LUSI LCLS Ultrafast Science Instruments

Engineering specification Document (ESD)	Doc. No. SP-391-001-43 R0	LUSI SUB-SYSTEM CXI Instrument

CXI 1.0 micron Sample Chamber

Prepared by: Jean-Charles Castagna Design Engineer	Signature	Date
Reviewed by: Paul Montanez CXI Lead Manager	Signature	Date
Reviewed by: Sébastien Boutet CXI Instrument Scientist	Signature	Date
Approved: Darren Marsh Quality Assurance Manager	Signature	Date
Approved: Nadine Kurita LUSI Chief Engineer	Signature	Date
Approved: Jerome Hastings Project Manager	Signature	Date

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R0	01AUG08	Initial release	

Table of Contents

1. Applicable Documents

PRD# SP-391-000-19	CXI Instrument
PRD# SP-391-000-21	CXI Reference Laser 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
PRD# SP-391-000-30	CXI Ion TOF
PRD# SP-391-001-44	CXI 1.0 micron Precision Instrument Stand
ESD# SP-391-000-85	CXI Instrument
ESD# SP-391-000-65	CXI 1 micron KB System
ESD# SP-391-000-68	CXI Ion TOF
ESD# SP-391-000-70	CXI Detector Stage
ESD# SP-391-000-73	CXI Reference Laser System
ESD# SP-391-000-75	CXI Particle Injector System
ESD# SP-391-001-44	CXI 1.0 micron Precision Instrument Stand
ESD# SP-391-001-36	Hutch 5 of the FEH

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 only the 1 micron KB System (PRD# SP-391-000-25) and not compatible with 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. Location

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

4. Environment

The humidity and temperature are controlled in the FEH hutches, therefore no component specific temperature stabilizing system will 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 +/-0.3°C), and 45% +/-10%, respectively.

5. Size Requirements and features

5.1. *Size*

The chamber shall be sufficiently large to accommodate all 6 experiment configurations described in PRD SP-391-000-19. A 22" diameter horizontal cylinder is foreseen at the present.

5.2. *Door*

The chamber shall be equipped with a quick access door on the x side, to easily load samples and change experiment configurations. Sealing of the door will be done by 2 concentric O rings with differential pumping in the interval. Two view ports with their axis in the interaction region focal plane will be provided on the door.

5.3. *Turbo pump cross*

A separate T-shaped 13.25" flange cross shall be attached below the main sample chamber to mount a turbo molecular pump with its gate valve.
This T-shaped section shall have the following added ports.

- 6" CF flange at the bottom for introducing a particle beam dump or a laser beam propagating along the particle beam
- 4 x 8"electrical feed through flanges for all in-vacuum positioners, motors and signal cables.
- 2 extra flanges for future use to be determined, including rough pumping of the chamber.

6. Vacuum Ports

6.1.1. Particle injector

6" CF flange for the particle injector, vertically mounted directly above the interaction region

6.1.2. Detector and KB ports

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 document PRD SP-391-000-28, *Physics Requirements for the CXI Detector Stage*. Both ports will allow for a 10" diameter detector to be introduced thru them.
Both ports will receive gate valves equipped with view ports to allow the reference laser to go through.

6.1.3. Ion TOF port

An 8" port will be provided with its axis aiming at the interaction region and in the XY focal plane. This port will most likely be installed on the –x side of the chamber at an angle of 22º ±10 from the horizontal plane.

6.1.4. Sample viewer microscope ports

2 x 4.625" ports will be provided to view the sample both on line (sample view in the axis of FEL beam) and off line (sample being removed from the interaction region for viewing, necessary in the time and delay configuration)

6.1.5. View ports

- At least 3 view ports with their axis aiming at the interaction region and in the XY focal plane will be provided to introduce lasers. At least one of these ports will have a matching mate on its axis on the other side of the chamber to allow the exit of the laser.
- Two extra view ports looking from both at an upstream angle and a downstream angle at the interaction region will be provided; they shall have an unimpeded view of the interaction region for all experimental configurations
- 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. 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.

6.1.6. Miscellaneous ports

3 x 8" ports for electrical or water feedthru
6 x 2.75 ports for vacuum accessories and control (angle valve, vacuum gage, burst disk, etc…)

7. Feedthroughs

7.1. The following electrical feedthrough connectors shall be present for motion controls

- 14 nano positioning translation stages
- 1 micro positioning translation stage
- 5 picomotors
- 1 stepper motor

7.2. 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)

7.3. It shall be possible to disconnect the inside connector to all electrical feedthroughs without the need to unbolt the feedthrough flanges from the chamber. A series of relay connectors shall be provided for easy connecting and disconnecting of the different elements inside the chamber.

8. Chamber Positioning Requirements

8.1. A fixed point inside the chamber, the interaction point, shall be located at the focal plane of the 1 micron KB System which is described in PRD SP-391-000-25, *Physics Requirements for the CXI 1 micron KB System*.

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

8.3. 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 Specifications for the CXI Instrument*.

8.4. Requirements 8.1 and 8.3 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.

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

8.6. The sample chamber shall be surveyed into a position where, with all the motion stages listed in Table 5 located at their nominal positions, the on-beam axis is oriented along the nominal unfocused LCLS beam to within ±1° in pitch, roll and yaw.

9. Chamber Motion Requirements

9.1. The requirements for the motions of the 1 micron Sample Chamber are described in PRD SP-391-001-42, *Physics Requirements for the CXI 1micron Precision Instrument Stand* and ESD SP-391-001-44, *Engineering Specifications for the CXI 1 micron Precision Instrument Stand.*.

10. Vacuum Requirements

10.1. 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.

10.2. The turbo molecular vacuum pump attached to the chamber shall be located away from the interaction region in order not to restrict access to the inside of the chamber.

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

10.4. It shall be possible to leave the chamber turbopump turned on while the chamber is vented to air.

10.5. 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.

10.6. The sample chamber shall be isolated from the upstream and downstream chambers by 2 gate valves equipped with view ports to allow the reference laser to go through.

11. Configurations

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

11.2. 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.

11.3. It shall be possible to go from the fixed target to the particle injection configuration without need to break the vacuum.

11.4. A change from the forward scattering configuration to the time and delay configuration will necessitate a major operation with vacuum break and a manual transfer of the detector stage to the upstream position.

11.5. *Sample and aperture holders*

To allow for easy reconfiguration of the sample environment the same frames will be used to hold the sample grid (fixed target), the mirror (time and delay) or the aperture grid.
See Figure 1.

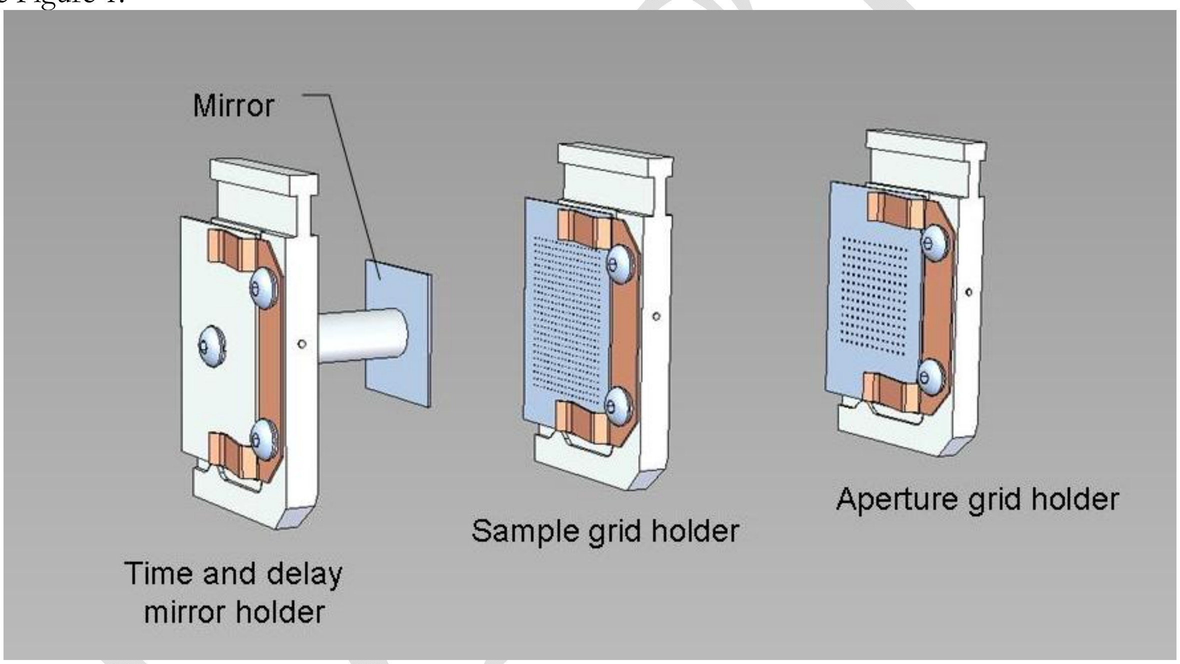

Figure 1: Sample, aperture and time-delay mirror holders.

11.6. *Forward scattering with fixed targets configuration*

The components listed in Table 1 shall be included in the forward scattering with fixed targets configuration, with or without a pump laser.
Figure 2 shows the apertures and sample configuration

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 periscope	View the sample and alternatively view the third aperture, FEL axis view	x, y, pitch, yaw

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

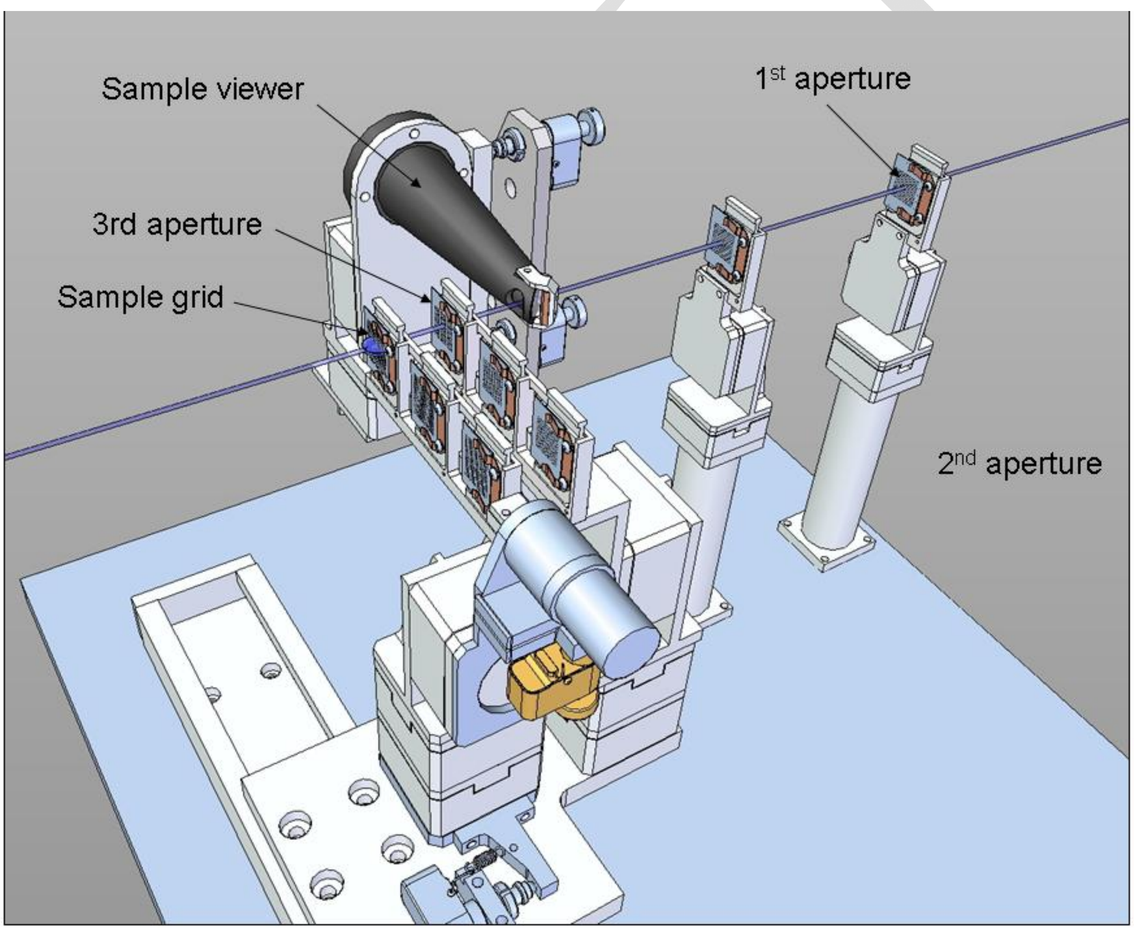

Figure 2: Aperture configuration in forward scattering with fixed target

11.7. *Forward scattering with injected particles configuration*

In this configuration, what used to be the sample stage becomes a fourth aperture or can be used as a dusting wafer to examine the particle beam footprint.
The components listed in Table 2 shall be included in the forward scattering with injected particles configuration, with or without a pump laser.
Figure 3 shows the apertures configuration

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
Electron TOF	Measure the kinetic energy of electrons from the exploded particles	None

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

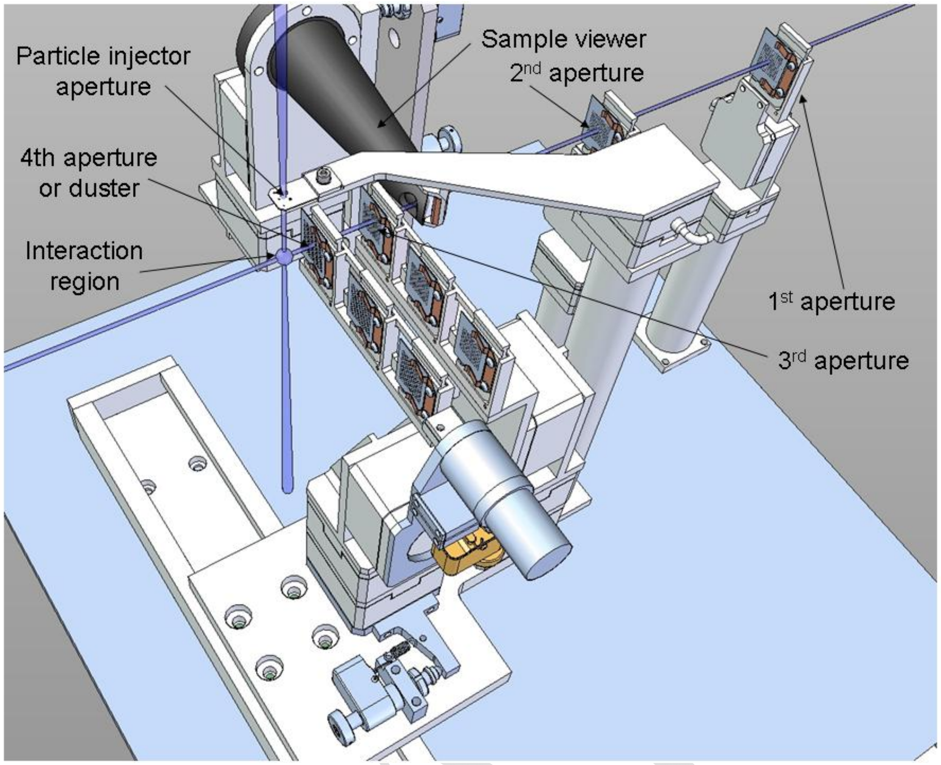

Figure 3: Apertures configuration in forward scattering with injected particles

11.8. *Time-delay scattering with fixed targets configuration*

In the time and delay configurations what used to be the sample stage and the third aperture stage are shifted downstream and become respectively the time and delay mirror stage and the sample stage.

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

Figure 4 shows the sample and mirror configuration

Component	Function	Necessary Motions
Sample stage	Position the sample at the interaction point	x, y, z
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, yaw
2D X-ray Detector	Mounted upstream of the sample	x, y

Table 3: Components necessary in time delay experiments with fixed targets.

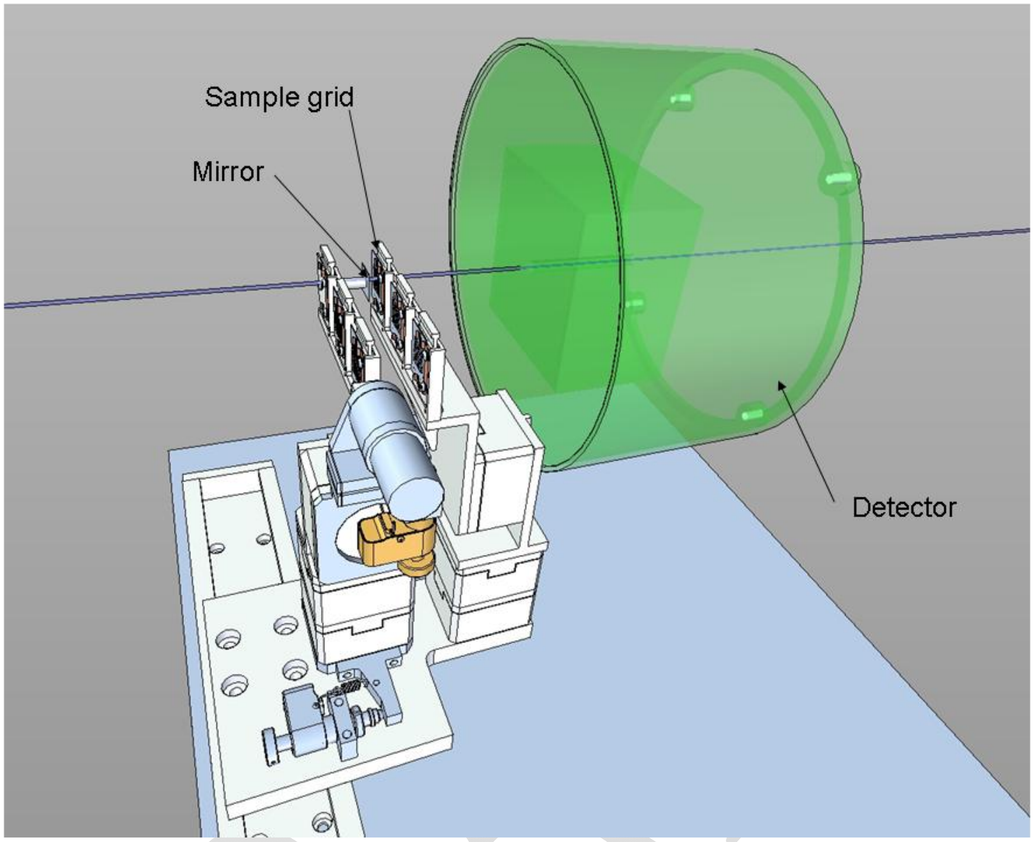

Figure 4: Sample and time-delay mirror configuration in time and delay scattering with fixed target

11.9. *Time-delay scattering with injected particles configuration.*

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

Figure 5 shows the aperture and mirror configuration

Component	Function	Necessary Motions
Sample stage	Used as an aperture Used as a dusting wafer	x, y, z, pitch, yaw
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 Not Xray axis view of the aperture but necessity to move aperture 350mm in X to view it	x, y, pitch, yaw
2D X-ray Detector	Mounted upstream of the sample	x, y
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 4: Components necessary in time delay experiments with injected particles.

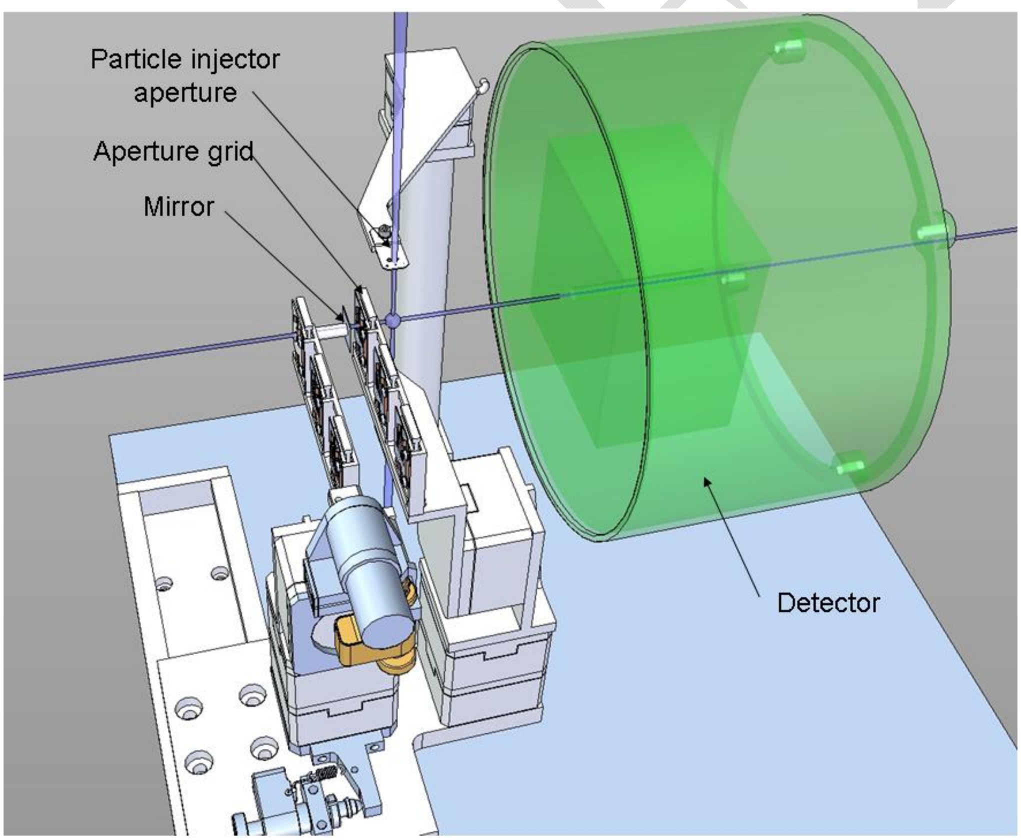

Figure 5: Aperture and time-delay mirror configuration in time and delay scattering with particle injector

12. In-vacuum Motion Requirements

12.1. Motorized motions summarized in Table 5 shall be provided for components inside the sample chamber.

12.2. 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.

Motion	Nom. Position	Range	Resolution	Repeatability	Vacuum
First aperture x position	0 mm	-10 mm < x < 10 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
First aperture y position	0 mm	-10 mm < y < 10 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
Second aperture x position	0 mm	-10 mm < x < 10 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
Second aperture y position	0 mm	-10 mm < y < 10 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
Third aperture x position	0 mm	-10 mm < x < 350 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
Third aperture y position	0 mm	-10 mm < y < 10 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
Third aperture z position	-25 mm	-35 mm < z < -15 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
Sample x position	0 mm	-10 mm < x < 160 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
Sample y position	0 mm	-10 mm < y < 10 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
Sample z position	0 mm	-10 mm < z < 10 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
Sample yaw	0 degree	±5°	5 µrad	5 µrad	≤ 10^{-7} Torr
Sample pitch	0 degree	±180°	5 µrad	5 µrad	≤ 10^{-7} Torr
Particle aperture x position	0 mm	-10 mm < x < 10 mm	10 µm	10 µm	≤ 10^{-7} Torr
Particle aperture z position	0 mm	-10 mm < y < 10 mm	10 µm	10 µm	≤ 10^{-7} Torr
Time-delay mirror x position	0 mm	-10 mm < x < 10 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
Time-delay mirror y position	0 mm	-10 mm < y < 10 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
Time-delay mirror z position	-10 mm	-20 mm < z < 0 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
Time-delay mirror pitch	0 degree	±5°	5 µrad	5 µrad	≤ 10^{-7} Torr
Time-delay mirror yaw	0 degree	±5°	5 µrad	5 µrad	≤ 10^{-7} Torr
Sample viewer mirror x position	0 mm	-10 mm < x < 10 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
Sample viewer mirror y position	0 mm	-10 mm < y < 10 mm	≤ 0.1 µm	≤ 0.3 µm	≤ 10^{-7} Torr
Sample viewer mirror pitch	0 degree	±5°	1 mrad	1 mrad	≤ 10^{-7} Torr
Sample viewer mirror yaw	0 degree	±5°	1 mrad	1 mrad	≤ 10^{-7} Torr

Table 5: Motion requirements for the components inside the chamber. (x,y,z)=(0,0,0) is defined as the interaction point.

13. Sample Chamber Components

First Aperture Assembly

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

13.2. The first aperture assembly shall have the motorized motions described in Table 5.

13.3. The beam blocking part of the first aperture assembly shall be large enough to cover the entire opening from the sample chamber to the upstream vacuum spool to block any stray light travelling down the beamline. Alternatively, this can be accomplished by placing a fixed sheet metal piece with a hole in it at the entrance of the sample chamber.

See Figure 6

Second Aperture Assembly

13.4. The second aperture assembly shall be located roughly 75 ± 30 mm downstream of the first aperture assembly.

13.5. The second aperture assembly shall have the motorized motions described in Table 5

See Figure 6

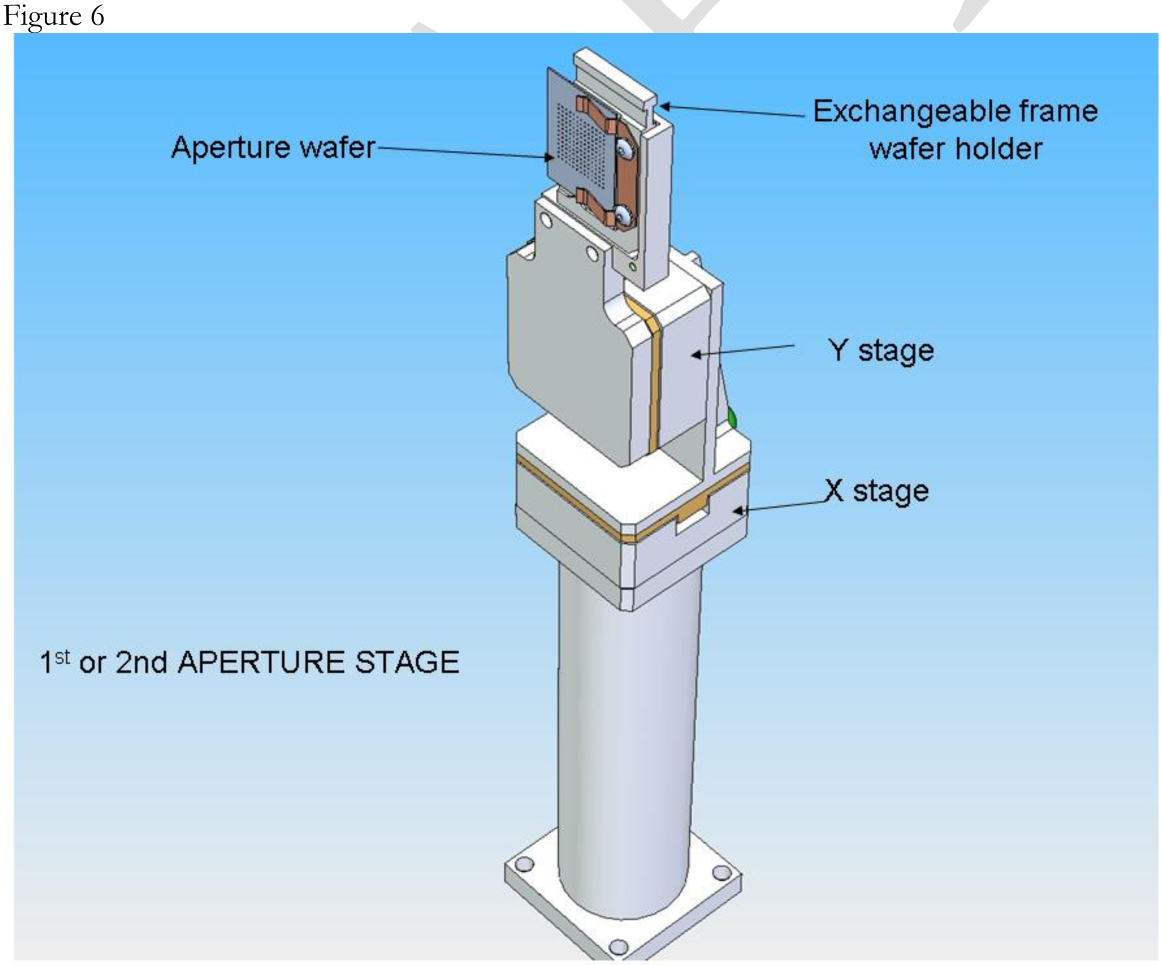

Figure 6: 1st or 2nd aperture stage

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

Third Aperture Assembly

13.7. 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.

13.8. The third aperture assembly shall have the motorized motions described in Table 5.

13.9. It shall be possible to manually 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.

13.10. Requirements 13.7 and 13.9 do not need to be achieved with the same setup. Two different mounts can be used to meet these requirements.

13.11. 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 5.

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

See Figure 7

Sample Assembly (Fourth Aperture Assembly)

13.13. The sample assembly shall be located so that the nominal position of the stages places the sample wafer at the interaction plane in the forward scattering configuration

13.14. The sample assembly shall have the motorized motions described in Table 5.

13.15. 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 5.

13.16. 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.

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

13.18. 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.

13.19. 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.

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

See Figure 7

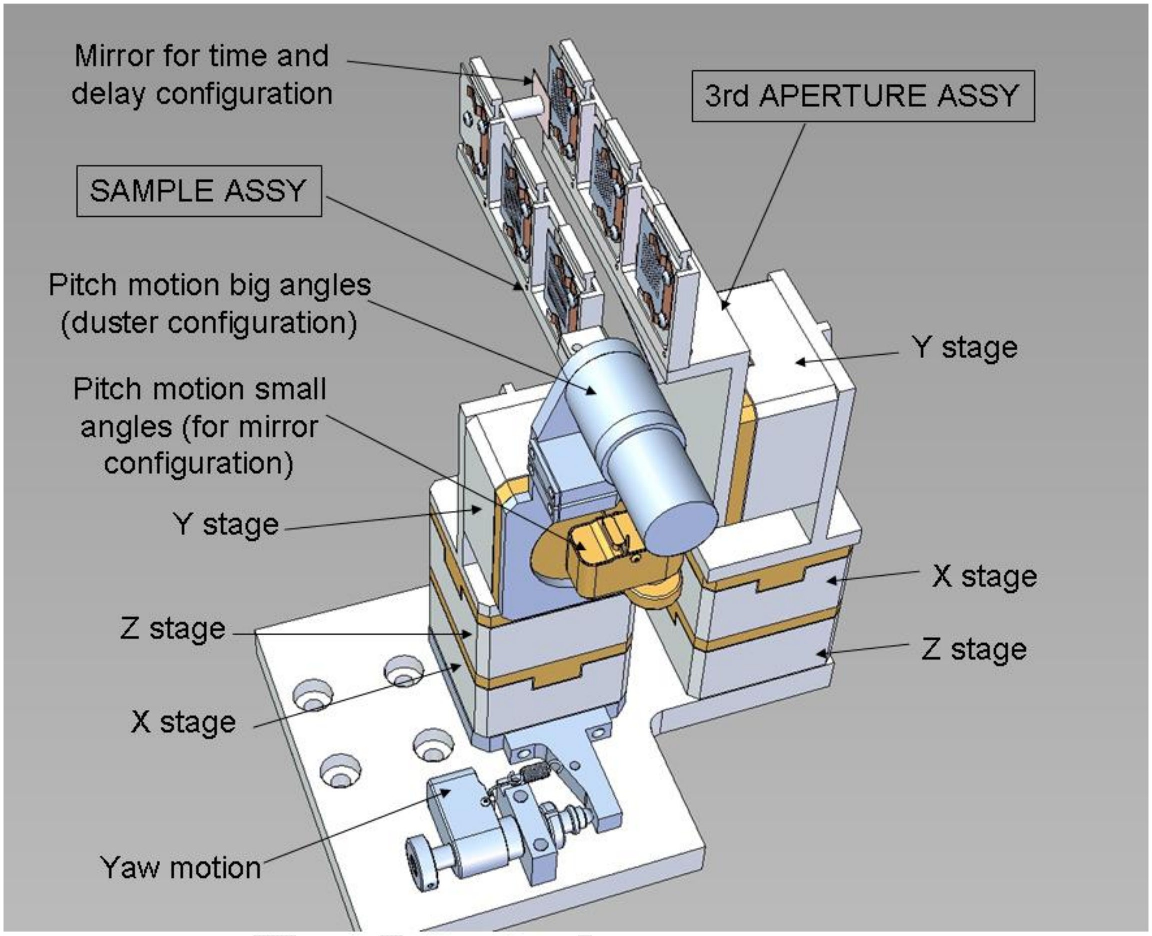

Figure 7: Third aperture and sample assemblies

Long range X motion on 3rd aperture and sample stage assembly

A long range X linear stage will support and move the 3rd aperture and sample stage assembly to position each pair of aperture/sample grid in the FEL beam. This stage will also provide a 350mm stroke to position the assembly in view of the telescope in the time and delay configuration

Time-Delay Mirror Assembly

13.21. The time-delay mirror assembly shall have the motorized motions described in Table 5.

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

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

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

13.25. The distance between the time-delay mirror and the interaction region shall be continuously adjustable in the 300 μm to 20 mm range.

See Figure 8

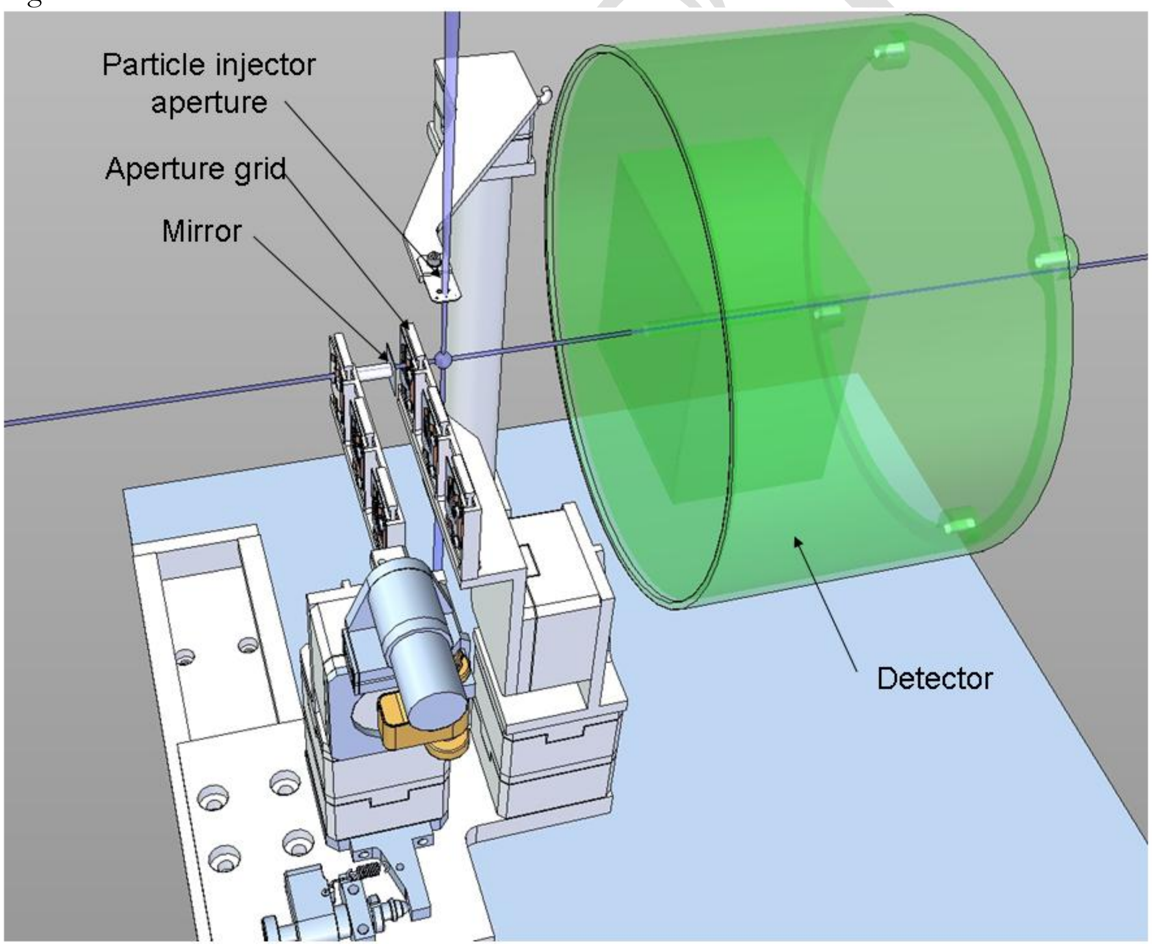

Figure 8: Sample and time-delay mirror assemblies

Sample Viewer Assembly

13.26. The viewing of the sample shall be done through a long range telescope installed out of vacuum.

13.27. A periscope equipped with a drilled mirror will allow the viewing of the sample along the same axis as the X-ray beam in the forward scattering configuration. This periscope will have all the motions described in Table 5 (sample viewer)

See Figure 9

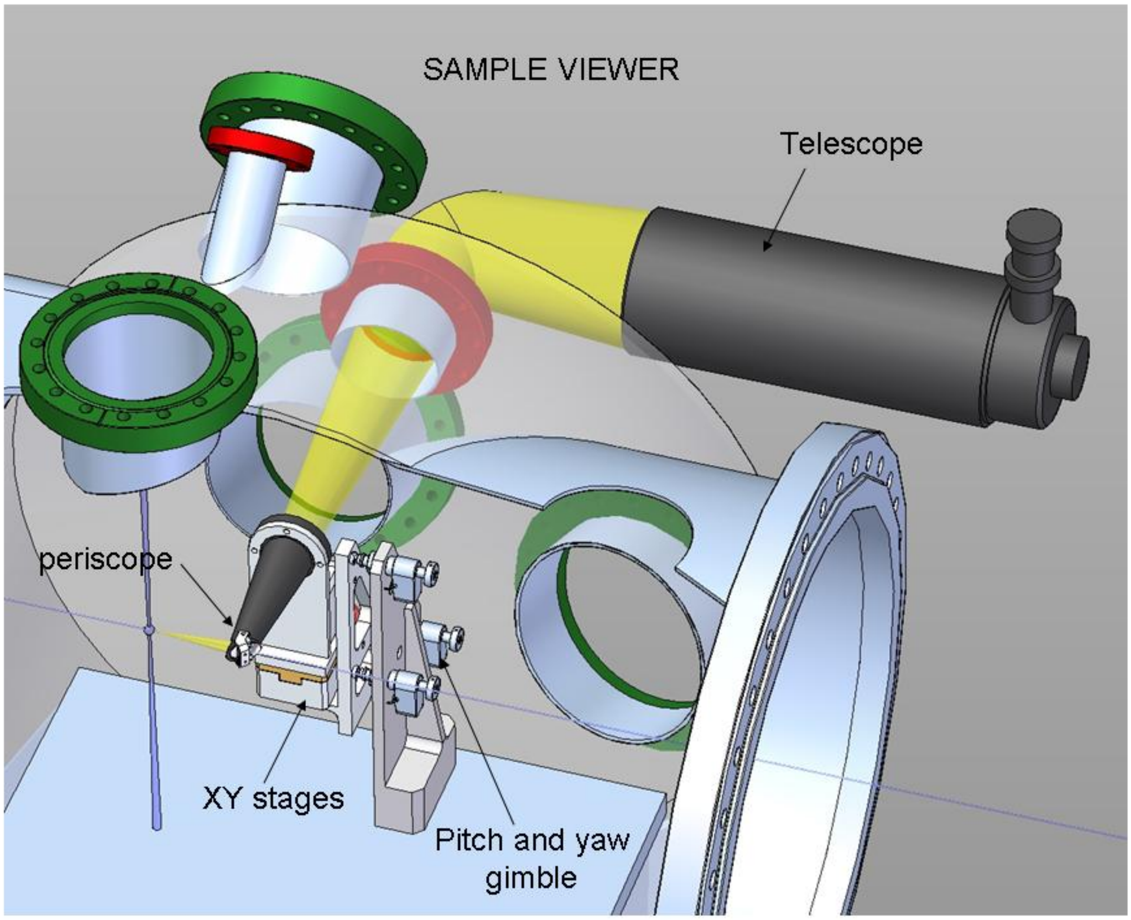

Figure 9: Sample viewer in the forward scattering geometry

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

13.29. 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.

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

13.31. 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.

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

13.33. In the time-delay configuration, the telescope will be used without the periscope and through a different port. 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. The viewing will not be on the beam axis in this configuration. The sample or mirror will be moved to a fixed position for viewing and then moved back to the measurement position.

13.34. Illumination that will 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 and upstream sides. The requirements listed here are the detector requirements that relate to the integration of the detector into the sample chamber.

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

13.36. The detector stage shall be reentrant to the sample chamber on the upstream side of the chamber.

13.37. 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 2.

13.38. The surface normal of the detector sensing area shall be parallel with the line between the interaction point and the geometric center of the detector to within $\pm 1°$.

13.39. 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 3 .

13.40. Switching between the two detector configurations shall be accomplished manually. The two configurations are: reentrant downstream and reentrant upstream.

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.

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

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

13.43. 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. Sufficient clearance shall exist within the chamber to allow for these motions.

13.44. 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 1 in order to avoid collisions.

13.45. 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 pilling 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.

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

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

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

13.49. The dusting wafer shall have a range of motion of ±10 mm in all three directions.

13.50. The dusting wafer shall be held on the same stage used for the fixed target in the forward scattering configuration. See Figure 7.

Particle Beam Aperture Assembly

13.51. 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.

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

13.53. It shall be possible to select the desired aperture size and position in the path of the particle beam to within the accuracy listed in Table 5.

13.54. Changing the size of the aperture on a single plate shall be accomplished in less than 1 second.

13.55. The particle beam aperture assembly shall have the motorized motions described in Table 5.

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

See Figure 10

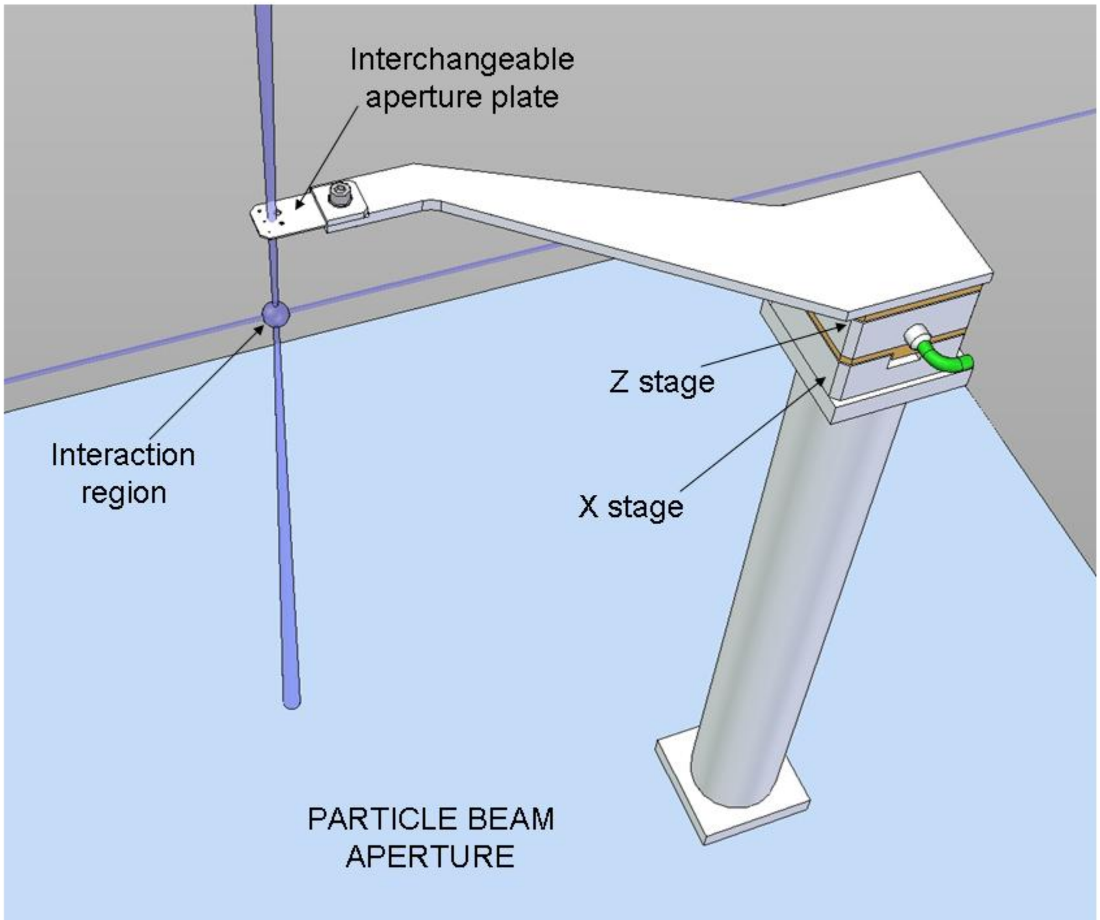

Figure 10: Particle beam aperture

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 detector into the sample chamber.

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

13.58. 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.

13.59. 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.

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

Second Charge Detector

13.61. The second charge detector shall be used only in the particle injection configuration. It can be retrieved for the fixed target configuration.

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

13.63. 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). This alignment is obtained with assembly mounting tolerances

13.64. 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.

13.65. The second charge detector mount shall be designed so that the charge detector is easily removable in less than 5 minutes (not including vacuum break)

Faraday Cup

The Faraday cup shall be used only in the particle injection configuration. It can be retrieved for the fixed target configuration.

13.66. The Faraday cup shall be located below the second charge detector.

13.67. The Faraday cup mount shall be designed so that the Faraday cup is easily removable in less than 5 minutes. (not including vacuum break time)

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

Particle Beam Dump

13.69. 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 chamber.

13.70. 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. This particle dump is not within the scope of the LUSI project. Only the clear path to the bottom of the chamber shall be provided.

13.71. A 2.75" port will be provided at the bottom of the chamber to accommodate for the beam dump.

Hatch

13.72. 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.

13.73. 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.

13.74. It shall be possible to open or close this door in less than 1 minute. (not including vacuum break time)

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.

13.75. 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".

13.76. The ion TOF mechanical components and electrical feedthroughs shall all be attached to a single 8" O.D. flange.

13.77. The long axis of the ion TOF shall be pointed directly at the interaction region to within ±1 degree.

13.78. 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 when the fourth aperture is located 5 mm upstream of the sample. No interference with other components in the chamber shall be allowed.

13.79. 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.

13.80. 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 8" flange. This electrode shall not interfere with any of the components in the chamber, including the ±45 degree detector angle stay-clear zone.

13.81. 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.

13.82. Removal of internal components such as the particle beam aperture might be necessary, to retrieve the ITOF from its port.

Desorption-Ionization Laser Ports

No desorption-ionization laser will be provided under the LUSI project. However, a port will be provided on the sample chamber to allow the addition of the laser at a later date..

13.83. 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.

13.84. 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.

13.85. 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

No particle alignment laser will be provided under the LUSI project. However, a port will be provided on the sample chamber to allow the addition of the laser at a later date..

13.86. 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.

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

13.88. 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.

13.89. 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

No pump laser will be provided under the LUSI project. However, a port will be provided on the sample chamber to allow the addition of the laser at a later date..

13.90. 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 1 and Table 2. This laser port shall not be through the chamber door.

13.91. 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 1 and Table 2 and the 2D X-ray detector stay-clear area. This laser port shall not be through the chamber door.

13.92. 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 (Not in current LUSI scope)

No electron TOF will be provided under the LUSI project. However, a port will be provided on the sample chamber to allow the addition of the electron TOF at a later date..

13.93. 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).

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

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

13.96. 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.

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

Aperture Wafers

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

13.99. 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 window next to the wafer in the wafer holder of the 3^{rd} and 4^{th} aperture . This will provide a clear path of vision for the sample viewer to look at the sample grid without obstruction from the 3^{rd} aperture.

See Figure 11

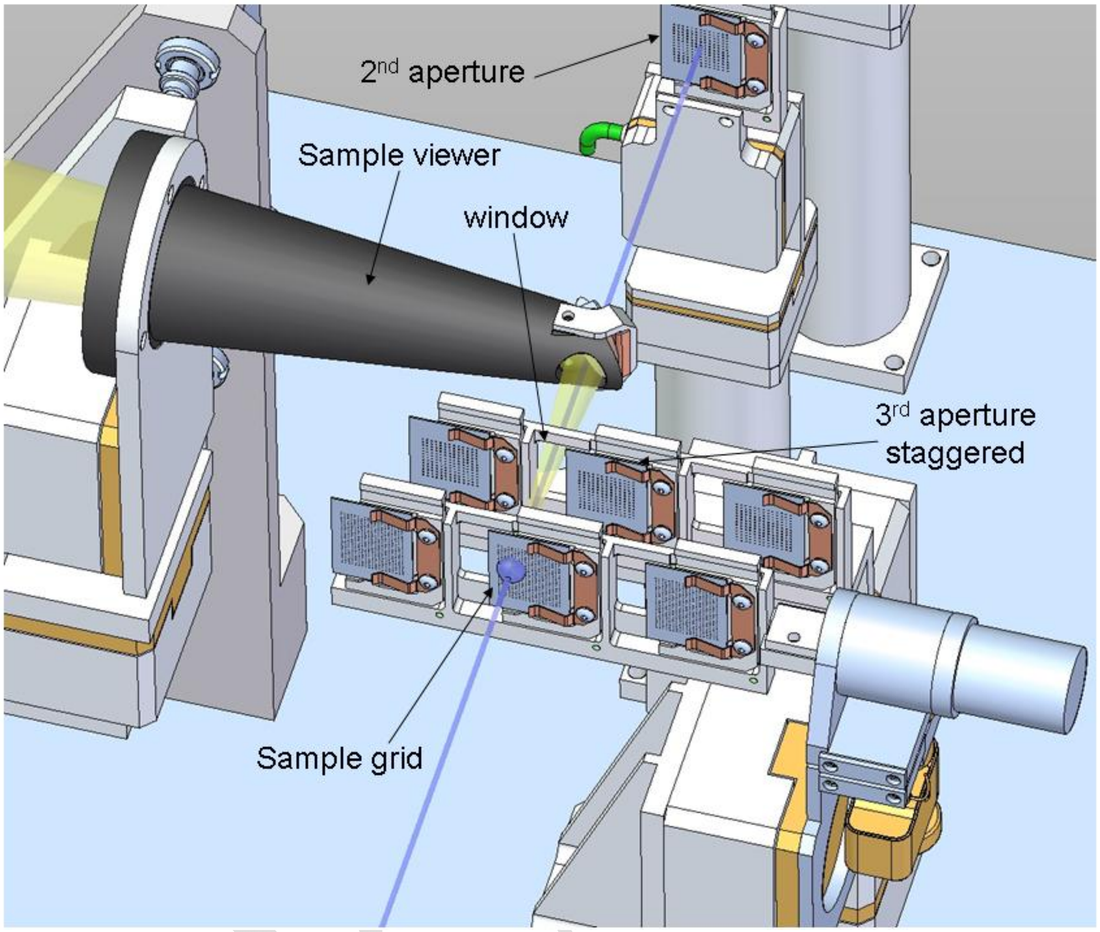

Figure 11: The third aperture wafer is moved to allow viewing of the sample

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

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

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

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

13.104. 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

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

13.106. 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.

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

13.108. 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.

13.109. 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.

14. Stay Clear Areas

14.1. A numerical aperture of √2, corresponding to a ±45 degree angle downstream from the interaction region shall be kept clear in the forward scattering configurations.

14.2. 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.

15. Interface Requirements

15.1. The sample chamber shall interface with the CXI Detector Stage on the downstream side. Both devices shall move together using the CXI 1 micron Precision Instrument Stand (PRD SP-391-001-42).

15.2. The sample chamber shall interface with the CXI Detector Stage on the upstream side. Both devices shall move together using the CXI 1 micron Precision Instrument Stand (PRD SP-391-001-42).

16. 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 System*. Requirements specific to the sample chamber are described below.

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

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

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

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

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

16.6. 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.

16.7. In the case of positioners, the absolute position of the stages shall not be lost when they are powered off except for the long range X motion of the 3rd aperture and sample stage assembly which will not have an encoder.

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

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

16.10. 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.

16.11. 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.

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

16.13. 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.

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

16.15. 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.

16.16. 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.

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

17. Safety Requirements

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

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

17.3. A burst disk shall be provided to avoid over pressurization of the chamber

17.4. The sample chamber on its precision stand shall respond to seismic regulations and requirements