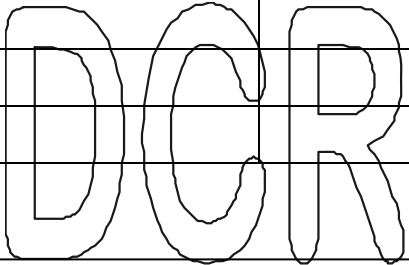


<b>Engineering specification Document (ESD)</b>	<b>Doc. No.</b> SP-391-000-70 R0	<b>LUSI SUB-SYSTEM</b> <b>CXI instrument</b>
<b>Engineering Specifications for the CXI Detector Stage</b>		
Prepared by: Jean-Charles Castagna Design Engineer	_____ Signature	_____ Date
Co-authored by: Paul Montanez CXI Lead Engineer	_____ Signature	_____ Date
Reviewed by: Sébastien Boutet CXI Instrument Scientist	_____ Signature	_____ Date
Approved: Darren Marsh Quality Assurance Manager	_____ Signature	_____ Date
Approved: Tom Fornek LUSI Project Manager	_____ Signature	_____ Date

Revision	Date	Description of Changes	Approved
R0	13FEB09	Initial release	

## Table of Contents

Table of Contents .....	2
1. Overview.....	2
2. Applicable documents.....	3
3. General Requirements .....	3
3.1. Location.....	3
3.2. Environment.....	3
3.3. Maintenance, Accessibility and Operations .....	3
3.4. Lifetime.....	4
4. Performance Requirements.....	4
5. Cyclic Requirements.....	4
6. Mechanical Interfaces.....	5
7. Materials .....	5
8. Size Requirement .....	5
9. Kinematics/Supports .....	5
10. Alignment/Fiducialization .....	6
11. Positioning Requirements .....	6
12. Detector chamber assembly positioning.....	6
13. Detector Z stage axis positioning.....	8
14. Cantilevered Detector Mount.....	11
15. Thermal Issues .....	11
16. Cooling requirements.....	11
17. Vacuum Requirements.....	11
18. Alignment laser intensity monitor.....	12
19. Lifting Features .....	12
20. Electrical Requirements.....	13
21. Feedthroughs.....	13
22. Controls Requirements.....	13
23. Environmental Safety and Health Requirements .....	13
23.1. Earthquake.....	14
23.2. Radiation Physics .....	14
23.3. Pressure Vessel/Vacuum Vessel .....	14

### 1. Overview

The 2D X-ray Detector used by the CXI instrument is described in document LCLS PRD # 1.6-002, *Physics Requirements for the 2-D X-Ray Detector*. The detector is required to be accurately placed so that the incident X-ray beam passes through the hole in the middle of the detector at various distances from the sample. The detector will be mounted in vacuum. The detector stage comprises the vacuum enclosure in which the detector is placed, the supports and motions of this vacuum enclosure and the in-vacuum mount and motion stages that hold the detector. This document describes the technical specifications of the detector stage system.

The coordinate system is defined in Mechanical Design Standards Supplement DS-391-000-36.

## 2. Applicable documents

PRD# SP-391-000-19	Physics Requirements for the CXI Instrument
PRD# SP-391-000-20	Physics Requirements for the CXI 0.1 micron Sample Chamber
PRD# SP-391-000-28	Physics Requirements for the CXI Detector Stage
PRD# SP-391-001-41	Physics Requirements for the CXI 1 micron Sample Chamber
PRD# SP-391-001-42	Physics Requirements for the CXI 1 micron Precision Instrument Stand
PRD# SP-391-000-63	Physics Requirements for the CXI 0.1 micron Precision Instrument Stand
LCLS PRD # 1.6-002	Physics Requirements for the 2-D X-ray Detector
LCLS ICD # 1.1-529	Interface Between the 2D-PAD and CXI Instrument
ESD# SP-391-000-67	Engineering Specifications for the CXI 0.1 micron Sample Chamber
ESD# SP-391-000-69	Engineering Specifications for the CXI 0.1 micron Precision Instrument stand
ESD# SP-391-001-43	Engineering Specifications for the CXI 1 micron Sample Chamber
ESD# SP-391-001-44	Engineering Specifications for the CXI 1 micron Precision Instrument Stand

## 3. General Requirements

### 3.1. Location

The CXI Detector Stage shall be located inside the CXI hutch (hutch 5) in the far experimental hall.

### 3.2. Environment

The humidity and temperature are controlled in the FEH hutches, therefore no component specific temperature stabilizing system shall be provided for the instrument, unless the expected temperature stability is determined to be insufficient to meet the stability requirements.

The temperature and relative humidity in the FEH Hutch 5 will be maintained at 72°F ±1°F (22.2°C ±0.5°C) and 45% ±10%, respectively.

### 3.3. Maintenance, Accessibility and Operations

The Detector Stage will need occasionally to change its mounting location in order to appropriately select a sample to detector distance for a given experiment. There shall be lifting fixtures on the Detector Stage to allow it to be hooked up to the Hutch crane and

moved to various locations on the Precision Instrument Stands (ESD# SP-391-001-44 and ESD# SP-391-000-69). Allowances shall be made to ensure that there is adequate clearance between the Detector Stage and the adjacent beamline serving hutch 6.

### **3.4. Lifetime**

The expected service life of the device is 10 years.

## **4. Performance Requirements**

**4.1.** It shall be possible to set the detector distance from the interaction region to values between 50 and 2600 mm.

**4.2.** It shall be possible to continuously and remotely vary the detector distance from the interaction region over a range of at least 600 mm.

**4.3.** It shall be a design goal to make it possible to mount the detector stage downstream and upstream of the 1 micron Sample Chamber. The Detector Stage shall not be mounted upstream of the 0.1 micron Sample Chamber under any circumstances.

**4.4.** A retractable visible light photodiode shall be included behind the X-ray 2D detector to align the detector hole with the CXI Reference Laser beam (PRD SP-391-000-21). This center of the photodiode shall be positioned to within 0.5 mm from the laser beam center. This can be achieved manually.

**4.5.** The photodiode shall be capable of measuring the intensity of the continuous laser light at a rate of 5 Hz.

**4.6.** A retractable screen shall be included behind the X-ray 2D detector to align the detector hole with the CXI Reference Laser beam (PRD SP-391-000-21). This screen shall allow visual inspection of the reference laser profile after it passes through the X-ray 2D detector. This visual inspection shall be performed with the x-ray beam turned off and the observer shall be standing inside the hutch. The retractable system may be manual.

## **5. Cyclic Requirements**

**5.1.** The z translation of the Detector Stage is expected to be actuated over its full stroke on average once daily. It is also expected to be actuated over small distances (<10 mm) on average 5 times daily for 10 years, with a peak of 50 times per day.

**5.2.** The x and y translations of the Detector Stage are expected to be actuated over small distances (<10 mm) on average 5 times daily for 10 years, with a peak of 50 times per day.

## 6. Mechanical Interfaces

**6.1.** The upstream flange of the detector stage shall connect to the downstream flange of the CXI Sample Chambers. This flange shall be a 14” non-rotatable CF flange.

**6.2.** The downstream flange of the detector stage shall be as large as the vacuum enclosure itself.

**6.3.** An adapter flange from the downstream flange down to a 6” non-rotatable CF flange shall be used to connect to the CXI beamline on the downstream end of the Detector Stage. An adapter flange is preferred over a 6” welded flange solution for possible future upgrades.

**6.4.** The Detector Stage shall be supported by either of the CXI Precision Instrument Stands and the baseplate of the Detector Stage shall be consistent with the mounting structures of the stands.

**6.5.** The CXI Detector Stage shall be occasionally mounted upstream of the CXI 1 micron Sample Chamber in order to perform time-delay experiments with the beam reflected back with an X-ray mirror. The Detector Stage shall interface with the 1 micron Sample Chamber upstream in the same manner it does downstream by rotating the Detector Stage assembly by 180 degrees. The 1 micron Precision Instrument Stand shall support the Detector Stage in this configuration.

## 7. Materials

**7.1.** 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. The device will be used in a radiation environment. Use of Teflon is specifically prohibited.

**7.2.** All applicable material safety data sheets (MSDS) shall be provided and stored in an accessible location.

## 8. Size Requirement

The detector will be provided to the CXI instrument housed in a 10” diameter cylinder that is 5” deep. This is a maximum envelope which will drive many of the design decisions.

**8.1.** The vacuum enclosure of the detector shall be large enough to enclose the detector, its mount and the Z motion in-vacuum stage. Room will be provided for a carrier for the cables and cooling lines to follow the Z motion of the detector.

**8.2.** The flange of the vacuum spool attached to the sample chamber shall be large enough to allow the detector to protrude into the sample chamber.

## 9. Kinematics/Supports

**9.1.** The detector stage will be hard mounted to the Sample Chamber or the spacer spool and all will have their coarse positions set by the Precision Instrument Stand. The Detector Stage Chamber shall not be positioned independently from the Sample Chamber. The support of the

Detector Stage shall be adjustable so it can accommodate the constrained mounting to the Sample Chamber.

## 10. Alignment/Fiducialization

**10.1.** Since the position and orientation of the Detector Stage vacuum enclosure will be entirely dictated by the Sample Chamber or the spacer spools, there is no need for fiducialization of the Detector Stage.

## 11. Positioning Requirements

The CXI instrument will have 2 Sample Chambers. The first one, the 1 micron Sample Chamber will have to ability to use the beam focused by the 1 micron KB System (PRD SP-391-000-24) as well as the direct beam. The second sample chamber (the 0.1 micron Sample Chamber) will use the beam focused by the 0.1 micron KB System only (PRD SP-391-000-25).

In all cases, the coarse positioning of the Detector Stage shall be achieved by the Instrument Stands (PRD SP-391-000-69 and PRD SP-391-001-43) supporting the Detector Stage. Only fine motions are required to position the 2D X-ray Detector after its main axis has been aligned to the LCLS beam.

**11.1.** The positioning of the vacuum enclosure around the detector shall be independent of the positioning of the detector within the vacuum enclosure.

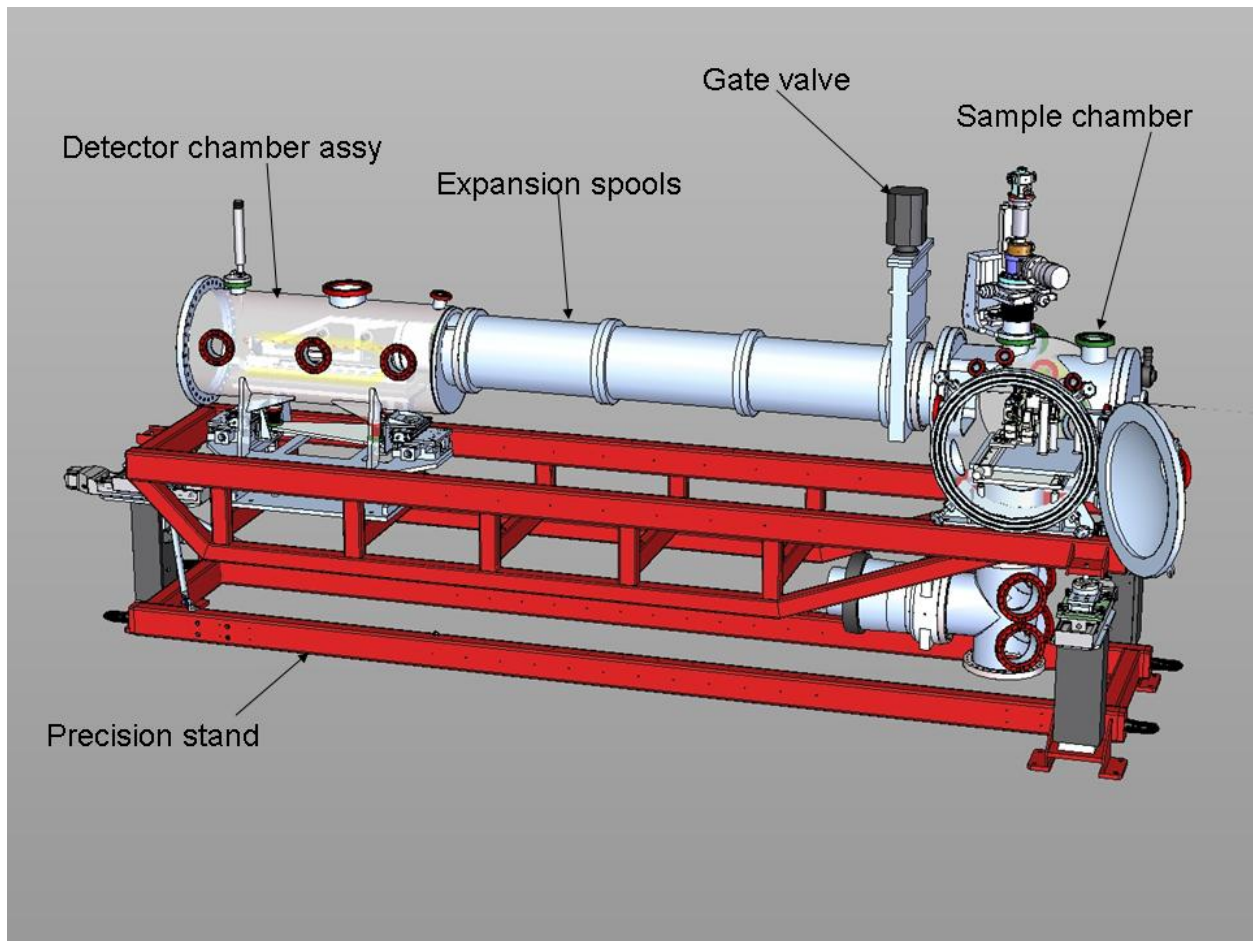
## 12. Detector chamber assembly positioning

**12.1.** The detector chamber assembly shall be attached to the same Precision Stands as the Sample Chambers as described in ESD# SP-391-000-69 and ESD# SP-391-001-44.

**12.2.** The Z axis of the chamber assembly shall be aligned by construction to the Z axis of the sample chamber. Both the sample chamber and the detector chamber assembly shall be positioned thru the precision stand to align their Z axis to the LCLS beam with the focusing optic in use.

**12.3.** The detector chamber assembly will follow all the motions of the sample chamber in x,y,z and yaw as described in ESD# SP-391-000-69 and ESD# SP-391-001-44.

**12.4.** Alternate positions of the detector chamber assembly on the precision stand shall be provided to cover the full range of motion of the detector. These positions will be obtained by manually moving the whole detector chamber assembly on the precision stand and inserting extension spools between the detector stage and the sample chamber, as shown on Figure 1.

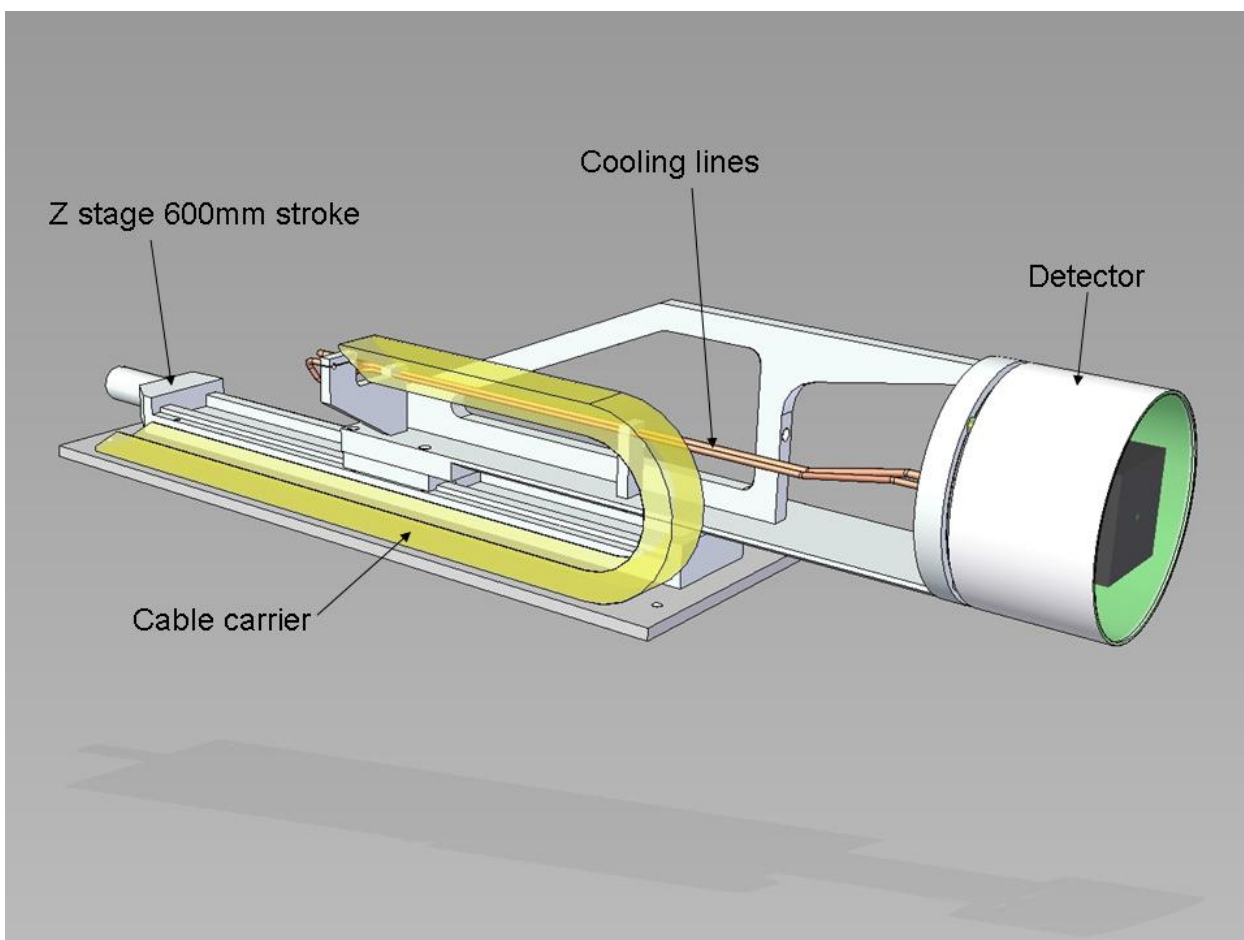


**Figure 1:** Detector Stage assembly shown at the downstream most location on the Precision Instrument Stand.

### 13. Detector Z stage axis positioning

**13.1.** A Z motion stage shall be provided inside the detector chamber to obtain a 600mm continuous range of the detector distance.

The Z detector stage assembly shall come as one unit that can be assembled outside of vacuum and installed in the vacuum chamber assembly. It consists of the Z linear stage, the detector with its support and cooling lines and the cable carrier. See Figure 2.



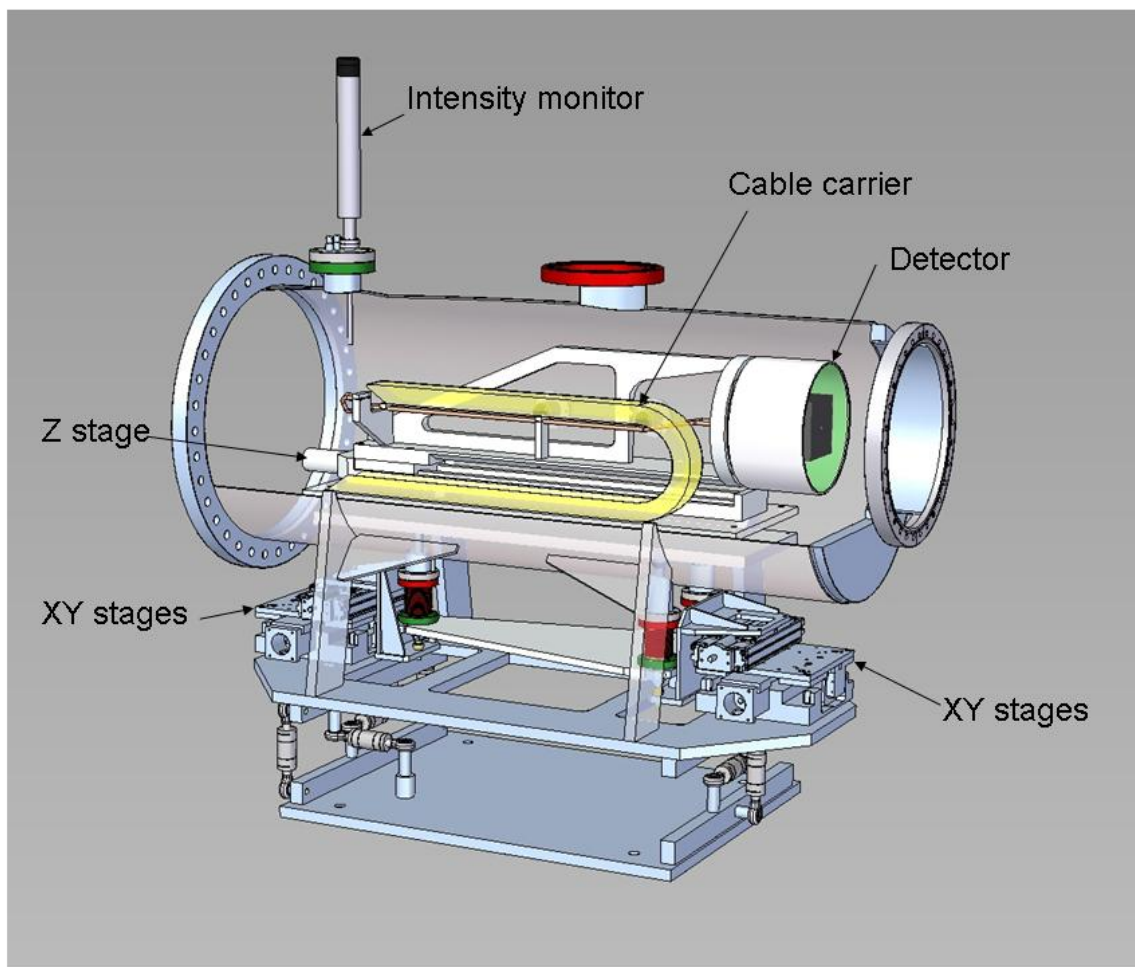
**Figure 2:** In-vacuum assembly of the Detector Stage controlling the Z position of the detector.



**13.2.** 2 pairs of additional XY stages included in the detector chamber assembly shall be provided to align the detector Z motion axis relative to the sample chamber Z axis. The X and Y motion of the detector will be driven by linear stages outside of vacuum. The combination of movements of the XY stages will provide a pitch and yaw alignment of the Z stage of the detector, as shown on Figure 3.

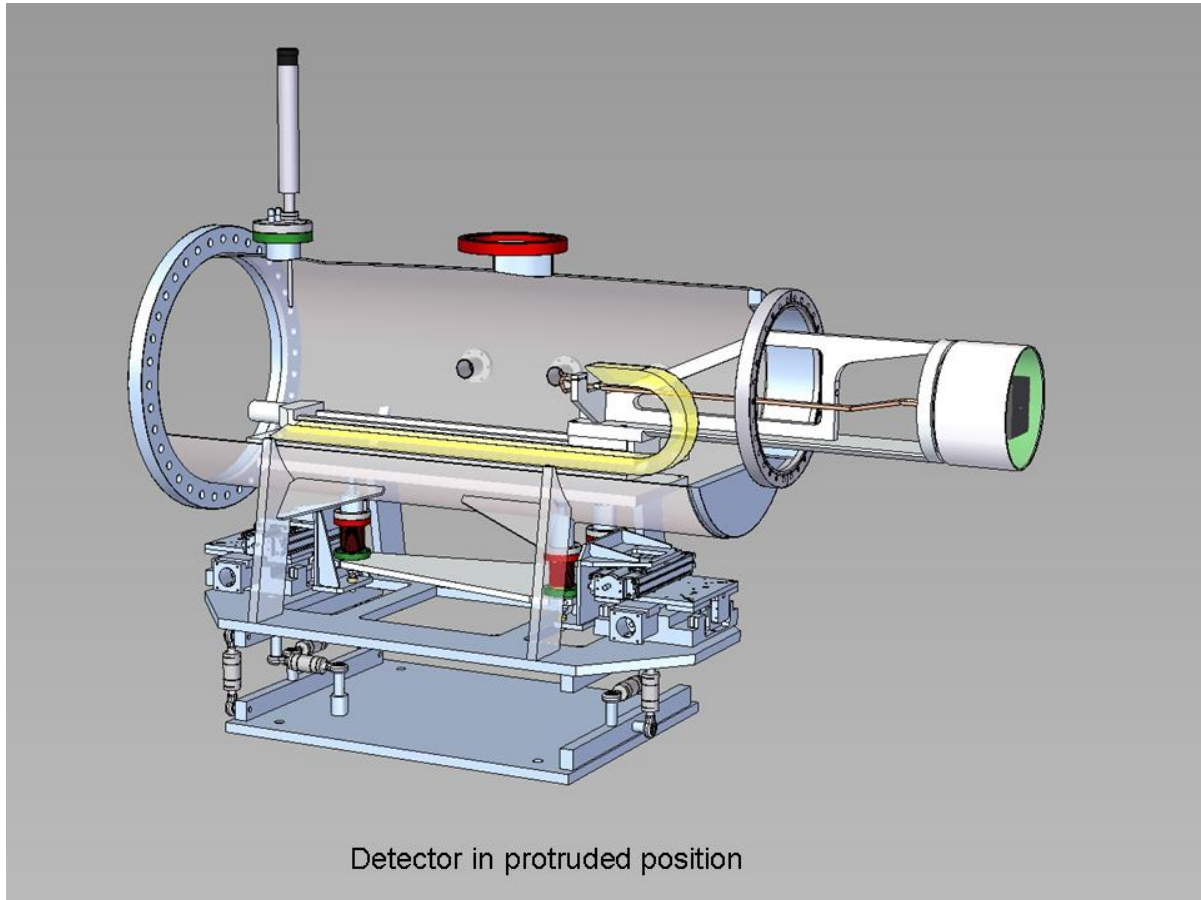
**13.3.** The XY stages shall allow the centering of the LCLS beam to within 10  $\mu\text{m}$  of the center of the hole in the detector, provided the coarse positioning is achieved by the Precision Instrument Stand. They will also provide for any necessary realignment of the Z stage motion axis to the LCLS beam.

**13.4.** The detector stage shall have the motorized motions listed in Table 1.



**Figure 3:** Detector Stage assembly showing the XY stages external to vacuum that allow the detector to be positioned transverse to the LCLS beam and also allow for pitch and yaw adjustment.

**13.5.** The detector shall be able to protrude out of its own chamber into the Sample Chamber and approach the sample to within 50mm, as shown on Figure 4.



**Figure 4:** Detector shown in the fully protruding position.

Motion	Nominal Position	Range	Resolution	Repeatability	Vibrational Stability	Thermal Stability
Out of vacuum y1	0	$-5 \text{ mm} < y < 5 \text{ mm}$	$10 \text{ }\mu\text{m}$	$10 \text{ }\mu\text{m}$	$1 \text{ }\mu\text{m}$	$10 \text{ }\mu\text{m}$
Out of vacuum x1	0	$-5 \text{ mm} < x < 5 \text{ mm}$	$10 \text{ }\mu\text{m}$	$10 \text{ }\mu\text{m}$	$1 \text{ }\mu\text{m}$	$10 \text{ }\mu\text{m}$
Out of vacuum y1	0	$-5 \text{ mm} < y < 5 \text{ mm}$	$10 \text{ }\mu\text{m}$	$10 \text{ }\mu\text{m}$	$1 \text{ }\mu\text{m}$	$10 \text{ }\mu\text{m}$
In-vacuum z	50 mm	$50 < z < 2600 \text{ mm}$ in steps of 600mm	$50 \text{ }\mu\text{m}$	$50 \text{ }\mu\text{m}$	$1 \text{ }\mu\text{m}$	$10 \text{ }\mu\text{m}$
Yaw (x combination)	$0^\circ$	$\pm 20 \text{ mrad}$	$100 \text{ }\mu\text{rad}$	$100 \text{ }\mu\text{rad}$	$10 \text{ }\mu\text{rad}$	$10 \text{ }\mu\text{rad}$
Pitch (Y combination)	$0^\circ$	$\pm 20 \text{ mrad}$	$100 \text{ }\mu\text{rad}$	$100 \text{ }\mu\text{rad}$	$10 \text{ }\mu\text{rad}$	$10 \text{ }\mu\text{rad}$

**Table 1:** Motion requirements for the Detector Stage. The vibrational stability represents stability over a period of a few seconds. The thermal stability represents the stability over a period of a few hours.

## 14. Cantilevered Detector Mount

**14.1.** The bracket used to mount the detector in the cantilevered configuration shown on Figure 4 shall not block the LCLS beam. That is, the LCLS beam shall pass through the hole in the center of the detector and then be allowed to propagate all the way out through the downstream end of the vacuum enclosure of the Detector Stage. A minimum 6" clear aperture shall be provided from the back of the detector all the way to the back flange of the Detector Stage.

## 15. Thermal Issues

**15.1.** The thermal stability listed in Table 1 shall be met given the temperature conditions inside the hutch described in Section 3.

## 16. Cooling requirements

**16.1.** The detector will use water cooling to remove the heat produced by the ASIC and circuit board and cooling lines shall be provided to the back plane of the detector.

**16.2.** These cooling lines shall follow all the motions of the detector and shall be reasonably easily disconnected and reconnected for maintenance.

**16.3.** The cooling lines shall not allow any water leak directly into vacuum. There shall be no in-vacuum connections on the cooling lines. The cooling lines should preferably be enclosed in a flexible bellows tube at atmospheric pressures so that any leak would be contained in this tube.

## 17. Vacuum Requirements

**17.1.** The detector shall be mounted in a  $10^{-7}$  Torr pressure environment or better (design goal  $10^{-9}$ ) and the appropriate vacuum practice for the design, manufacturing, and installation of the system components shall be implemented. The device's vacuum sealing surfaces shall be leak tested.

**17.2.** 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.

**17.3.** 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.

**17.4.** It shall be possible to isolate the vacuum of the Detector Stage from the vacuum of the Sample Chamber with a gate valve, as shown on Figure 1.

**17.5.** The isolation gate valve shall be equipped with a view port to let the CXI Reference Laser pass through when the valve is closed.

**17.6.** A port for visual inspection of the front face of the detector shall be provided to the extent possible. A likely alternate option would be to include a viewport for inspection on one of the spacer spools.

**17.7.** The feedthrough(s) for the detector signals and power shall be located near the downstream end of the vacuum enclosure.

**17.8.** There shall be a feedthrough flange near the downstream end of the chamber for cooling lines.

**17.9.** The 2D X-ray detector housing will have an open back end. The pumping on the vacuum enclosure of the detector stage shall be designed to make any outgassing from the detector flow away from the interaction region. A suitable size turbo pump shall provide the pumping of the detector enclosure.

**17.10.** The turbo pump shall be located on top of the Detector Stage vacuum enclosure at the center point along the Z axis.

**17.11.** The downstream end of the vacuum enclosure of the detector shall allow more vacuum sections to be attached to let the beam propagate further to diagnostics devices.

**17.12.** 6 extra ports will be provided on the chamber for vacuum accessories and control.

**17.13.** The vacuum enclosure of the Detector Stage shall be made as short as possible along the Z axis. The total length can be minimized, for example, by placing the front face of the detector on the same plane as the entrance flange. Contrary to what is shown on Figure 3, there is no need to be able to retract the detector beyond the entrance flange and the overall length of the device can be reduced in this manner.

## **18. Alignment laser intensity monitor**

**18.1.** The detector and its Z motion axis shall be aligned to the FEL beam by using a Reference Laser collinear to the FEL beam. This laser will emit 635 nm light (red light).

**18.2.** A detector diode suitable for 635 nm light shall be installed in the vacuum enclosure, downstream of the detector, to monitor the alignment of the detector with the laser beam. The diode shall measure the red laser intensity passing through the detector aperture and shall allow the user to center the detector on the laser path.

**18.3.** The diode shall be attached to a retractable mount to move it out of the way of the FEL beam after the alignment process is done. This diode assembly is shown on Figure 3.

**18.4.** Another optional configuration is to put the diode outside of vacuum and install a mirror on the feedthrough to reflect the laser to the diode via a view port.

**18.5.** Limit switches shall be used to ascertain that the photodiode is either in the beam path or retracted from the beam path. These limit switches shall be used as input signals for the interlock system to prevent the LCLS beam from impinging on the photodiode.

## **19. Lifting Features**

**19.1.** Clearly defined lifting features and instructions shall be provided to facilitate the assembly/installation and moving the Detector Stage along the Z axis.

## **20. Electrical Requirements**

**20.1.** Acquisition of unique, device specific controllers, when required, will be the responsibility of CXI; all other power supplies and control cables shall be provided by the Controls/Data Acquisition Group.

**20.2.** The interface from the control racks to the Detector Stage (cable trays and routing, connector supports, etc.) shall be determined jointly with the Controls/Data Acquisition Group.

## **21. Feedthroughs**

**21.1.** The following vacuum feedthroughs shall be provided

- Water Supply
- Water Return
- In-vacuum Z stage
- Detector Signal and Power cables

## **22. Controls Requirements**

The controls and data acquisition associated with the detector stage shall be consistent with the requirements outlined in the documents PRD SP-391-000-03, Physics Requirements for the LUSI Controls and Data System and PRD SP-391-000-06, Physics Requirements for the LUSI Data Management. Requirements specific to the detector stage are described below.

**22.1.** Remote operation of all the positioners shall be implemented via the instrument control system.

**22.2.** Password protection shall be implemented for all the positioners of the Detector Stage to protect the detector from damage due to the LCLS beam in the event of an accidental move.

**22.3.** Interlocks shall be implemented to prevent the gate valve separating the sample chamber from the detector vacuum spool from closing while the detector is protruding through the valve.

**22.4.** Interlocks shall be implemented to prevent the LCLS beam from used unless the red laser photodiode is completely removed from the beam path.

**22.5.** Vacuum interlocks shall prevent the valve separating the sample chamber from the detector vacuum spool from opening while the pressure is above  $10^{-5}$  Torr.

**22.6.** The position of every positioner shall be recorded on every pulse for which experimental data is measured and these positions shall be embedded in the experimental metadata.

**22.7.** Limit switches and software interlocks shall be used to prevent the detector from colliding with the walls of the vacuum enclosure or the components inside the sample chamber.

**22.8.** Temperature monitoring will be provided on the detector.

## **23. Environmental Safety and Health Requirements**

### **23.1. Earthquake**

SLAC National Accelerator Laboratory (SLAC) is situated in an active seismic zone. All hardware exceeding a weight of 400 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 (CBC) and SLAC ES&H Division document SLAC-I-720-0A24E-001-R002: “Seismic Design Specification for Buildings, Structures, Equipment, and Systems”.

### **23.2. Radiation Physics**

No supplemental radiation shielding will be required for the Detector Stage since it shall located in a radiation hutch.

### **23.3. Pressure Vessel/Vacuum Vessel**

The Detector Stage shall be designed for use in a High Vacuum environment with the appropriate safety factors.

Pressure relief safe guards will be provided, where appropriate, to ensure compliance with all applicable guidelines/regulations, i.e. 10CFR851.