

<b>LCLS</b> <b>Physics Requirements Document # 1.6-002</b>	<b>X-ray Endstation Sys-</b> <b>tems</b>	<b>Revision 1</b>
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## Physics Requirements for the 2D X-Ray Detector

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**Brief Summary:**

This document presents the physics requirements for the portion of the LCLS described by WBS sections 1.06.05.02 and 2.06.05.02, the 2D X-Ray Detector



## Change History Log

Rev Number	Revision Date	Sections Affected	Description of Change
0	7/27/2005	All	Initial Version
0	9/28/2005	Document ID number	Changed document ID number from 1.6-013-r0 to 1.6-002-r0
1	3/17/2008	Section 2 and 3	Update specs and add mechanical, DAQ and controls requirements

## 1. Introduction

The LCLS Endstation Systems group will develop several prototype x-ray detectors that will be tested and evaluated during initial LCLS experiments. These detectors will be used for various activities that are directly related to experiments with LCLS x-rays, activities such as experimental system alignment, beam monitoring, and data collection.

The most ambitious of these activities will be the development of an advanced 2-dimensional detector for x-ray scattering experiments. To match the LCLS characteristics, this detector should have a 120 Hz frame-readout rate and a wide dynamic range. To discern weak scattering signals, it must also have a low noise figure, such that single photons can be reliably counted.

Such a detector is not currently available as a commercial item. Its development will require significant R&D. LCLS has initiated a collaboration with Cornell University for the R&D related to this detector, and for production of the detector prototype.

## 2. 2-D X-Ray Detector requirements

The 2D X-ray detector prototype is expected to meet the specifications given in Table 2.1

### 2.1. Detector specifications

Parameter	Requirement	Comments
Energy Range	4-8 keV	4 to 24 keV total operating range
Well-depth/pixel	$10^3$ photons	8 keV photons
Readout frame rate	120 Hz	10 to 120 Hz typical experiment rate
Signal/Noise	>3	For a single 8 keV photon
QE	> 90%	At 8 keV
Pixel size	100-200 $\mu\text{m}$	110 $\mu\text{m}$ for first detector
Detector area	> 500x500 pixels	Final version 758 x 758

- Radiation hardness to 65 MRad (Si) (for  $10^{12}$  8 keV photons per 110  $\mu\text{m}$  pixel), referred to the detector face. A 500  $\mu\text{m}$  thick sensor absorbs 99.92% of the radiation. Therefore the ASIC has to be

radiation hard to about 50 kRad (Si). The total number of photons is calculated for 90 days of running at 120 Hz in 3 years with  $10^3$  photons/pixel/pulse.

- The pixel to pixel variation in sensitivity shall be capable of calibration to 0.5%
- The temperature stability shall meet the calibration specification.
- The Point Spread Function shall be <1% of maximum value in neighboring pixel for x-ray incident at pixel center, and <0.01% for next nearest neighbor pixel.
- The fraction of random dead pixels shall be < 3%

### 3. Data Acquisition & Controls

- The detector shall be interfaced to the LCLS PCD (Photon Controls & Data) systems, see LCLS ICD 1.1-514 and .
- The 2D PAD detector shall be controlled via the LCLS PCD systems, e.g. bias voltage, pixel gain, acquire image, see LCLS ICD 1.1-514.
- The detector shall have a data link with a minimum data throughput of 150 MB/s (for the initial 16 tiles).
- The detector shall be part of the MPS to prevent the LCLS beam in the hutch during e.g. alignment.
- The detector shall be monitored by the LCLS PCD systems, e.g. temperature, currents, voltages.
- The detector shall have shielding against EM pickup, e.g. for large (5kV) pulses from Time-Of-Flight instrument with a closest distance of approach of roughly 50 mm.
- Real time image processing shall be performed by the LCLS PCD systems.
- The detector reading shall be monitored at 5 Hz for so called 'quick look analysis' by the LCLS PCD systems.

### 4. Mechanical interface

- The detector weight shall not exceed 11 kg (25 pounds).
- The detector dimension shall not exceed a diameter of 216 mm (8.5 inch) and a depth of 127 mm (5 inch).

- The detector shall have a hole in the center with a variable diameter of 1 mm up to 10 mm by moving detector sets relative to each other.
- The detector cables (signal, power, etc.) shall be connected to the LCLS PCD systems via vacuum feedthrus.
- A broken detector module (2 x 1) shall be swappable.
- The detector shall be operated and cooled between 10 - 20 °C with sufficient temperature stability to meet the calibration specifications.
- The detector shall be placed in a vacuum of  $10^{-7}$  Torr. All the detector materials (including cables) shall be vacuum compatible with  $10^{-7}$  Torr.
- The detector shall be moved along the beam-direction  $\geq 700$  mm. Therefore, the cables need to be flexible; both electrical cables and cooling leads.
- The detector shall be mounted on motion stages to position the detector remotely without braking the vacuum, see LUSI PRD SP-391-000-28.
- The position stability shall be less than 1/10 of the pixel size or  $\sim 10$   $\mu\text{m}$ .
- The detector shall be partitioned in quadrants (e.g. 2 detectors, 4 ASICs).
- The detector shall have shielding (against visible light, infrared, sample residue) for different detector positions. A Beryllium window shall serve as a shield and has a hole in the middle. This Beryllium window does not hold vacuum but helps pumping on the back side.
- The detector needs protection from the full LCLS beam after repositioning and alignment. Attenuators should prevent the sensitive detector elements to be exposed to the full LCLS beam due to misalignment.
- The detector shall have back protection when the detector is placed in the upstream position.
- The maximum detector temperature shall not exceed 110 degrees C (for baking).
- The detector shall be modular to be able to upgrade to a large detector area a.s.a.p.