LUSI
LCLS Ultrafast Science Instruments

PHYSICS REQUIREMENT DOCUMENT (PRD)	Doc. No. SP-391-000-15 R0	LUSI SUB-SYSTEM Diagnostics/Optics

Physics Requirements for LUSI Wavefront Monitor

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1. Overview

The LCLS FEL beam exhibits intrinsic fluctuations in source point, transverse positions, and mode composition on a pulse-by-pulse basis. When the X-ray beam is focused to a very tight spot as small as 0.1 μm on the CXI instrument and used for diffraction experiments, a diagnostic device is required to characterize the wavefront of the beam at the focal spot. Due to the extremely high peak power at the focal point, this device can only be used at measurement plane far from the focus whereby the 2-dimensional intensity profile of the beam is captured and used to extract quantitative measurement of the wavefront by using known reconstruction algorithms. This document describes the physics requirements of this wavefront measurement device.

The coordinate system is defined in Design Standards Supplement DS31100036.

2. Requirements

2.1. Performance Requirements

2.1.1. The wavefront monitor shall be designed to capture 2-dimensional images of the X-ray beam in the XY plane to determine the X-ray beam spatial shape, centroid, and intensity.

2.1.2. The wavefront monitor shall be designed to work for X-ray energies from 2 keV up to 25 keV.

2.1.3. At high X-ray fluences, attenuation of the X-ray beam is acceptable to avoid saturation and potential permanent damage of the sensor.

2.1.4. There shall be the capability of providing attenuation just before the monitor but after the sample interaction point.

2.1.5. The wavefront monitor per instrument shall be capable of capturing images on a pulse-by-pulse basis.

2.1.6. The wavefront monitor shall be designed to operate in variable field of view (FOV) with a maximum FOV of 12x12 mm^2 and a minimum FOV of 1x1 mm^2.

2.1.7. The wavefront monitor shall have a spatial resolution of 50 μm and 4 μm in the large and narrow FOV respectively.

2.1.8. Then profile shall have 256 grey levels or 8 bits for intensity measurements with the design goal of 1024 or 10 bits.

2.2. Mechanical

2.2.1. Two operating positions are required for the wavefront monitor: 'In' and 'Out'.

2.2.2. The wavefront monitor state should have the ability to be changed in ~ 3 seconds.

2.2.3. When in the 'In' position, the nominal LCLS beam shall impinge at the center of the sensor to within 10% of the sensor size and the surface normal of each sensor shall be aligned to the z-axis of the LCLS coordinate system to within ±1°. This can be achieved manually.

2.2.4. A translational repeatability of 50 microns and a rotational repeatability (pitch and yaw) of 0.1° shall be maintained when the sensor is placed in the 'In' position.

2.2.5. A minimum stay clear radius of 0.5" will be maintained when the sensor is in the 'Out' position.

2.2.6. The design of the wavefront monitor should be compatible with the overall design of all

instruments (XPP, CXI and XCS).

2.2.7. The design of the wavefront monitor should permit replacement of the sensor in the field.

2.3. Vacuum

2.3.1. The wavefront monitor 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.

2.4. Controls and Data Systems

2.4.1. The wavefront monitor state, FOV operation mode and frame acquisition shall be controlled remotely.

2.4.2. There shall be the capability of displaying the profile image for visual inspection of single pulses at a rate of 30 frames/sec (retinal persistence).

2.4.3. There shall be the capability of capturing the profile images at a rate of 120 frames/sec for the per pulse operation.

2.4.4. There shall be rudimentary image processing of the captured frames to characterize the X-ray beam including, but not limited to: beam centroid, X and Y FWHM of the intensity profile, and estimating peak intensity. More complicated processing may involve averaging of multiple images, and calculating certain statistical quantities such as beam position jitters.

2.4.5. The wavefront monitor must allow the capability of saving images and/or image processing data described in 2.4.4.

2.4.6. The operation of the monitor shall be constrained by the status of other optical components to prevent potential damages.