59: “Engineering Review Guidelines”. SLAC reserves to right to employ an internal (SLAC direct), external independent, or mixed source review panel.

Particular review attention will be devoted to:

- Personnel access restriction methodology
- Emergency stop methodology / mechanisms
- Power failure provision – fault modes
- Electrical subsystem Lock-Out / Tag-Out:

As previously stated, all hardware exceeding a weight of 300 Lbs. and / or mounted greater than 4 feet above the floor will be reviewed by a SLAC “citizen safety committee” for seismic loading resistance.

All electrical hardware and connections will be reviewed for compliance to local electrical code(s).

21.Supplemental System Requirements:

Requirements, including but not restricted to the following topics, will be addressed in detail in subsequent procurement specifications and contracts.

- i. Inspection, testing and acceptance
- ii. Installation support services
- iii. Training support services
- iv. Maintenance procedures, schedules and assistance
- v. Repair and overhaul services