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LUSI Pulse Picker System

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R0	01DEC08	Initial release	

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1. Overview

The LUSI instruments require the ability to reduce the repetition rate of the LCLS pulse train. This document describes the requirements of a Pulse Picker system that performs this task.

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

2. Applicable Documents, Specifications and Codes

2.1. Stanford Linear Accelerator Center (SLAC) Specifications

The following documents are cited in this specification by the reference numbers given below.

1. SP-391-000-23	Physics Requirements for the LUSI Pulse Picker System
2. SP-391-001-45	LUSI XPP Instrument to DCO ICD
3. AD-391-900-00	Attenuator Device Top Assembly
4. SP-391-000-60	Engineering Specification for the Attenuator Device
5. LCLS PRD 1.1-014	LCLS Beam Parameters PRD
6. LCLS 1.9-1017	LCLS Room Data Sheet, Near Experimental Hall Overall, Revision 2
7. LCLS 1.9-1037	LCLS Room Data Sheet, Far Experimental Hall Overall, Revision 2
8. TBD	X-Ray Transport Tunnel Environment
9. DS-391-000-36	Design Standards Supplement
10. FP-202-631-14	Fabrication of UHV Components

2.2. Acronyms

CXI	Coherent X-Ray Imaging
EVR	Event Receiver
FEH	Far Experimental Hall
FWHM	Full Width Half Max
MEE	Matter under Extreme Environments
MPS	Machine Protection System
NEH	Near Experimental Hall
SASE	Self amplifying spontaneous emission (lasing)
XCS	X-Ray Correlation Spectroscopy
XPP	X-Ray Pump Probe
XTOD	X-Ray Transport Optics And Diagnostics
XRT	X-Ray Transport Tunnel

3. General Requirements

3.1. Location

- XPP: The Pulse Picker will be mounted to the Attenuator, which will be mounted on a common support with the other optics in this segment in Hutch 3.
- XCS: The Pulse Picker will be mounted to the Attenuator, which will be mounted on a common support with the other optics in this segment. It may be located at the end of the X-Ray Transport Tunnel (XRT), or the beginning of Hutch 4.
- CXI: Pulse Picker will be mounted to the Attenuator, which will be mounted on a common support with the other optics in this segment at the end of the X-ray Transport Tunnel.

3.2. Space Constraints

The volumetric envelope for the Pulse Picker Device is such that that the Pulse Picker shutter assembly fully resides within the Attenuator Chamber and therefore has no specific size constraints. The vertical stage that translates the Pulse Picker shutter assembly up and down is sufficiently small enough that it fits well within the +/-X directions/dimensions of the Attenuator Device, so it also has no specific size constraints. Additionally, there is no +Y constraint on the height of the Vertical stage. The volumetric envelope for the Attenuator Device is shown in Reference 2. The coordinate system is listed in Reference 9.

3.3. Environment

The Pulse Picker Device will be installed in both a lab environment and a tunnel environment. The design is driven by the worst case environment, the XRT. The temperature and humidity requirements were derived from References 6, 7 and 8.

- Temperature: 72°F +/- 5°F. Temperature stability is not a critical issue for this device. The temperature will vary diurnally in the XRT.
- Humidity: Attenuator shall be capable of operating in 50 +/- 30% relative humidity environment.
- Vibration: The Pulse Picker vibration environment is a function of how the facility generated vibrations are transmitted through the Optics raft and the 6 degree of freedom mount (Section 4.11) to the device. In order to avoid interactions with lower frequency and higher amplitude facility vibrations, the Attenuator chamber, which the Pulse Picker mounts to, shall have a fundamental mode of vibration greater than 120 Hz.
- Radiation: The Pulse Picker shall be capable of withstanding 1 Krads/year for its lifetime as defined in Section 4.4.

- The Pulse Picker shall incorporate covers to protect personnel from moving parts, in addition to keeping airborne dust from settling on moving parts and bellows.

3.4. Maintenance, Accessibility and Operations

The Pulse Picker Device shall be individually accessible and removable/replaceable in the field. Vacuum may be broken to facilitate accessibility.

3.5. Lifetime

The service life of the device shall be 10 years, minimum.

4. Mechanical Requirements

4.1. Performance Requirements

- The FEL beam characteristics including FWHM spot size, energy per pulse and spectral range as defined in Reference 5 shall be used for design purposes.
- The Pulse Picker system shall have the capability of reducing the repetition rate of the LCLS X-ray pulse train to any frequency from zero Hz to 10 Hz.
- The Pulse Picker shall have the ability to select any random pattern of pulses provided the pattern corresponds to an average rate of equal to or less than 10 Hz. Each shutter opening within the pattern shall be synchronized with the LCLS pulses.
- The Pulse Picker shall have an opening time and closing time of 3 msec or less.
- The Pulse Picker shall have the ability to perform one open and close cycle in less than 8 msec.
- The Pulse Picker shall have the ability to remain open for as long as desired.
- The Pulse Picker shall have the ability to remain closed for as long as desired.
- The Pulse Picker must withstand the full LCLS flux (white beam) at all locations downstream of and including NEH Hutch 2, across the 2-25 keV spectral range without degradation due to radiation damage. The beam parameters in Hutch 2 can be calculated from the parameters listed per Reference 5.
- The transmission through the Pulse Picker, with the shutter in the closed position, shall be no more than 10^{-11} throughout the entire spectral range of 2-25 keV.
- Reflection of the beam off the Pulse Picker shall not be allowed to propagate down the beamline.

4.2. Aperture Requirement

- A clear aperture of 3.5 mm must be present for the LCLS beam when the shutter is in the open position.

4.3. Positioning Requirements

- Two operating positions shall exist for the Pulse Picker shutter assembly: "IN" or "OUT". The following positioning requirements are relative to the theoretical beam centerline in the Attenuator Device, which the Pulse Picker will be mounted to, as defined in Reference 2. See Section 4.9 for alignment requirements for the entire device.
  - When in the "IN" position, the LCLS beam shall propagate through the center of the Pulse Picker aperture within less than or equal to 50 microns.
  - The accuracy and repeatability of the "IN" position of the Pulse Picker aperture shall be less than or equal to 50 microns.
  - In the "OUT" position, a minimum stay clear radius of 12.7 mm from the theoretical beam centerline shall be maintained.
- Remote operation:
  - The Pulse Picker design shall include a remotely operated mechanism for moving the Pulse Picker head to the IN or OUT position without breaking vacuum. This IN to OUT and OUT to IN translation should occur in less than 60 seconds.
  - The Pulse Picker shutter operation (open, closed or actuating) shall also be able to be controlled remotely.

4.4. Life Cycle Requirements

- The vertical linear actuator on the Pulse Picker may be cycled up to 5 times daily, 60 days a year for 10 years (or roughly 3,000 cycles) at 72 +/-5° F and 10^{-7} Torr pressure. The motor driving this linear actuation is outside of vacuum and a bellows is used in the system.
- The shutter mechanism on the Pulse Picker may be cycled up to 10,000 times daily (16.7 minutes at 10 Hz), 60 days a year for 10 years (or roughly 6 million cycles) at 72 +/-5° F and 10^{-7} Torr pressure. The shutter frequency can be anywhere from zero to ten Hz, or any irregular pattern of pulse selection, but for the majority of the run time the shutter will be running in the 0.01 Hz to 1.0 Hz range.

4.5. Mechanical Interfaces

- The flanges of the vacuum system that connect to the LCLS beamline shall be per Reference 2. The Attenuator Chamber flange that the Pulse Picker will mount to shall be a 6 inch diameter non-rotatable CF flange.
- The Attenuator shall be supported per Reference 2 and Section 4.11.

4.6. Vacuum

- The Pulse Picker will reside in a 10^{-7} Torr pressure environment and the appropriate vacuum practice for the design, manufacturing, and installation of the system components shall be implemented. Manufacturing, cleaning, handling, storage and leak testing operations shall be per Reference 10.
- The Pulse Picker design shall allow for visual inspection in the field or remote inspection (depending on it's location) by the means of a video camera, while the system is under vacuum.

4.7. Materials

- All parts and materials for the device shall be new and compatible with the performance requirements of this specification. Mill source certifications, including heat number and chemical analysis, for all materials used in the manufacturing of the device shall be furnished per Reference 10.
- The use of Teflon is specifically prohibited.

4.8. Thermal Issues

The Pulse Picker Shutter shall be able to withstand, without degradation, a heat load of 240 mW from the X-Ray beam. Refer to section 8.2 for the length of time this may occur.

4.9. Alignment/Fiducialization

During installation, the Attenuator chamber that the Pulse Picker mounts to shall be aligned such that the as-measured centerline shall lie along the nominal beam centerline. Chamber position (x, y, z, pitch, roll, yaw) shall be recorded. Fiducialization (likely using tooling balls) shall be performed to ensure compliance with positioning requirements noted in section 4.3.

4.10. Stability

- The Pulse Picker should be thermally stable within 50 microns, or less, over a period of one week.
- The Pulse Picker shall be stable due to induced vibrations such that the vibration amplitude at frequencies above 1 Hz shall be less than 10 microns, additionally, the angular vibration amplitude at frequencies above 1 Hz shall be less than +/-0.5 degrees (pitch, yaw).

4.11. Kinematics/Supports

The Pulse Picker Device will be mounted to the Attenuator Chamber which will be mounted to a 6 degree of freedom mount that allows precise centering and aligning of theoretical beam centerline of the Pulse Picker Device to the actual FEL beam path.

5. Electrical Requirement

The shutter opening and closing as well as the vertical positioning stage of the Pulse Picker are required to be controlled remotely via the corresponding instrument's control system.

6. Inspections, Test Provisions and Testing

Reserved.

7. Major Interfaces

- The Pulse Picker Device is fixed in position on the Optics raft in Hutch 3 (XPP) and moves with it. All external connections shall be flexible and allow for 1 meter of translation in X. The same flexible external connections are required on the Pulse Picker Device in Hutch 4 (XCS).

- The Pulse Picker Device in the CXI beamline is fixed in place. Normal external connections can be applied at this device location.

8. Controls

8.1. Motion Control

- Remote operation of the shutter frequency and vertical positioning stage of the Pulse Picker are required.
- The body of the Pulse Picker Device shall move out of the beam path such that the nearest physical part of the Pulse Picker will be at least 12.7 mm away from the beam centerline.
- Actuation of the shutter shall be initiated/controlled by the EVR system.

8.2. Feedback

- A video signal showing the view of the Pulse Picker shutter actuation status (open, closed or actuating) is required on the Pulse Picker located in the XRT and will be obtained via an appropriately mounted video camera. This video signal shall produce an image that shall be displayed at the instrument control console when desired by the user at a frame rate of 30 Hz. Pulse Pickers in other areas require only viewport/s, in order to allow personnel the ability to view the shutter actuation status.
- The state of the all Pulse Picker shutter and shutter speed/frequency shall be recorded in the experimental metadata.

- The status of the vertical positioning stage of all Pulse Pickers shall be recorded in the experimental metadata.
- Coordination is required between the PPS Photon Stopper and the Pulse Picker, via a signal, such that anytime the shutter is left in the closed position, with the beam impinging upon the shutter, for a period of time greater than TBD minutes, that the PPS Photon Stopper will be signaled to stop the beam.
- Coordination is required between the PPS Photon Stopper and the Pulse Picker, via a interlock, such that anytime the shutter is signaled to move out of or into the beam path the PPS Photon Stopper will be signaled to stop the beam.

8.3. Fail Safe

- The vertical positioning stage of the Pulse Picker shall default to the "OUT" position in the event of a system fault, as defined in Section 4.3.

9. Quality Assurance

Reserved

10. Environmental Safety and Health Requirements

10.1. Earthquake

No special design requirements are necessary for the Pulse Picker Device relative to earthquake safety issues.

10.2. Radiation Physics

The Pulse Picker Devices will be located in radiologically controlled areas and there are no radiation physics issues.

10.3. Pressure Vessel/Vacuum Vessel

- The Pulse Picker Device shall be designed for use in an Ultra High Vacuum (UHV) environment with the appropriate safety factors.
- Pressure relief safe guards will be provided at a higher level assembly.

10.4. Safety Requirements

- Any radiation produced by the interaction of the LCLS beam with the Pulse Picker shall be absorbed with the use of slits or shields so that it does not propagate down the beamline.
- Reflections of the LCLS off the Pulse Picker shall not be allowed to hit the walls of the vacuum enclosure at any point downstream of the pulse picker (refer to Section 4.1).