LUSI LCLS Ultrafast Science Instruments

PHYSICS REQUIREMENT DOCUMENT (PRD)	Doc. No. SP-391-000-20 R1	LUSI SUB-SYSTEM Coherent X-Ray Imaging

Physics Requirements for the CXI 0.1 micron Sample Chamber

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R0	23JUN08	Initial release	
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1. 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-391-000-26	CXI Particle Injector System
PRD# SP-391-000-28	CXI Detector Stage
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LCLS PRD # 1.6-002	2-D X-Ray Detector
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2. Overview

The samples that will be studied using the CXI instrument will be required to be kept in a high vacuum environment in order to minimize the background noise. Samples that do not require cryogenic cooling will be introduced in the sample chamber in two ways that were previously described in document PRD SP-391-000-19, *Physics Requirements for the CXI Instrument*. These are samples fixed on a support of some kind, so called fixed targets and samples injected into the vacuum chamber using a particle injector.

This document describes the requirements for a vacuum chamber that will be used for both types of samples without cryogenic cooling. This vacuum chamber will be compatible with both the 1 micron KB System (PRD# SP-391-000-25) and the 0.1 micron KB System (PRD# SP-391-000-24).

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

3. Size Requirements

3.1. The chamber shall be sufficiently large to accommodate all 6 experiment configurations described in PRD SP-391-000-19, *Physics Requirements for the CXI Instrument.*.

3.2. The chamber shall be sufficiently large to allow a reentrant 2D X-ray detector at both the upstream and downstream end of the chamber. The 2D X-ray detector and the stage on which it shall be mounted are described in documents LCLS PRD #1.6-002, *Physics Requirements for the 2D X-ray Detecto*r and PRD SP-391-000-28, *Physics Requirements for the CXI Detector Stage* respectively.

3.3. The size of the exit flange of the sample chamber shall allow for future upgrades of the X-ray 2D detector and shall therefore be made a large as possible and as close to the interaction region as possible. The design goal for this exit flange shall be for the opening to span an angle ± 45 degrees from the interaction point in both the x and y directions. At a minimum, this angle shall be ± 30 degrees.

4. Chamber Positioning Requirements

4.1. The sample chamber shall be located inside the CXI hutch, hutch #5 in the Far Experimental Hall.

4.2. A fixed point inside the chamber, the interaction point, shall be located at the focal plane of both focusing optics of the CXI instrument. Each of these focusing optics, namely, the 0.1 micron KB System and the 1 micron KB System, shall have the same focal plane but they each shall have different focal points in the xy plane, as described in the following documents: PRD SP-391-000-24, *Physics Requirements for the CXI 0.1 micron KB System* and PRD SP-391-000-25, *Physics Requirements for the CXI 1 micron KB System.*

4.3. It shall also be possible to position the interaction point of the chamber into the direct, unfocused LCLS beam.

4.4. The sample chamber shall be positioned so that the interaction plane is as close to the upstream wall of the CXI hutch with all the in-hutch upstream optics described in document PRD SP-391-000-19, *Physics Requirements for the CXI Instrument.*

4.5. Requirements 4.2 and 4.4 taken together imply that the position of the chamber shall be determined by the most upstream possible location in the hutch of the 1 micron KB System.

4.6. The interaction region is not required to be at the geometric center of the chamber.

4.7. The sample chamber shall be surveyed into a position where, with all the motion stages located at their nominal positions, the on-beam axis of the chamber is oriented along the nominal unfocused LCLS beam to within $\pm 1°$ in pitch, roll and yaw.

5. Chamber Motion Requirements

5.1. The requirements for the motions of the 0.1 micron Sample Chamber are described in PRD SP-391-000-63, *Physics Requirements for the CXI 0.1micron Precision Instrument Stand.*

6. Vacuum Requirements

6.1. The sample chamber shall operate with a 10^{-7} Torr pressure environment or better under all operating conditions and the appropriate vacuum practice for the design, manufacturing, and installation of the system components shall be implemented.

6.2. The vacuum pump(s) attached to the chamber shall be located away from the interaction region in order not to restrict access to the inside of the chamber.

6.3. It shall be possible to vent the sample chamber to air while maintaining high vacuum upstream and downstream of the chamber.

6.4. It shall be possible to leave the chamber turbopump(s) turned on while the chamber is vented to air.

6.5. It shall be possible to use the reference laser described in document PRD SP-391-000-21 whether the chamber is at atmospheric pressure or under vacuum.

6.6. Differential pumping may be required between the sample chamber and the CXI 0.1 micron KB System to protect the lower pressure of the KB0.1 system.

7. Configurations

7.1. The sample chamber design shall be able to accommodate all 6 experiment configurations described in PRD SP-391-000-19.

7.2. The chamber shall be designed so that parts can be used with all configurations as much as possible, with as little need for manual intervention as possible when changing between configurations.

7.3. It shall be possible to go from the fixed target to the particle injection configuration without breaking the vacuum.

7.4. The components listed in Table 7-1 shall be included in the forward scattering with fixed targets configuration, with or without a pump laser.

Component	Function	Necessary Motions
First aperture stage	Clean the X-ray beam halo	x, y
Second aperture stage	Clean the X-ray beam halo	x, y
Third aperture stage	Clean the X-ray beam halo	x, y, z
Sample stage	Position the sample at the interaction point	x, y, z, pitch, yaw
Sample viewer	View the sample and view the third aperture	x, y, pitch, yaw
Pump laser ports	Introduce laser beam into the chamber and onto the sample	None

Table 7-1: Components necessary in forward scattering fixed target configuration.

7.5. The components listed in Table 7-2 shall be included in the forward scattering with injected particles configuration, with or without a pump laser.

Component	Function	Necessary Motions
First aperture stage	Clean the X-ray beam halo	x, y
Second aperture stage	Clean the X-ray beam halo	x, y
Third aperture stage	Clean the X-ray beam halo	x, y, z
Sample stage	Used as a fourth aperture Used as a dusting wafer	x, y, z, pitch, yaw
Sample viewer	View the fourth and third apertures View the dusting spot	x, y, pitch, yaw
Particle beam aperture	Clean the particle beam halo	x, z
Particle injector	Deliver a beam of particles to the interaction region	x, y, z
Dusting wafer	Provides a surface to accumulate particles to view the position of the particle beam	x, y, z, pitch
First charge detector	Detect charged particles above the interaction point	Moves with the particle injector
Second charge detector	Detect charged particles below the interaction point	None
Faraday cup	Measure a current from the particle beam	None
Ion TOF	Detect charged fragments from the exploded particles	None
Particle beam dump	Allows a flight path for the particle beam to propagate to a particle beam dump	None
Desorption-ionization laser ports	Introduce laser beam into the chamber and onto the sample	None
Particle alignment laser ports	Align the particles along a preferred axis	None
Pump laser ports	Introduce laser beam into the chamber and onto the sample	None
Port for electron TOF	Measure the kinetic energy of electrons from the exploded particles	None

Table 7-2: Components necessary in forward scattering with injected particles configuration.

7.6. The components listed in Table 7-3 shall be included in the time-delay scattering with fixed targets configuration.

Component	Function	Necessary Motions
Sample stage	Position the sample at the interaction point	x, y, z, pitch*
Time delay mirror stage	Reflect the beam back onto the sample	x, y, z, pitch, yaw
Sample viewer	View the sample View the time delay mirror	x, y, pitch, yaw
2D X-ray Detector	Mounted upstream of the sample	None

Table 7-3: Components necessary in time delay experiments with fixed targets. *Items labeled with a star are design goals and not strict requirements.

7.7. The components listed in Table 7-4 shall be included in the time-delay scattering with injected particles configuration.

Component	Function	Necessary Motions
Sample stage	Used as an aperture Used as a dusting wafer	x, y, z, pitch*
Time delay mirror stage	Reflect the beam back onto the sample	x, y, z, pitch, yaw
Sample viewer	View the final aperture View the time delay mirror	x, y, pitch, yaw
2D X-ray Detector	Mounted upstream of the sample	None
Particle beam aperture	Clean the particle beam halo	x, z
Particle injector	Deliver a beam of particles to the interaction region	x, y, z
Dusting wafer	Provides a surface to accumulate particles to view the position of the particle beam	x, y, z, pitch
First charge detector	Detect single charged particles above the interaction point	Moves with the particle injector
Second charge detector	Detect single charged particles below the interaction point	None
Faraday cup	Measure a current from the particle beam	None
Ion TOF	Detect charged fragments from the exploded particles	None
Desorption-ionization laser ports	Introduce laser beam into the chamber and onto the sample	None
Particle alignment laser ports	Align the particles along a preferred axis	None
Pump laser ports	Introduce laser beam into the chamber and onto the sample	None
Port for electron TOF	Measure the kinetic energy of electrons from the exploded particles	None

Table 7-4: Components necessary in time delay experiments with injected particles. *Items labeled with a star a design goals and not strict requirements.

8. In-vacuum Motion Requirements

8.1. Motorized motions summarized in Table 8-1 shall be provided for components inside the sample chamber. All these motions shall be in 10^{-7} Torr vacuum or better. The stability listed refers to short term (few minutes) with respect to the KB mirrors and not absolute stability in space.

Motion	Nom. Position	Range	Resolution	Repeatability	Stability
First aperture x position	0 mm	-10 mm < x < 10 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
First aperture y position	0 mm	-10 mm < y < 10 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
Second aperture x position	0 mm	-10 mm < x < 10 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
Second aperture y position	0 mm	-10 mm < y < 10 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
Third aperture x position	0 mm	-10 mm < x < 160 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
Third aperture y position	0 mm	-10 mm < y < 10 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
Third aperture z position	-25 mm	-35 mm < z < -15 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
Sample x position	0 mm	-10 mm < x < 160 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
Sample y position	0 mm	-10 mm < y < 10 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
Sample z position	0 mm	-10 mm < z < 10 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
Sample yaw	0 degree	±1˚	5 μrad	5 μrad	1 μrad
Sample pitch	0 degree	±180˚	5 μrad	5 μrad	1 μrad
Particle aperture x position	0 mm	-10 mm < x < 10 mm	10 μm	10 μm	0.1 μm
Particle aperture z position	0 mm	-10 mm < y < 10 mm	10 μm	10 μm	0.1 μm
Time-delay mirror x position	0 mm	-10 mm < x < 10 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
Time-delay mirror y position	0 mm	-10 mm < y < 10 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
Time-delay mirror z position	-10 mm	-20 mm < z < 0 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
Time-delay mirror pitch	0 degree	±1˚	5 μrad	5 μrad	1 μrad
Time-delay mirror yaw	0 degree	±1˚	5 μrad	5 μrad	1 μrad
Sample viewer mirror x position	0 mm	-10 mm < x < 10 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
Sample viewer mirror y position	0 mm	-10 mm < y < 10 mm	≤ 0.1 μm	≤ 0.3 μm	0.01 μm
Sample viewer mirror pitch	0 degree	±1˚	1 mrad	1 mrad	0.1 mrad
Sample viewer mirror yaw	0 degree	±1˚	1 mrad	1 mrad	0.1 mrad

Table 8-1: Motion requirements for the components inside the chamber. (x,y,z)=(0,0,0) is defined as the interaction point.

8.2. No possible collision between two or more motions shall exist, to the extent possible while still satisfying the range of motion requirements, as well as the functionality requirements.

9. Sample Chamber Components

First Aperture Assembly

9.1. The first aperture assembly shall be located as far upstream as possible in the sample chamber.

9.2. The first aperture assembly shall have the motorized motions described in Table 8-1.

9.3. The beam blocking part of the first aperture assembly shall be large enough to cover the entire opening from the sample chamber to the KB0.1 vacuum enclosure to block any stray light travelling down the beamline.

Second Aperture Assembly

9.4. The second aperture assembly shall be located downstream of the first aperture assembly.

9.5. The second aperture assembly shall have the motorized motions described in Table 8-1.

9.6. The second aperture assembly shall have a design identical to the first aperture assembly to the extent possible.

Third Aperture Assembly

9.7. The third aperture assembly shall be located so that the third aperture wafer can be positioned as close as 15 mm from the interaction region.

9.8. The third aperture assembly shall have the motorized motions described in Table 8-1.

9.9. It shall be possible to move the third aperture wafer to 70 mm or more in the z-direction upstream of the interaction point without any collision with other components.

9.10. Requirements 9.7 and 9.9 do not need to be achieved with the same setup. Two different mounts can be used to meet these requirements.

9.11. It shall be possible to mount at least 3 aperture wafers on the third aperture assembly. These multiple wafers shall span the entire travel range in the x-direction described in Table 8-1.

9.12. The third aperture assembly shall serve as the sample assembly for time-delay experiments on fixed targets.

Sample Assembly (Fourth Aperture Assembly)

9.13. The sample assembly shall be located so that the nominal position of the stages places the sample wafer at the interaction plane.

9.14. The sample assembly shall have the motorized motions described in Table 8-1.

9.15. It shall be possible to mount at least 3 wafers (sample or aperture wafers) on the sample assembly. These multiple wafers shall span the entire travel range in the x-direction described in Table 8-1.

9.16. The sample wafers shall have an area perpendicular to the LCLS beam as close to 15 x 20 mm^2 as possible without interference with other devices.

9.17. In particle injection mode, the sample assembly shall be used for dusting experiments, requiring full 360 degree rotation in pitch.

9.18. In particle injection mode, the sample assembly shall be used as a fourth aperture assembly, requiring the fourth aperture wafer to be moved upstream of the interaction plane by up to 10 mm.

9.19. In the particle injection configuration, the sample assembly shall be electrically grounded to control the electric field used to extract ions and electrons into the time-of-flight mass spectrometers.

9.20. In the time-delay configuration, the sample assembly shall be used as the time-delay mirror assembly.

Time-Delay Mirror Assembly

9.21. The time-delay mirror assembly shall have the motorized motions described in Table 8-1.

9.22. The time-delay mirror assembly shall be used to accurately orient and position an X-ray mirror downstream of the interaction region.

9.23. The time-delay mirror assembly shall be used only in the time-delay configuration.

9.24. Due to their similar requirements and non-concurrent use, the time-delay mirror assembly and the sample assembly could consist of a common positioning assembly with a specific holder for each case.

9.25. The distance between the time-delay mirror and the interaction region shall be continuously adjustable in the 0 μm to 20 mm range. The time-delay mirror shall have sufficient range of motion to bring it in contact with the sample at the interaction point. Damage to the sample and the mirror shall be avoided by using vision cameras to determine the position of the mirror and prevent collisions.

Sample Viewer Assembly

9.26. Viewing the sample shall be done along the same axis as the X-ray beam in the forward scattering configuration.

9.27. The sample viewer shall allow an object of 3 μm located at the interaction point to be viewed at the highest magnification setting.

9.28. The sample viewer shall be capable of viewing objects at planes ranging from -40 to +10 mm from the interaction plane on the LCLS beam axis. This means the sample viewer can be used to view the sample downstream of the X-ray focus and can also be used to view the third aperture wafer upstream of the interaction point.

9.29. Changing the plane of observation shall be accomplished remotely via the instrument control system and in less than 5 seconds.

9.30. The field of view of the sample viewer shall be at least 1 mm at low magnification. The resolution can be larger than 3 μm in this situation.

9.31. The alignment and focusing of the sample viewer shall be accomplished remotely via the instrument control system.

9.32. In the time-delay configuration, the sample viewer shall allow the upstream face of the sample to be viewed. It shall also allow the time-delay mirror to be viewed. Both the mirror and the sample shall be visible to the same resolution as in the forward scattering configuration The viewing is not required to be on the beam axis in this configuration. The sample or mirror can be moved to a fixed position for viewing and then moved back for the measurement.

9.33. The sample viewer assembly shall have the motorized motions described in Table 8-1.

9.34. Optics and the camera for the sample viewer can be mounted outside the sample chamber. A suitable mount shall be present to allow proper pointing and positioning of the optics consistent with the sample viewer requirements of Table 8-1.

9.35. Illumination that can be remotely turned on and off shall be provided to view the object of interest with the sample viewer.

2D X-ray Detector and Detector Stage (SP-391-000-28)

The 2D X-ray detector for the CXI instrument will be mounted on a stage located in a separate vacuum enclosure from the sample chamber. The requirements for this detector stage are found in document PRD SP-391-000-28, *Physics Requirements for the CXI Detector Stage*. However, this stage will be reentrant into the sample chamber to bring the detector to within 50 mm of the interaction point on the downstream side. The requirements listed here are the detector requirements that relate to the integration of the detector into the sample chamber.

9.36. The detector stage shall be reentrant to the sample chamber on the downstream side of the chamber.

9.37. The detector stage shall be reentrant to the sample chamber on the upstream side of the chamber when the 0.1 micron KB system is removed (PRD SP-391-000-24).

9.38. The 2D X-ray detector shall have the possibility to be mounted as close as 50 mm from the interaction region in the forward scattering configurations, with both fixed targets and particle injection. This shall be achieved without interference with any of the components listed in Table 7-2.

9.39. The detector shall be mounted in the sample chamber 50 mm upstream of the interaction region in the time-delay configuration with no interference from any of the components listed in Table 7-4.

9.40. Switching between the three detector configurations shall be accomplished manually and can be an operation requiring multiple hours. The three configurations are: reentrant downstream, reentrant upstream and upstream inside the sample chamber.

Particle Injector (PRD SP-391-000-26)

The physics requirements for the particle injector are described in document SP-391-000-26, *Physics Requirements for the CXI Particle Injector System*. The requirements listed here are those affecting the sample chamber design and integration.

9.41. The particle injector shall be oriented in the negative y-direction.

9.42. A 6" flange shall be used directly above the interaction region to mount the particle injector.

9.43. The closest point of approach of the particle injector assembly, including any particle beam diagnostics attached to the exit of the injector such as a charge detector, from the interaction point shall be variable from 30 to 150 mm without any collision possible with any of the devices listed in Table 7-2. Sufficient clearance shall exist within the chamber to allow for these motions.

9.44. It shall also be possible to bring the exit nozzle of the particle injector into the interaction region. This may require the removal of some of the components listed in Table 7-2 in order to avoid collisions.

9.45. The particle injector shall translate over a range of 10 mm in both the x and z directions. Sufficient clearance shall exist within the chamber to allow for these motions.

Dusting Wafer

Dusting consists of producing a visible spot by piling particles up on a greased surface perpendicular to the particle beam. This spot can then be viewed to determine the position of the particle beam.

9.46. The dusting wafer shall have the capability of being positioned perpendicular to the particle beam.

9.47. The dusting wafer shall be viewable in-vacuum using the sample viewer.

9.48. It shall be possible to perform dusting experiments immediately before or after fixed target experiments without breaking the vacuum of the sample chamber.

9.49. The dusting wafer shall have a total range of motion of 20 mm in all three directions.

Particle Beam Aperture Assembly

9.50. A set of apertures ranging in size from 250 μm to 1 mm in steps of 250 μm, and from 1 mm to 3.5 mm in steps of 500 μm shall be provided between the particle injector exit and the interaction region.

9.51. It shall be possible to remove the aperture plate rapidly in the field. Multiple plates that can be replaced rapidly are acceptable and not all aperture sizes are required to fit on a single plate.

9.52. It shall be possible to select the desired aperture size and position it in the path of the particle beam to within the accuracy listed in Table 8-1.

9.53. Changing the size of the aperture on a single plate shall be accomplished multiple times per day and shall therefore be possible in less than 5 seconds. The positioning stages shall move at a reasonably fast speed.

9.54. The particle beam aperture assembly shall have the motorized motions described in Table 8-1.

9.55. The particle beam aperture assembly shall be located far enough above (in the +y-direction) the interaction region so that a ±45 degree angle is unblocked from the interaction point to the detector. This corresponds to a numerical aperture of $\sqrt{2}$.

First Charge Detector

The charge detector is a device capable of measuring the image charge produced on a conductor by a charged particle flying past it. It will be used to determine the transmission of the particle injector and for alignment of the particle beam. Details on the charge detector requirements are found in the particle injector PRD SP-391-000-26, *Physics Requirements for the CXI Particle Injector System.* The requirements listed here pertain to the integration of the charge detectors into the sample chamber.

9.56. The first charge detector and its associated in-vacuum electronics shall be attached directly to the exit of the particle injector.

9.57. The first charge detector and its in-vacuum electronics shall be designed in a way that allows the entire assembly to pass through the 6" flange for the particle injector. This will allow the entire injector and charge detector assembly to be removed without disassembly.

9.58. The signal cable(s) or wire(s) feedthroughs of the first charge detector shall be included in the particle injector assembly so that no wire or cable needs to be disconnected in order to remove the particle injector and the first charge detector assembly.

9.59. If requirement 9.58 cannot be achieved in a reasonable manner, then the signal cable(s) from the in-vacuum electronics of the first charge detector to the electrical feedthrough in the sample chamber shall be easily disconnected when the operator wishes to remove the particle injector from the chamber.

9.60. The first charge detector shall not interfere with the ±45 degree angle from the sample to the detector.

Second Charge Detector

9.61. The second charge detector shall be used only in the particle injection configuration.

9.62. The second charge detector shall be located below the interaction region, in the –y-direction.

9.63. The detection axis of the second charge detector shall be aligned to the axis of the particle injector to within ±1 degree (in pitch and roll).

9.64. The signal cable(s) from the in-vacuum electronics of the second charge detector shall be easily disconnected when the operator wishes to remove the charge detector from the chamber.

9.65. The second charge detector mount shall be designed so that the charge detector is easily removable in less than 5 minutes.

Faraday Cup

9.66. The Faraday cup shall be used only in the particle injection configuration.

9.67. The Faraday cup shall be located below the second charge detector (in the negative y-direction).

9.68. The Faraday cup mount shall be designed so that the Faraday cup is easily removable in less than 5 minutes.

9.69. The signal cable of the Faraday cup shall be easily disconnected.

Particle Beam Dump

9.70. When in the particle injection configuration and the faraday cup is removed, there shall be a clear path for the particle beam all the way to the bottom of the sample chamber.

9.71. There shall be the possibility of introducing a cooled particle dump to catch the particles that were not hit by the LCLS beam near the bottom of the chamber.

Hatch

9.72. The sample chamber shall have a door large enough to allow easy access for modifications of the internal components of the sample chamber in the field.

9.73. The only access to the internal components of the chamber will be through this hatch. This fact shall be considered in the design to ensure that every component can be accessed for installation or modifications. The distance from the door to these components shall be small enough for a user to gain easy access. This could be accomplished with a sliding platform that brings the components close to the door when work is required and slides back into the beam for measurements.

9.74. It shall be possible to open or close this door in less than 1 minute.

Ion Time-Of-Flight Mass Spectrometer (PRD SP-391-000-30)

The physics requirements for the ion TOF are described in document SP-391-000-30, *Physics Requirements for the CXI Ion TOF*. The requirements listed here are those affecting the sample chamber design and integration.

9.75. The ion TOF shall consist to a first approximation of a cylindrical drift tube of inner diameter no larger than 1.6" and outer diameter no larger than 2".

9.76. The ion TOF mechanical components and electrical feedthroughs shall all be attached to a single flange no larger than 8" O.D.

9.77. The long axis of the ion TOF shall be pointed directly at the interaction region to within ±3 degrees.

9.78. There shall be a 1" clear radius around the line of sight between the interaction region and the center of the flange that holds the ion TOF over the entire length of the drift tube. No interference with other components in the chamber shall be allowed.

9.79. The end of the cylinder near the interaction region, where a grid electrode will be located shall have a closest point of approach to the interaction point so that the 1" clear radius does not encroach on the ±45 degree angle between the interaction region and the detector.

9.80. A second electrode shall be located on the opposite side of the interaction region, with the surface normal of the electrode parallel to the long axis of the drift tube. The support for this electrode shall also be attached directly to the drift tube so that the whole assembly is mounted to the same flange. This electrode shall not interfere with any of the components in the chamber, including the ±45 degree detector angle stay-clear zone.

9.81. The port for the ion TOF shall be located so that the TOF assembly can be inserted and removed without interference with other hutch components such as the beamline to Hutch #6.

Desorption-Ionization Laser Ports (SP-391-000-55)

9.82. The port on the sample chamber used to introduce the desorption-ionization laser beam shall have an unimpeded view of the interaction region for all experimental configurations.

9.83. This port shall be in a direction such that the laser beam can propagate through the interaction region and out the other side of the sample chamber.

9.84. A second port on the opposite side of the chamber shall be used to let the laser beam out of the chamber for diagnostics.

Particle Alignment Laser Ports (SP-391-000-27)

9.85. There shall be at least 1 laser port located in the xy-plane to allow the introduction of a particle alignment laser beam into the chamber.

9.86. These laser ports shall have an unimpeded view of the interaction region for all particle injection configurations.

9.87. There shall be a laser port at the bottom of the sample chamber to allow a laser beam to propagate collinear with the particle beam.

9.88. There shall be an unimpeded path to the interaction region from the laser port at the bottom of the chamber for all particle injection configurations, when the faraday cup is removed.

Pump Laser Ports (SP-391-000-27)

9.89. At least 1 pump laser port looking at the upstream face of a sample target shall be provided. The path of the laser beam to the interaction region shall be as collinear to the LCLS beam as possible without interference with any of the components listed in Table 7-1 and Table 7-2. This laser port shall not be through the chamber door.

9.90. At least 1 pump laser port looking at the downstream face of a sample target shall be provided The path of the laser beam to the interaction region shall be as collinear to the LCLS beam as possible without interference with any of the components listed in Table 7-1 and Table 7-2 and the 2D X-ray detector stay-clear area. This laser port shall not be through the chamber door.

9.91. An extra pump laser ports shall be included through the chamber hatch door in the xy plane at the LCLS beam height.

Electron TOF Mass Spectrometer (PRD SP-391-000-31)

The electron TOF is not within the scope of the LUSI project. However, it may be added to the instrument in the future and the sample chamber will be designed to allow this addition.

9.92. Provisions shall be made on the sample chamber to allow the future addition of an electron TOF identical to the AMO device (drawing MO39122500.asm).

9.93. The electron TOF mechanical components and electrical feedthroughs shall all be attached to a single 6.75" O.D. flange.

9.94. The long axis of the electron TOF shall be pointed directly at the interaction region within ±1 degree.

9.95. The end of the electron TOF closest to the interaction region shall be located far enough away from the interaction region so that the electron TOF does not encroach on the ±45 degree angle from the interaction region to the detector.

9.96. It shall be possible to use the electron TOF concurrently with all other devices listed in Table 7-2 with no mechanical interferences between devices.

Aperture Wafers

9.97. A minimum of 15 apertures shall be included in a single aperture wafer.

9.98. The aperture wafers shall have a surface area of 15 x 20 mm^2, which is smaller than the travel range of the aperture stages. This shall allow a 5 x 20 mm^2 hole next to the wafer.

9.99. Each aperture in the wafer shall have an apodized or soft edge to minimize scattering.

9.100. It shall be possible to quickly replace an aperture wafer in the field.

9.101. The aperture size shall range between 20 and 2000 μm.

9.102. Different wafers with various combinations of aperture sizes shall be available.

9.103. The wafers supporting the apertures shall have a transmission of 10^{-7} of the beam or less in the 2-8.3 keV spectral range.

Sample, Aperture and Time-Delay Mirror Holders

9.104. The design of the sample and aperture holders shall permit rapid replacement in the field.

9.105. The sample and aperture holders shall have a common design that allows an aperture or a time-delay mirror to be mounted in place of a sample and vice versa.

9.106. The wafer shall be mounted on the downstream side of the holder, keeping most of the material of the holder to the upstream side.

9.107. The material in the holder above the wafer shall be kept to a minimum to allow the particle injector to approach the interaction region without collisions.

9.108. The mounts which support the aperture holders shall be designed individually for each aperture assemblies and the sample assembly. These mount can be different and each assembly may require a set of many specialized mounts for each configuration. They shall however be designed so that the standard holder can be used with all the different mounts interchangeably.

10. Stay Clear Areas

10.1. A numerical aperture of $\sqrt{2}$, corresponding to a ±45 degree angle in both x and y downstream from the interaction region shall be kept clear in the forward scattering configurations.

10.2. A cylindrical volume with diameter of 4" starting 2" above the interaction region shall be reserved for the particle injector and shall be clear of obstructions.

11. Interface Requirements

11.1. The sample chamber shall interface to the vacuum enclosure of the 0.1 micron KB System on the upstream side. This interface shall allow the sample chamber to rotate without causing the KB mirrors to move.

11.2. The sample chamber shall interface with the CXI Detector Stage on the downstream side. Both devices shall move together using the CXI 0.1 micron Precision Instrument Stand (PRD SP-391-000-63).

12. Vacuum Ports

12.1. An L-shaped or T-shaped vacuum chamber shall be attached below the main sample chamber to mount a turbopump.

12.2. This L-shaped or T-shaped section shall have the following ports.

- 6" CF flange at the bottom for introducing a particle beam dump or a laser beam propagating along the particle beam
- Feedthrough flange(s) for all in-vacuum positioners, motors and signal cables.
- A small number of extra flanges for future use to be determined, including rough pumping of the chamber.
- A small hatch that can be opened and closed rapidly to allow easy access to the interior connectors of the feedthrough flanges. This hatch is not strictly required in the presence of an in-vacuum cable relay panel as discussed in Requirements 13.1 and 13.2.

12.3. The following vacuum ports shall be included in the main chamber.

- 6" CF flange for the particle injector, directly above the interaction region.
- Port upstream on the LCLS beam axis to connect to KB0.1 mirror vacuum tank. This port shall be large enough to accept the reentrant detector stage.
- Port for a miniature valve between the KB0.1 tank and the sample chamber. This shall be used with a reentrant KB0.1 design that will allow a shorter KB focal length.
- Port (with a valve) downstream on the LCLS beam axis to connect to reentrant detector vacuum stage.
- Hatch or door to access the apparatus (on +x side of the chamber).
- Port(s) for particle alignment laser.
- Port(s) for pump laser.
- CF Port for ion TOF.
- 6.75" Port for electron TOF.
- Ports for the sample viewer.
- Ports for vacuum gauges
- Port for a burst disk
- Port for a right angle valve
- 3 additional ports for visual inspection of the apparatus.
- 3 x 8" ports for miscellaneous use.

13. Feedthroughs

13.1. Relay cables shall be used from the feedthrough flanges up to a relay panel inside the sample chamber. Each component, such as the positioning stages shall then be connected to this relay panel.

13.2. The relay panel shall be locate so that easy access through the sample chamber door is available to connect or disconnect each in-vacuum cable, without the need to be able to reach the feedthrough flanges.

13.3. The following feedthroughs shall be present for motion controls

- 14 nanopositioning translation stages
- 1 micropositioning translation stages
- 5 picomotors
- 1 stepper motor

13.4. The following feedthroughs shall be present for signals

- 2 charge detector multipin connectors
- BNC connector for the charge detectors
- 1 faraday cup BNC
- Multiple BNC and high voltage for the TOFs (to be included on the same flange that holds the TOFs)
- 2D X-ray Detector, possibly multiple connectors (when in the time-delay configuration with the detector inside the chamber)

13.5. There shall be a feedthrough for fluid lines for cooling of the X-ray 2D detector when in the time-delay configuration with the detector inside the chamber.

13.6. If water is used for cooling the X-ray 2D detector, there shall be no possibility of water leaks directly to vacuum.

13.7. It shall be possible to disconnect all in-vacuum cables without the need to unbolt the feedthrough flanges from the chamber. An in-vacuum relay panel would be a good solution.

14. Controls Requirements

The controls and data acquisition associated with the sample chamber 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 sample chamber are described below.

14.1. There shall be different configurations of the controls system for each of the CXI configurations, namely fixed targets, injected particles and time-delay configurations.

14.2. Only the motions necessary in a given configuration shall be available in the instrument control system. All other motions or controls shall be disabled.

14.3. Remote operation of all chamber components shall be implemented via the instrument control system.

14.4. It shall be possible to scan every motion at a constant speed or constant time between steps during data collection.

14.5. It shall be possible to synchronize the scanning steps with the LCLS pulses.

14.6. Due to some possible electromagnetic interference between components, it shall be possible to power off every component or motor after each move or during the collection time of the 2D X-ray detector or at any time specified by the user.

14.7. In the case of positioners, the absolute position of the stages shall not be lost when they are powered off.

14.8. Software limits on the motions that can lead to collisions with other components shall be implemented.

14.9. It shall be possible, with password control, to modify the software limits at any time from the control console.

14.10. The software limits shall not be restricted to absolute positions since some collisions may occur due to a combination of multiple motions. Relative software limits shall also be implemented on top of absolute limits.

14.11. 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.

14.12. Vacuum interlocks shall prevent the valves on the chamber from opening while the pressure is above 10^{-5} Torr.

14.13. 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.

14.14. Only line power is required for the devices included in the sample chamber. Up to 30 outlets shall be located near the chamber.

14.15. A vision camera shall be used with the sample viewer. The output of the camera shall be displayed at the control console at 30 Hz when desired by the user. It shall be possible to capture frames and short movies with the sample viewer camera when desired by the user.

14.16. It shall be possible to place a marker on the vision camera display to identify the position of the LCLS beam. This marker shall remain until specifically erased or moved by the user.

14.17. The position of all stages shall be displayed at the control console and refreshed after every move.

15. Safety Requirements

15.1. The vacuum pump(s) attached to the chamber shall be installed so that no object can be dropped in it (them).

15.2. If collisions are possible within the range of motion of the stages, software limits shall be set to prevent them.

15.3. There shall be provisions made for a suitable pressure relief mechanism for the possibility of over pressuring the sample chamber.