LUSI — LCLS Ultrafast Science Instruments

Engineering specification Document (ESD)	Doc. No. SP-391-000-67 R0	LUSI SUB-SYSTEM CXI Instrument

Engineering Specifications for the CXI 0.1 micron Sample Chamber

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1. 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 CXI 0.1 micron KB System (PRD SP-391-000-25) and not compatible with the CXI 1 micron KB System (PRD SP-391-000-24).

The CXI 0.1 micron Sample Chamber will have the same functionality as the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43 to the extent possible. The extremely short focal length of the 0.1 micron KB System leads to a very short working distance which will limit the space available inside the 0.1 micron Sample Chamber. Therefore some components of the 1 micron Sample Chamber will simply not be available in the 0.1 micron Sample Chamber.

The basic concept, to a first approximation, will be to use the mechanical design of the 1 micron KB System along with the mechanical design of the 1 micron Sample Chamber and fuse them together. All interferences in the combined system will then be resolved in the design phase. A conceptual design for the integrated system is shown on Figure 1.

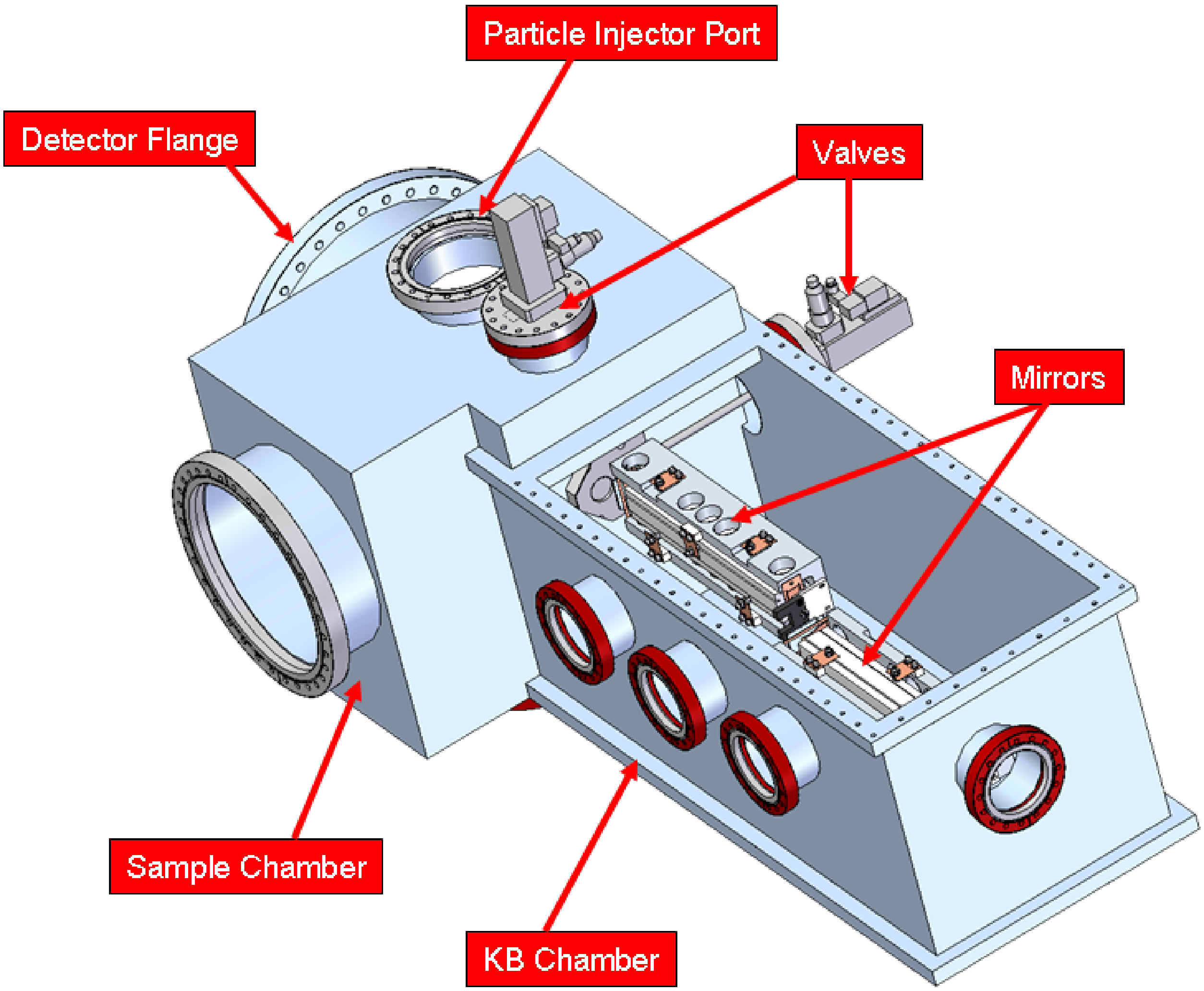

Figure 1: Conceptual design of the 0.1 micron Sample Chamber and 0.1 micron KB System integrated assembly with a single vacuum enclosure for both components.

This document follows the same outline as the 1 micron Sample Chamber and at times refers to it when the requirements are identical. The differences between the two Sample Chambers are highlighted and this document contains specifications that are unique to the 0.1 micron Sample Chamber.

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

2. Applicable Documents

2.1. SLAC National Accelerator Laboratory (SLAC) Specifications

PRD# SP-391-000-03	Physics Requirements for the LUSI Controls and Data System
PRD# SP-391-000-06	Physics Requirements for the LUSI Data Management System
PRD# SP-391-000-19	Physics Specifications for the CXI Instrument

PRD# SP-391-000-21	Physics Requirements for the CXI Reference Laser System
PRD# SP-391-000-24	Physics Requirements for the CXI 0.1 micron KB Mirror System
PRD# SP-391-000-26	Physics Requirements for the CXI Particle Injector System
PRD# SP-391-000-28	Physics Requirements for the CXI Detector Stage
PRD# SP-391-000-30	Physics Requirements for the CXI Ion Time-Of-Flight
PRD# SP-391-001-41	Physics Requirements for the CXI 1 micron Sample Chamber

ESD# SP-391-000-64	Engineering Specifications for the CXI 0.1 micron KB System
ESD# SP-391-000-68	Engineering Specifications for the CXI Ion TOF
ESD# SP-391-000-69	Engineering Specifications for the CXI 0.1 micron Precision Instrument Stand
ESD# SP-391-000-70	Engineering Specifications for the CXI Detector Stage
ESD# SP-391-000-75	Engineering Specifications for the CXI Particle Injector System
ESD# SP-391-000-85	LUSI CXI Instrument Engineering Specification
ESD# SP-391-001-13	Engineering Specifications for the CXI Instrument Controls
ESD# SP-391-001-43	Engineering Specifications for the CXI 1 micron Sample Chamber
ICD# SP-391-001-14	XES PCDS to LUSI CXI Instrument ICD (ICD)
LCLS ESD 1.9-113	Engineering Specifications for Hutch 5 of the FEH
SLAC-I-720-0A24E-001	Seismic Design Specification for Buildings, Structures, Equipment, and Systems

2.2. Acronyms

CF	Conflat Flange
CXI	Coherent X-Ray Imaging
ESD	Engineering Specification Document
FEL	Free Electron Laser
FEH	Far Experimental Hall
KB	Kirkpatrick-Baez (Mirror System)
LCLS	Linac Coherent Light Source
LUSI	LCLS Ultrafast Science Instruments
PRD	Physics Requirement Document
TOF	Time of Flight

3. General Requirements

3.1. Location

The CXI 0.1 micron Sample Chamber shall be located inside the CXI hutch (hutch 5) in the Far Experimental Hall.

3.2. Environment

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

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

3.3. Maintenance, Accessibility and Operations

The Sample Chamber will need to be accessed frequently for changing of samples or experimental setup. An access door shall be located on the positive X side. Allowances shall be made to ensure that there is adequate clearance between the sample chamber and the adjacent beamline serving hutch 6.

3.4. Lifetime

The expected service life of the device is 10 years.

4. Sample Chamber Configurations and Components

4.1. Sample Chamber Configurations

The 0.1 micron Sample Chamber design shall be able to accommodate only the forward scattering configurations described in PRD SP-391-000-19. The time-delay configurations shall not be used with this sample chamber.

The same internal components of the 1 micron Sample Chamber shall be reused, to the extent possible, in the 0.1 micron Sample Chamber.

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

4.1.1. Forward Scattering with Fixed Targets Configuration

The components listed in Table 1 shall be included, to the extent possible, in the forward scattering with fixed targets configuration, with or without a pump laser. Space restrictions may prevent the use of the first and second aperture assemblies.

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 with fixed targets configuration

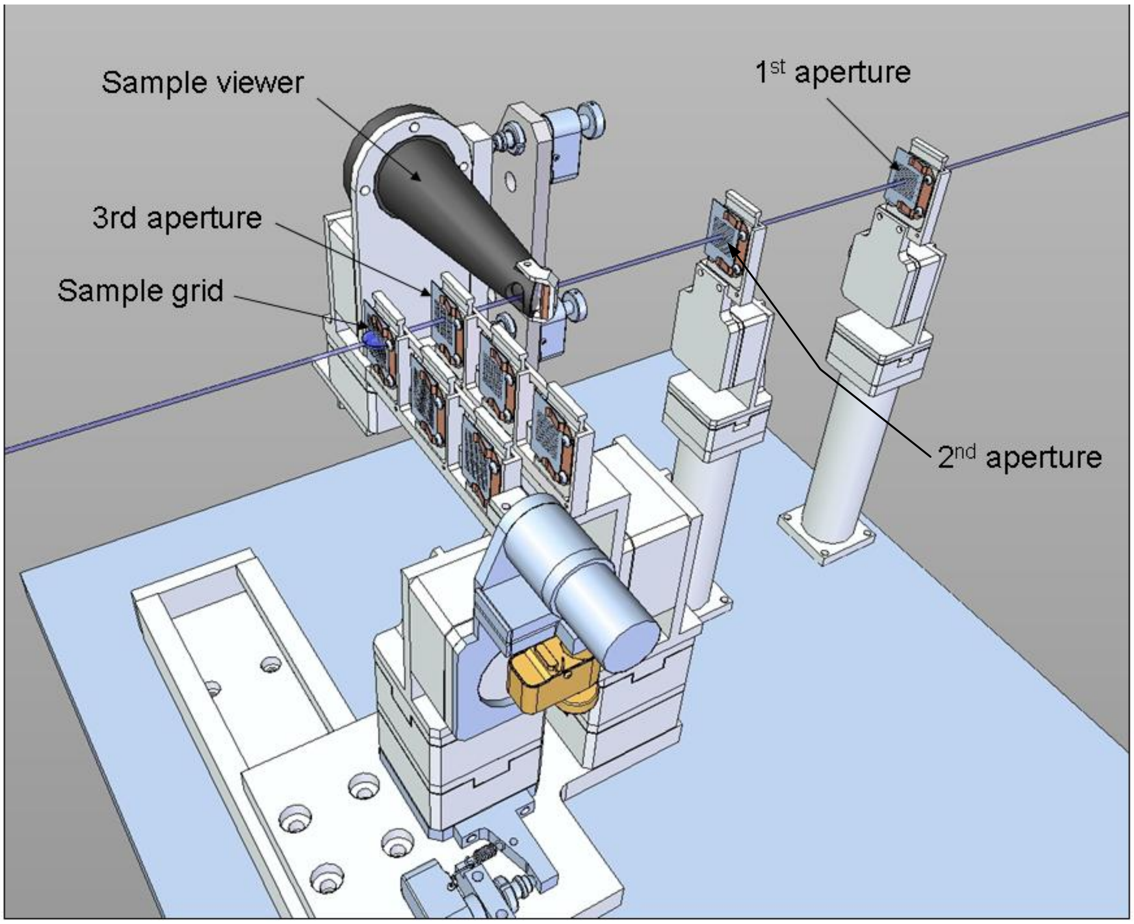

Figure 2: Aperture configuration in forward scattering with fixed target

4.1.2. 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. Again, space restrictions may prevent the use of the first and second aperture.

Figure 3 shows the aperture 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 focused 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

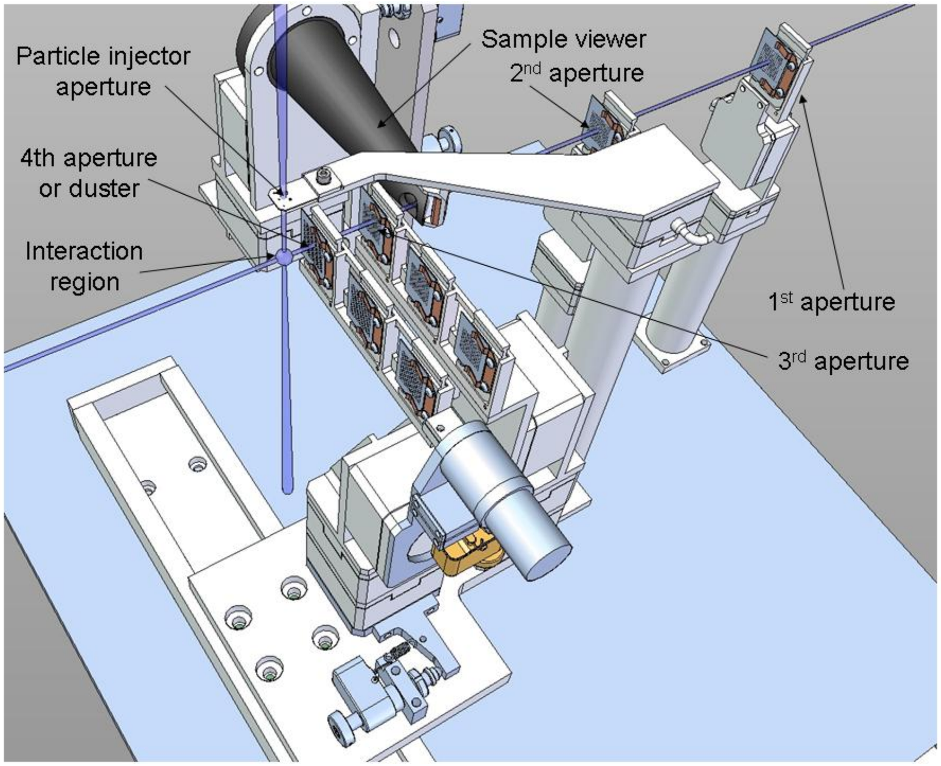

Figure 3: Aperture configuration in forward scattering with injected particles

4.2. Sample Chamber Components

4.2.1. Entrance Aperture

The Entrance Aperture shall consist of a hole in the wall separating the KB chamber and the Sample Chamber as shown on Figure 4.

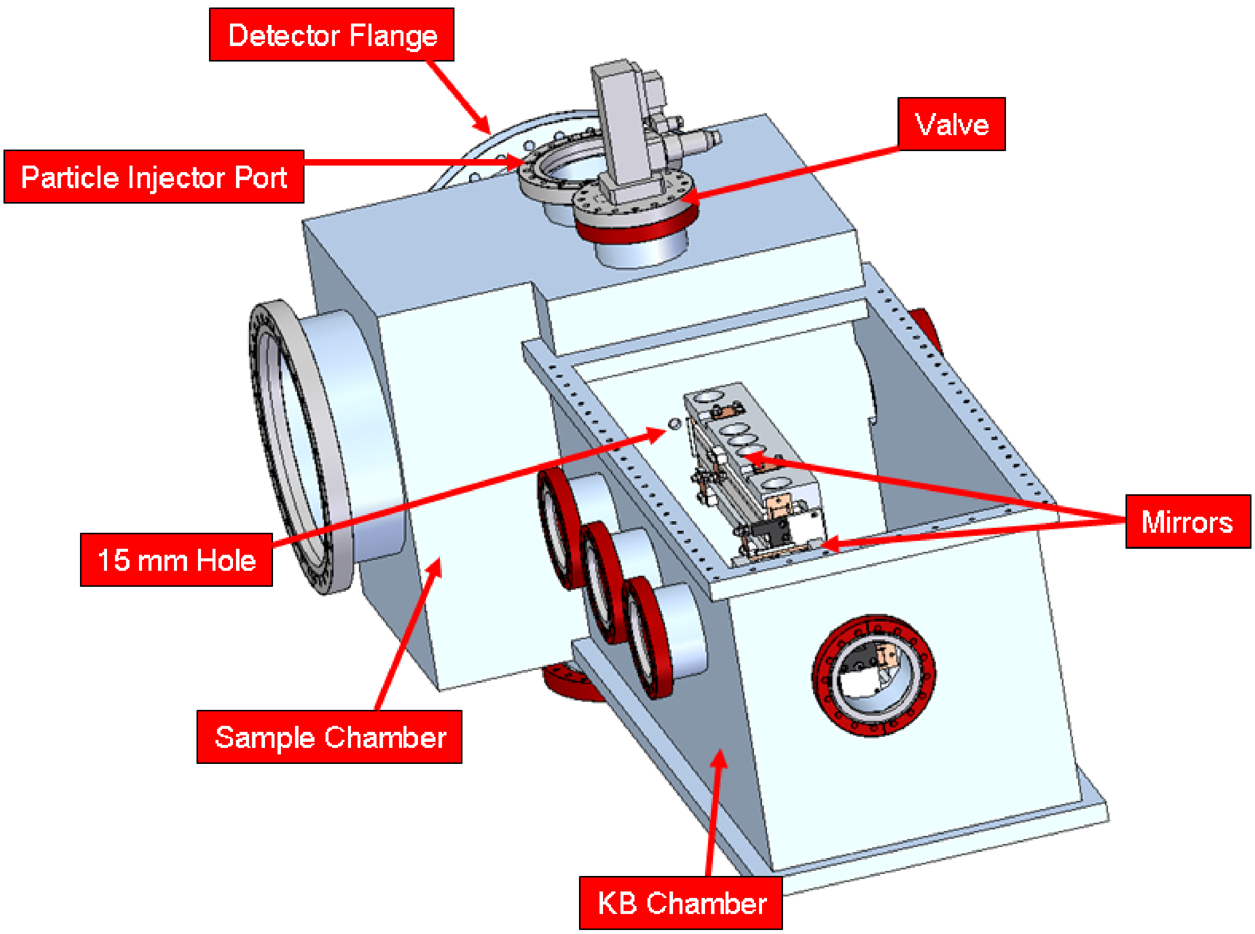

Figure 4: Conceptual design of the 0.1 micron Sample Chamber and 0.1 micron KB combined assembly. A wall must separate the two parts of the vacuum system with a 15 mm diameter hole to let the beam pass. The valve on the KB chamber side is hidden in this view.

4.2.2. Sample and Aperture Holders

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43.

4.2.3. First Aperture Assembly

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43, provided sufficient space is available.

4.2.4. Second Aperture Assembly

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43, provided sufficient space is available.

4.2.5. Third Aperture Assembly

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43, except that the time-delay configuration is not used.

4.2.6. Sample Assembly (Fourth Aperture Assembly)

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43, except that the time-delay configuration is not used.

4.2.7. Long Range X-Motion on Third Aperture and Sample Stage Assembly

A long range X-motion linear stage will support and move the Third Aperture and Sample Stage Assembly to position each pair of aperture/sample grid in the FEL beam.

4.2.8. Time-Delay Mirror Assembly

Not in use for the 0.1 micron Sample Chamber.

4.2.9. Sample Viewer Assembly

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43, except that the time-delay configuration is not used.

See Figure 5.

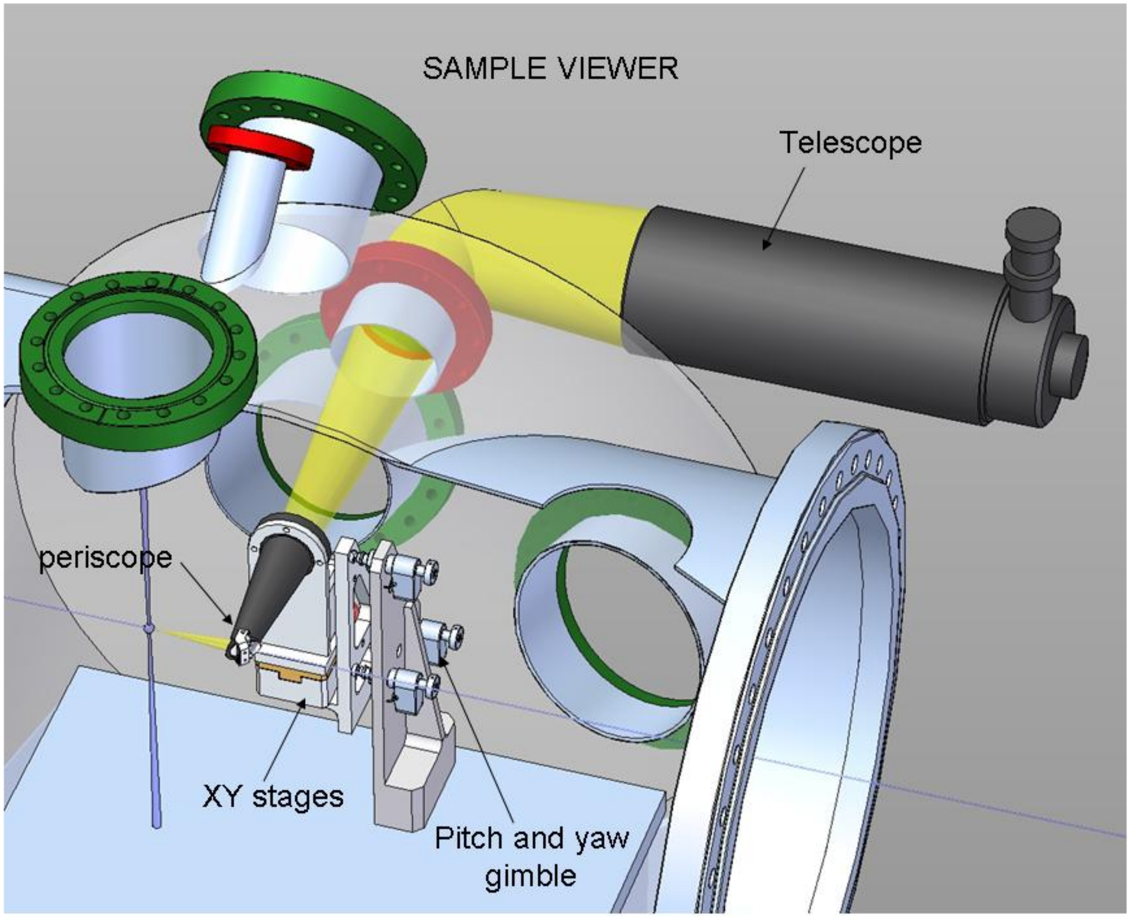

Figure 5: Sample viewer in the forward scattering configuration

4.2.10. 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* and document ESD SP-391-000-70, *Engineering Specifications for the CXI Detector Stage*. However, this stage will be reentrant into the 0.1 micron 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. The CXI Detector Stage shall be supported independently from the CXI 0.1 micron Sample Chamber. A separate stand shall be used to support the Detector Stage.

- The Detector Stage shall be reentrant to the Sample Chamber on the downstream side of the chamber.
- 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.

- 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 ±1 degree.

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

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43. The Particle Injector port shall be located above the interaction region as shown on Figure 6.

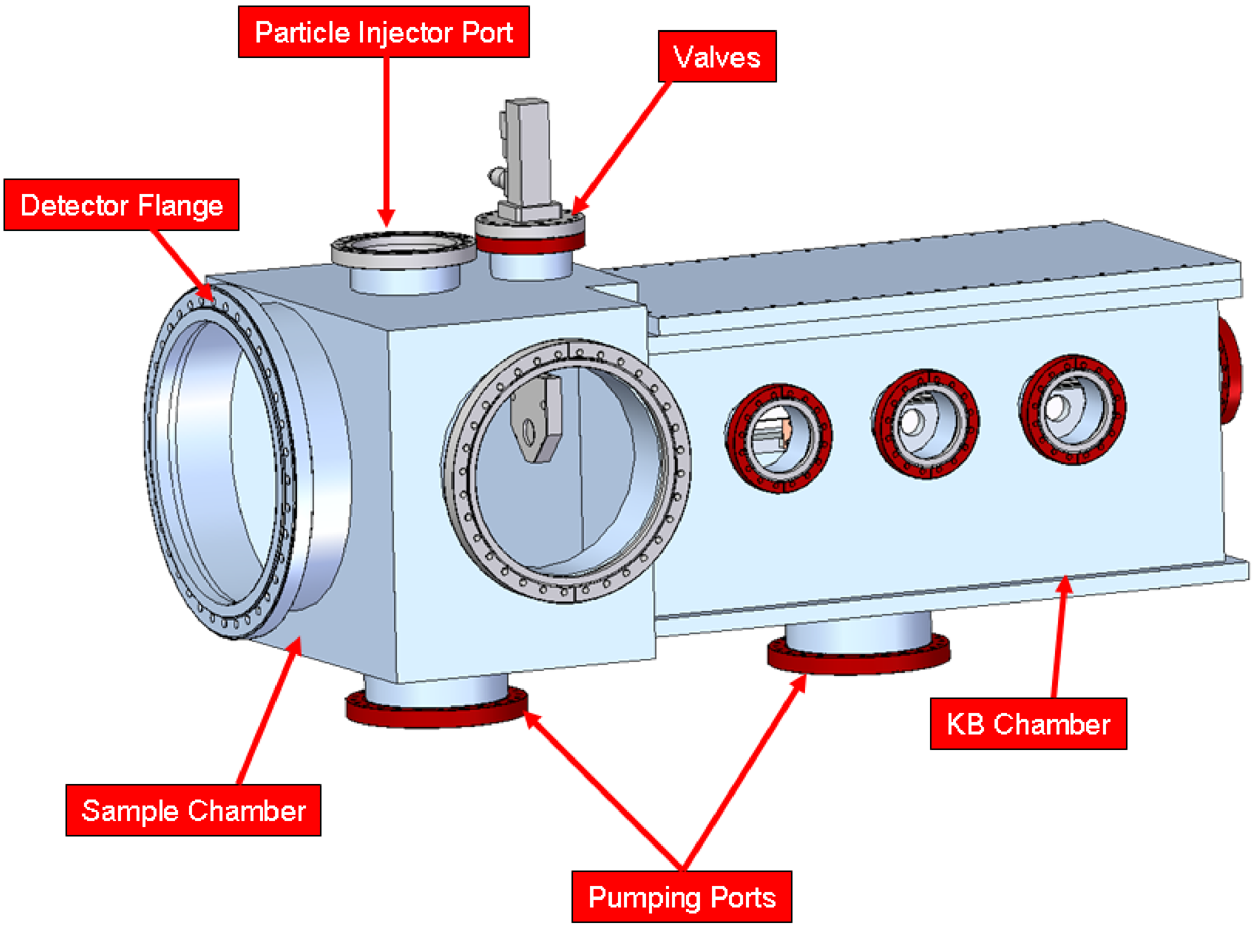

Figure 6: Conceptual design of the 0.1 micron Sample Chamber and 0.1 micron KB assembly. The Particle Injector port is located directly above the interaction region.

4.2.12. Dusting Wafer

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43.

4.2.13. Particle Beam Aperture Assembly

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43.

See Figure 7.

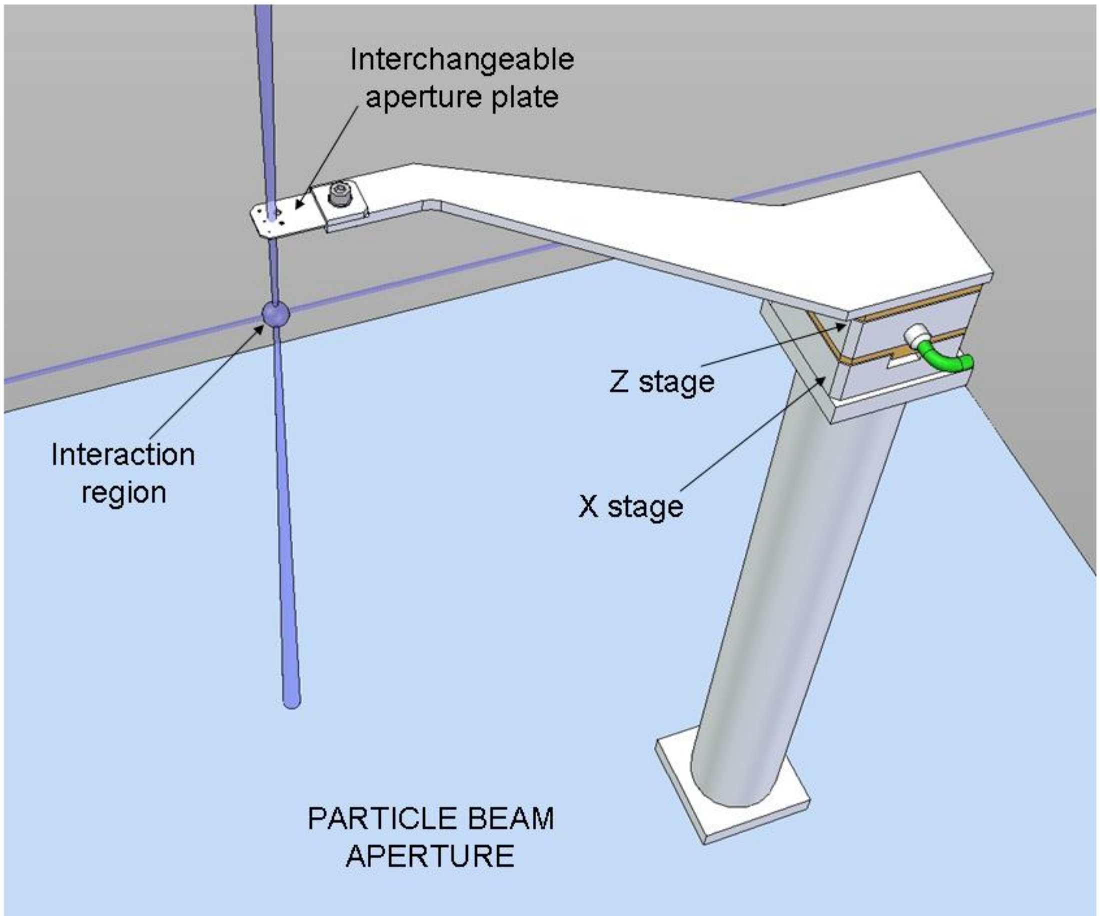

Figure 7: Particle beam aperture assembly

4.2.14. First Charge Detector

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43.

4.2.15. Second Charge Detector

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43.

4.2.16. Faraday Cup

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43.

4.2.17. Particle Beam Dump

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43.

4.2.18. Hatch

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43. The hatch shall attach to a large flange on the side of the Sample Chamber as shown on Figure 6.

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

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43.

4.2.20. Desorption-Ionization Laser Ports

The same requirements as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43 apply. Due to the different size and shape of the 0.1 micron Sample Chamber, the exact location of the ports may be different. As many potential ports for lasers as possible shall be provided.

4.2.21. Particle Alignment Laser Ports

The same requirements as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43 apply. Due to the different size and shape of the 0.1 micron Sample Chamber, the exact location of the ports may be different. As many potential ports for lasers as possible shall be provided.

4.2.22. Pump Laser Ports

The same requirements as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43 apply. Due to the different size and shape of the 0.1 micron Sample Chamber, the exact location of the ports may be different. As many potential ports for lasers as possible shall be provided.

4.2.23. Electron TOF Mass Spectrometer

The same requirements as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43 apply. Due to the different size and shape of the 0.1 micron Sample Chamber, the exact location of the port may be different.

4.2.24. Aperture Wafers

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43.

4.2.25. Sample and Aperture Holders

Same as for the 1 micron Sample Chamber described in SLAC document ESD# SP-391-001-43.

5. Mechanical Requirements

5.1. Performance Requirements

5.1.1. Chamber Positioning Requirements

5.1.1.1. A fixed point inside the chamber, the interaction point, shall be located at the focal plane of the 0.1 micron KB System which is described in PRD SP-391-000-24 and ESD SP-391-000-64.

5.1.1.2. The location of the 0.1 micron Sample Chamber is determined by the position of the 0.1 micron KB System since they are located in the same vacuum enclosure, as shown on Figure 6.

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

5.2. Cyclic Requirements

5.2.1. First Aperture Assembly

x and y stage	50X 20 μm/day for 30 days/year

5.2.2. Second Aperture Assembly

x and y stage	50X 20 μm/day for 30 days/year

5.2.3. Third Aperture Assembly

x, y and z stage	4000X 20 μm/day for 30 days/year

5.2.4. Sample (Fourth Aperture) Assembly

x, y and z stage	4000X 20 μm/day for 30 days/year
pico motor/fine pitch	4000X 1 μm/day for 30 days/year
stepper motor/course pitch	360X 1 degree/day for 30 day/year (4X 0.25 degree steps)

5.2.5. Long Range X-Motion Stage Assembly

x stage	1000X full range/day for 30 day/year

5.2.6. Particle Aperture Assembly

x and z stage	50X 1 mm/day for 30 days/year

5.2.7. Sample Viewer

Pico motor	20X 1 μm/day for 30 day/year

5.3. Mechanical Requirements

5.3.1. Size

The 0.1 micron Sample Chamber shall be sufficiently large to accommodate all forward scattering configurations described in PRD SP-391-000-19.

5.3.2. Door

The chamber shall be equipped with an access door on the +X-side, to load samples and change experiment configurations. The sealing of this door shall be compatible with UHV (10^{-9} Torr or better) operation. View ports with their axis in the interaction region focal plane will be provided on the door.

5.3.3. Pump Location

The vacuum pump(s) attached to the chamber shall be installed so that no object can be dropped in it (them). See also 5.4.1 and 5.5.5.

5.4. Mechanical Interfaces

5.4.1. Turbo Pump Cross and Turbo Pump Cross Ports

A separate T-shaped 13.25" flange cross shall be attached below the main 0.1 micron Sample Chamber to mount a turbo molecular pump with its gate valve.

This T-shaped section shall have the following additional ports.

- One non-rotatable minimum 6" CF at the bottom for introducing a particle beam dump or a laser beam propagating along the particle beam.
- Four non-rotatable 8" electrical feed through CFs for all in-vacuum positioners, motors and signal cables.
- One additional flange for rough pumping of the chamber.

The mating flange at the Sample Chamber shall be a rotatable 13.25" CF.

5.4.2. Particle Injector Port

A non-rotatable 8" CF shall be provided for the particle injector, vertically mounted directly above the interaction region.

5.4.3. Detector and Upstream Connection to the 0.1 micron KB System

The Sample Chamber shall be sufficiently large to allow a reentrant 2D X-Ray Detector at the 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 and ESD SP-391-000-70. The port will allow for a maximum 11.25" diameter detector to be introduced thru it. The detector port is shown conceptually on Figure 8.

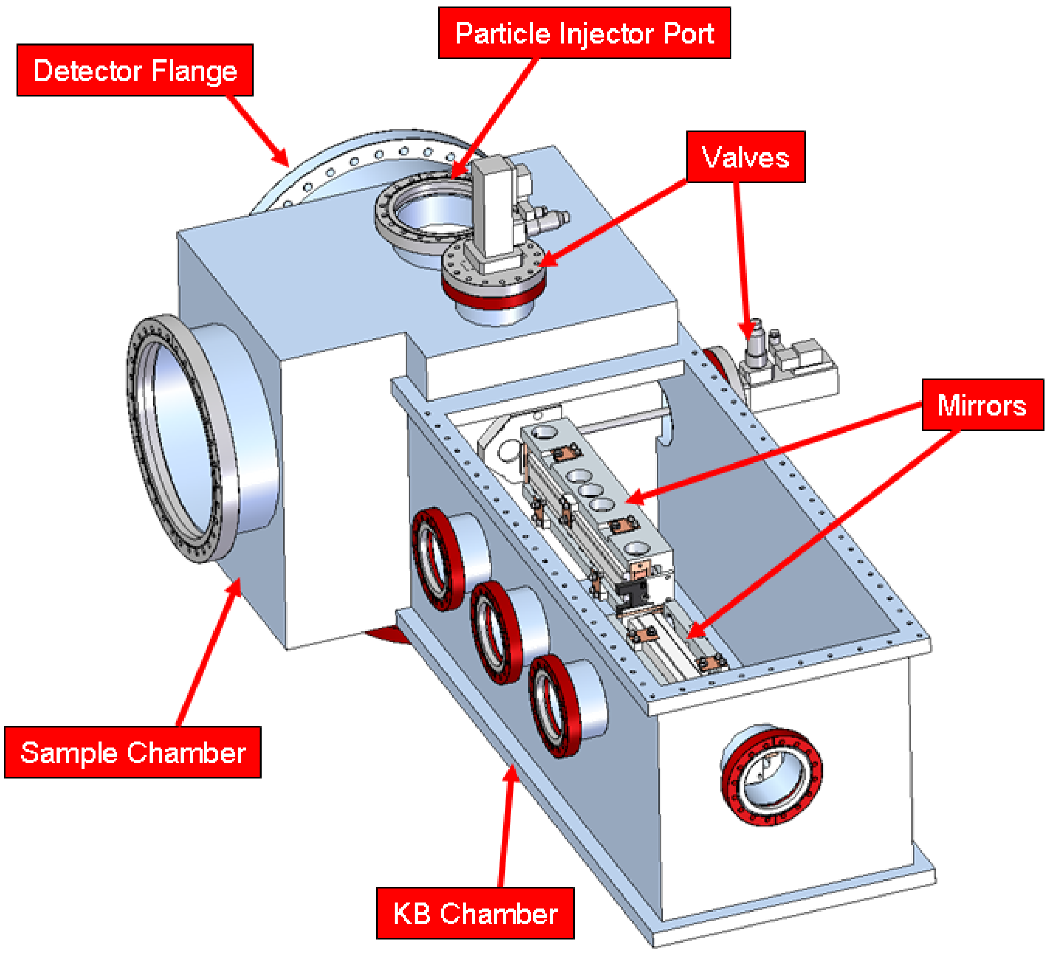

Figure 8: Conceptual design of the 0.1 micron Sample Chamber and 0.1 micron KB System assembly. A large detector flange is required on the downstream end and the two parts of the vacuum enclosure are separated by two custom valve systems, one on each side of the wall..

Due to the close proximity of the 0.1 micron KB System, the 0.1 micron Sample Chamber shall be part of the same weldment as the KB System. A wall with a small (10-15 mm) hole shall separate the Sample Chamber area from the KB mirror area. This wall shall be sufficiently thick and strong to allow, with the addition of a custom-made valve, to vent the Sample Chamber to atmosphere while the mirror portion of the chamber is kept under Ultra-High Vacuum. A concept for the separation wall and the custom valve is shown on Figure 6, Figure 8, Figure 9, Figure 10 and **Error! Reference source not found.** .

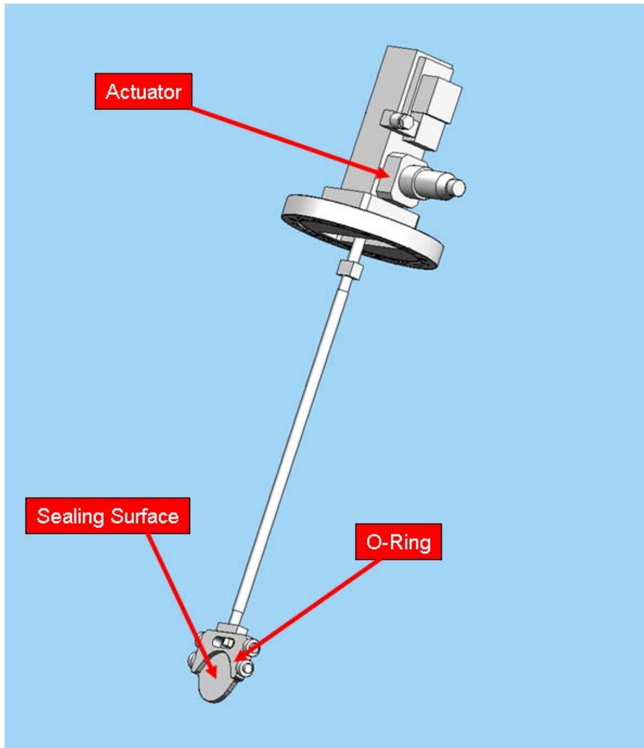

Figure 9: Design of a plunger system for a custom valve separating the two parts of the vacuum enclosure. This plunger is inserted into the fixed receptacle shown in Figure 10.

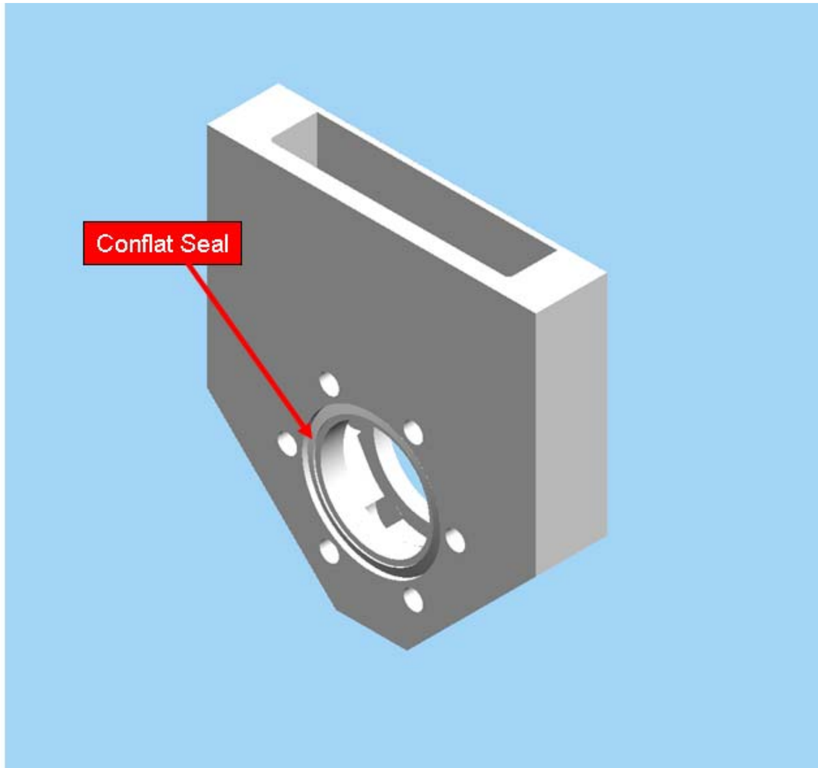

Figure 10: Conceptual design, receptacle part of a custom valve separating the two parts of the vacuum enclosure.

The downstream adapter flange (to a fixed 19-9/16" wire seal flange) shall be a rotatable 14" CF.

The downstream port will receive a gate valve equipped with optically transparent windows to allow the reference laser to pass through. The custom valve between the sample volume and the KB volume will also have an optically transparent window.

5.4.4. Ion TOF Port

A rotatable CF, not larger than 8", shall be provided with its axis aiming at the interaction region and preferably in the XY-focal plane.

5.4.5. Electron TOF Port

A rotatable CF, not larger than 8", shall be provided with its axis aiming at the interaction region and preferably in the XY-focal plane.

5.4.6. Sample Viewer Ports

A 4.625" CF shall be provided to view the sample online (sample view in the axis of FEL beam) with the Sample Viewer.

5.4.7. View Ports

- At least three view ports with their axis aiming at the interaction region and in the XY focal plane shall be provided to introduce lasers. At least one of these ports shall have a matching mate (fourth view port) on its axis on the other side of the chamber to allow the exit of the laser. One of the ports can be mounted on the door.
- Two extra view ports looking from both at an upstream angle and a downstream angle at the interaction region shall be provided. They shall have an unimpeded view of the interaction region for all experimental configurations.
- One laser port at the bottom of the 0.1 micron Sample Chamber shall 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 and the Particle Beam Dump are removed. Removal of the Second Charge Detector may not be necessary.
- A view port shall be provided for the sample viewer. This port shall have direct sight onto a mirror assembly to view in parallel with the beam.
- The viewport locations of the 1 micron Sample Chamber shall be replicated, to the extent possible, in the 0.1 micron Sample Chamber.

5.4.8. Miscellaneous Ports

- Three rotatable 8" CFs shall be provided for electrical or water feedthroughs.
- Four fixed 2.75" CFs shall allow for vacuum accessories and control (angle valve, vacuum gauge, burst disk, spare).

5.5. Vacuum Requirements

5.5.1. The Sample Chamber shall operate with a 10^{-7} Torr pressure environment or better under all operating conditions, with the potential for operations under UHV (10^{-9} Torr or better) when operating conditions allow it. The appropriate vacuum practice for the design, manufacturing, and installation of the system components shall be implemented.

5.5.2. The chamber shall be leak tested before assembly.

5.5.3. All lubricants, cutting fluids, etc., used in manufacturing shall be "sulfur-free". SLAC document No. SC-700-866-47 is a compendium of SLAC approved lubricants. The use of sanding discs, abrasive paper or grinding wheels is typically prohibited. In special circumstances good vacuum practices should be followed when grinding and polishing is required. This process shall be reviewed and approved by the engineer for its vacuum compatibility.

5.5.4. All parts and subassemblies shall be cleaned for UHV. Once parts are cleaned for vacuum, handle only with clean latex or nitrile gloves in/on a clean room/surface. This includes all subassemblies. For storage or transportation, place in clean sealed vacuum grade plastic bag that has been back-filled with nitrogen.

5.5.5. 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.

5.5.6. It shall be possible to vent the Sample Chamber to air while maintaining ultra-high vacuum upstream and high vacuum downstream of the chamber. This implies that a custom made valve is required between the sample volume and the KB mirror volume as shown on Figure 8.

5.5.7. It shall be possible to leave the chamber turbo pump turned on while the chamber is vented to air.

5.5.8. 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.

5.5.9. The Sample Chamber shall be isolated from the upstream and downstream chambers by valves equipped with view ports to allow the reference laser to pass.

5.5.10. Separation Between the Sample and Mirror Vacuum

Under some experimental conditions, the vacuum level inside the 0.1 micron Sample Chamber will not meet the stringent requirements for the vacuum of the 0.1 micron KB System. In order to allow the valve separating the Sample Chamber from the KB system to be opened, it may be necessary to separate the vacuum areas.

- Thin Non-Vacuum Holding Window

It shall be possible to insert a thin (10-20 microns thick) X-ray transmissive window (either Si, Be or Diamond) between the KB mirrors and the focal plane. A tight seal shall exist between this window and the separation wall so that the sample chamber vacuum cannot contaminate the vacuum of the mirrors. A concept for this window is shown below. This window can be mounted on the custom valve assembly. This solution requires two custom valves in series as shown on Figure 8. The first valve will be capable of holding vacuum when the Sample Chamber is vented to atmosphere while the second valve will only provide an X-ray transmissive barrier when both sides of the vacuum enclosure are evacuated and the pressure difference is small ($10^{-9} – 10^{-7}$ torr)

5.6. Materials

All parts and materials for the device shall be new and compatible with the performance requirements of this specification. Mil source certifications, including heat number, chemical analysis for all materials used in the manufacturing of the device shall be furnished. The device will be used in a radiation environment. Use of Teflon is specifically prohibited.

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

5.7. Structural Issues

The 0.1 micron Precision Instrument Stand, which supports the 0.1 micron Sample Chamber and the 0.1 micron KB System, shall provide enough stability to fulfill the repeatability requirements in Table 3. The Sample Chamber shall be mounted directly to the upper frame of the stand. The telescope shall also be mounted directly to the Sample Chamber to avoid relative motion to the sample area.

The door shall be mounted in such a way that self-opening or self-closing is avoided.

5.8. Precision Motion

5.8.1. Out-Of-Vacuum-Motion Requirements (Chamber Motion)

The 0.1 micron Sample Chamber shall be fixed in space and its alignment shall be determined by the positioning requirements of the 0.1 micron KB mirror, as described in document ESD# SP-391-000-64.

5.8.2. In-Vacuum-Motion Requirements

Motorized motions summarized in Table 3 shall be provided for components inside the Sample Chamber.

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. These internal components shall be identical to the corresponding internal components of the 1 micron Sample Chamber, to the extent possible.

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 < 350 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 - course	0 degree	±180°	10 mrad	20 mrad	≤ 10^{-7} Torr
Sample pitch - fine	0 degree	±5°	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	-15 mm	-25 mm < z < -5 mm	≤ 0.1 μm	≤ 0.3 μm	≤ 10^{-7} Torr
Time-delay mirror pitch - fine	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 3: Motion requirements for inside chamber components. (x,y,z)=(0,0,0) is defined as the interaction point

5.9. Lifting Features

Lifting fixtures shall be provided as part of the 0.1 micron KB system vacuum enclosure.

5.10. Alignment/Fiducialization

The alignment of the 0.1 micron Sample Chamber shall be entirely dictated by the alignment of the 0.1 micron KB mirrors.

5.11. Stability

The mount of the chamber shall be stable and respond to all applicable seismic requirements. The door shall open easily and stable enough to allow for proper seal. The sample area support plate shall be stable enough to support all mounted components and to allow required repeatability.

5.12. Kinematics/Supports

The Sample Chamber shall be supported in the same way as the 0.1 micron KB System, on the same fixed stand.

6. Electrical Requirements

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

The interface from the control racks to the 0.1 micron Sample Chamber (cable trays and routing, connector supports, etc.) will be determined jointly with the Controls/Data Acquisition Group.

6.1. Electrical Feedthroughs for Motion Controls

6.1.1. Electrical Feedthroughs for Motion Controls

The following electrical feedthrough connectors shall be present for motion controls:

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

6.1.2. Electrical Feedthroughs for Signals

The following feedthrough connectors shall be present for signals:

- 2 charge detector multi-pin 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)

6.1.3. Connectors

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.

6.1.4. Safety

To comply with OSHA/DOE regulations, all electronics will have certification either through a National Recognized Testing Laboratory (NRTL) or the Authority Having Jurisdiction (AHJ) as per the SLAC Electrical Equipment Inspection Program.

7. Major Interfaces

7.1. Sample Area

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

7.1.2. 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.

7.2. Sample Chamber and Detector

7.2.1. The 0.1 micron Sample Chamber shall interface with the CXI Detector Stage on the downstream side. The CXI Detector Stage shall be supported on a separate stand from the 0.1 micron Sample Chamber. A bellows at the upstream end of the Detector Stage shall allow proper relative alignment of the two devices.

7.2.2. The Sample Chamber shall interface with the 0.1 micron KB System on the upstream side.

8. Controls

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.

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

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

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

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

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

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

8.7. 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.

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

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

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

8.11. 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.

8.12. 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.

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

8.14. 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.

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

8.16. 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.

8.17. 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.

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

8.19. A pumping and venting sequence shall be developed to prevent the thin window from damage due to pressure differentials.

9. Environmental Safety and Health Requirements

9.1. Seismic

SLAC National Accelerator Laboratory (SLAC) is situated in an active seismic zone. All hardware exceeding a weight of 400 Lbs. and / or mounted greater than 4 feet above the floor will be reviewed by a SLAC "citizen safety committee" for seismic loading resistance. Applicable loads and structural behavior will be evaluated for compliance to the 2007 version of the California Building Code (CBC) and SLAC ES&H Division document

SLAC-I-720-0A24E-001-R002: "Seismic Design Specification for Buildings, Structures, Equipment, and Systems".

Submission of the seismic calculations shall be provided for SLAC approval prior to the start of manufacturing. (Allow for at least one month of time for seismic approval.)

9.2. Radiation Physics

No supplemental radiation shielding will be required for the 0.1 micron Sample Chamber.

9.3. Pressure Vessel/Vacuum Vessel

The 0.1 micron Sample Chamber shall be designed for use in a Ultra-High Vacuum environment with the appropriate safety factors.

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