PHYSICS REQUIREMENT DOCUMENT (PRD)	Doc. No. SP-391-000-28 R0	LUSI SUB-SYSTEM CXI

Physics Requirements for the CXI Detector Stage

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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, the cabling and cooling lines going to the detector and the in-vacuum mount and motion stages that hold the detector. This document describes the requirements of the detector stage system.

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

2. Applicable Documents

PRD# SP-391-000-03	LUSI Controls and Data System
PRD# SP-391-000-06	LUSI Data Management System
PRD# SP-391-000-19	CXI Instrument
PRD# SP-391-000-21	CXI Reference Laser System
PRD# SP-391-000-24	CXI 0.1 micron KB System
PRD# SP-391-000-25	CXI 1 micron KB System
PRD# SP-391-000-30	CXI Ion TOF
PRD# SP-391-000-63	CXI Precision Instrument Stand
LCLS PRD # 1.6-002	2-D X-Ray Detector

3. Performance Requirements

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

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

3.3. It shall be a design goal to make it possible to mount the detector stage downstream and upstream of the sample chamber. The 0.1 micron KB system (PRD SP-391-000-24) shall be

removed to allow the detector stage to be mounted in the upstream position, if the 0.1 micron KB system is located in a chamber separate from the sample chamber. If the engineering solution is to have the 0.1 micron KB system located inside a larger sample chamber, then this requirement no longer applies.

3.4. A retractable visible light photodiode shall be included behind the X-ray 2D detector to align the detector hole on 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.

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

3.6. A retractable screen shall be included behind the X-ray 2D detector to align the detector hole on 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.

4. 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.

4.1. The vacuum enclosure of the detector shall be large enough to enclose the detector, its mount, the in-vacuum cooling lines, the in-vacuum cables and the in-vacuum stages used to move it.

4.2. 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.

5. Positioning Requirements

Two focusing optics will be used for the CXI instrument and they will each have a different focal spot location in the xy interaction plane. Furthermore, the unfocused beam will also be located at a third point in the x-y plane. The KB1 and KB0.1 systems (PRD SP-391-000-24, *Physics Requirements for the CXI 1 micron KB System* and PRD SP-391-000-25, *Physics Requirements for the CXI 0.1 micron KB System*) will deflect the beam in the horizontal plane by 6.8 to 12 mrad. This exact angle is still to be determined. While the deflection angle will be the same for both KB systems, the upstream location of the KB1 system causes a large displacement in the x direction at the detector location. The following requirements are designed to account for these beam displacements to be able to align the detector on any of the 3 beam directions. Some of these requirements can be accommodated by the CXI Precision Instrument Stand (PRD SP-391-000-69) on which the detector stage shall be mounted.

5.1. The CXI Precision Instrument Stand (PRD SP-391-000-63) shall be used to support the CXI Detector Stage.

5.2. The rough alignment of the pitch and yaw angle of the detector stage to the LCLS beam direction which depend on the focusing optics used shall be accomplished using the CXI Precision Instrument Stand (PRD SP-391-000-69).

5.3. The detector stage shall translate in the x and y directions to allow centering of the LCLS beam to within 50 μm of the center of the hole in the detector for any of the focusing optics (KB0.1, KB1 and unfocused beam).

5.4. The detector stage shall move the detector in the z direction within the range described in requirements 3.1 and 3.2 with a repeatability of 50 μm.

5.5. The detector stage shall allow fine alignment of the pitch and yaw angle of the z stage to the LCLS to within a repeatability of 0.5 mrad.

5.6. The detector stage shall have the motorized motions listed in Table 5-1. The stability requirement listed means over a period of a few days.

5.7. The in-vacuum translation range along the z-axis shall not be required to be continuous. A minimum continuous range shall be at least 600 mm.

5.8. Spacer vacuum spools shall be used to span the space between the sample chamber and the detector stage when the detector stage is not attached directly to the sample chamber.

5.9. The surface normal of the detector sensing area shall be parallel with direction of travel of the z stage to within ±2°.

Motion	Nominal Position	Range	Resolution	Repeatability	Stability
x	0	-5 mm < x < 5 mm	10 μm	10 μm	1 μm
y	0	-5 mm < y < 5 mm	10 μm	10 μm	1 μm
z	50 mm	50 < z < 2600 mm	50 μm	50 μm	1 μm
Pitch	0 mrad	-20 mrad < z < 20 mrad	100 μrad	100 μrad	10 μrad
Yaw	0 mrad	-20 mrad < z < 20 mrad	100 μrad	100 μrad	10 μrad

Table 5-1: Motion requirements for the detector stage.

6. Vacuum Requirements

6.1. The detector shall be mounted in a 10^{-7} Torr pressure environment or better and the appropriate vacuum practice for the design, manufacturing, and installation of the system components shall be implemented.

6.2. It shall be possible to isolate the vacuum of the detector stage from the vacuum of the sample chamber and the vacuum of everything downstream of the detector stage.

6.3. A port for visual inspection of the detector shall be provided. This port shall allow viewing of the front face of the detector at an angle as close to normal as possible.

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

6.5. There shall be a feedthrough flange near the downstream end of the tube for cooling lines.

6.6. There shall be no water to vacuum joints that could lead to a water leak directly into vacuum.

6.7. 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 outgasing from the detector flow away from the interaction region.

6.8. 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.

7. 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.

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

7.2. 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.

7.3. 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.

7.4. Vacuum interlocks shall prevent the valves upstream and downstream of the detector stage from opening while the pressure is above 10^{-5} Torr.

7.5. 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.

7.6. Limit (software or hardware) shall be used to prevent the detector from colliding with the walls of the vacuum enclosure and the components inside the sample chamber.