Stanford Linear Accelerator Center
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LCLS Engineering Specification Document # 1.4–110 LCLS Document # L1450204-00037	Undulator Wire Scanner Beam Profiler	Revision 00

Technical Specifications for the Undulator Wire Scanner Beam Profiler (Long Break)

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Brief Summary: This document defines requirements for the scanning wire electron beam profilers that are to be used in the Linear Coherence Light Source undulator system.

Keywords: Undulator, diagnostics, instrument, specification, scanning wire, electron beam profile measurement

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1.0 INTRODUCTION

1.1 Purpose

This Engineering Specification Document (ESD), in conjunction with the associated fabrication specifications and drawings, defines the requirements for the wire scanner beam profiling system that is to be used in the Linac Coherence Light Source (LCLS) undulator system.

The purpose of the wire scanner is to provide high-resolution measurement of the electron beam profile over multiple shots. It is based on direct interaction of the electron beam with a thin wire, and the assumption that the flux of secondary product is proportional to the intensity of the electron beam passing through the wire. The secondary products currently include scattered high-energy electrons, gamma ray photons, and secondary electron current. The LCLS wire scanner will be used in all long break sections.

A second, potential use of the wire scanner system is to provide high-resolution measurement of x-ray beam profile averaged over multiple shots. It will be based on diffraction or absorption of x-ray photons on the surface layer, and based on the assumption that the flux of secondary product is proportional to the intensity of the x-ray beam impacting the wire. The secondary products currently include diffracted x-ray photons and fluorescence x-ray photons. This use is being studied and the related specification will be added at a later date.

1.2 Scope

This ESD defines the requirements for the design, materials, inspection, and packaging of the LCLS wire scanner system.

1.3 Required Equipment

This ESD specifies the requirement for the design, fabrication, and testing of the wire scanner system assembly.

In-vacuum motion components shall be prototyped, tested, and evaluated in a vacuum test chamber. The equipment required for this testing will be specified in a separate document. In addition, prototype assemblies will be tested for positioning accuracy both under air and vacuum conditions. Equipment required for these tests is specified under a separate document.

Equipment required for inspection and testing of the final article will be specified in a separate document.

2.0 TECHNICAL REQUIREMENTS

The Advanced Photon Source/Argonne National Laboratory (APS/ANL) shall supply the detail drawings and procurement specification for fabrication of parts and purchasing of catalog items. Vendors shall supply parts in accordance with these documents. Any deviations from these documents must be approved in writing by APS/ANL.

General requirements for materials, fabrication, cleaning and surface treatment, handling and assembly, welding and brazing, quality assurance and testing, and preparation for delivery will be specified in a separate document.

2.1 Spatial Resolution

The spatial resolution is the most important performance specification of a profile measurement system. With the current design, the rms electron beam sizes in the undulator will be from 37 μm (at 13.6 GeV) to 55 μm (at 4.3 GeV). A 12 μm rms system resolution will be sufficient for accurate measurement of the electron beam profile. This resolution requirement is the key consideration in the specifications for components.

2.2 Overall Positioning Accuracy

The minimum rms radius of the electron beam in the LCLS undulator is 37 μm. Using 10% beam size over the range of 10 beam radii as the tolerance of wire motion, we derive the following requirements for its linear motion. Theoretically, the error on the wire position along the beam direction or the wire direction can be fairly larger. In practice, motions in the three degrees of freedom are slightly coupled. Thus we assigned 15 μm as their tolerance.

Table 1 ---Tolerance of errors in wire scanner linear motion

Direction of Motion	Tolerance	Notes
Axial	4 μm over 0.4 mm	Effect on all three wires.
Transverse (beam direction)	15 μm over 0.3 mm	
Second transverse direction	15 μm over 0.3 mm	Effect on 45 degree wires only.

2.3 Wire Scanner Assembly

The wire scanner will include the following components:

1. A linear guide with adequate load capacity and micron-accuracy linear motion.
2. A linear actuator in the form of a drive screw, ball screw, or linear motor.
3. A measurements / feedback device in the form of a linear encoder.
4. A wire card assembly

The wire scanner assembly shall not exceed the following dimensions:

650 mm vertically up from the beam centerline.
155 mm in the horizontal, traverse to the beam, direction.
155 mm in the horizontal, along the beam, direction.

2.4 Linear Guide

Positioning accuracy: In accordance with Table 1 above.

Size and motion: Total stroke of 50 mm (±25 mm from center position).

Load capacity: Minimum allowable static moment = 2.5 N-M. Minimum allowable dynamic (or accidental) moment = 12 N-M.

Operating Environment: Ambient air or vacuum.

2.5 Linear Actuator

Positioning accuracy: In accordance with Table 1 above.

Stroke: Total stroke 40 mm (±20 mm from center position).

Speed: A traveling speed of 1 – 3 mm/sec will be used to move the wire from the parked position to the beam region. A scanning speed of 0.02 – 0.24 mm/sec will be used to move the wire across the electron beam.

Load capacity: The linear actuator must drive the wire card against the vacuum force at an accuracy specified in Table 1. It is 3 μm / 0.3 mm under the axial load of approximately 22 kg of vacuum force.

Operating Environment: Ambient air or vacuum. No radiation hardening is required.

2.6 Linear Encoder

A linear encoder will be used to measure the displacement of the wire independently from the linear actuator. The measurement should be reliable at both high and low speeds. To work over a long distance from the indexer, the encoder needs to have a differential output (RS-422) that matches the input requirements of the indexer.

Encoder resolution: 0.25 – 1.0 μm.

Repeatability of the home position: 15 μm, peak to peak.

Stroke: Total stroke 40 mm.

Operating Environment: Ambient air or vacuum. No radiation hardening is required.

2.7 Wire Card Assembly

The wire card design will be based on field-proven SLAC designs.

Wire diameter: 20 – 30 μm.

Wire operation length: 6 mm maximum intercepting electron beam.

Wire material: Tungsten, carbon fiber, or other material, to be determined by SLAC.

Electric connection: The wire will be electrically insulated from the ground. A single coaxial feedthrough with ceramic seal will be provided for the electrical connection to the wire.

Wire vibration amplitude: Less than 5 μm.

3.0 OTHER REQUIREMENTS

3.1 Wakefield Shield

During normal FEL operations, the wire scanner will be replaced by a wakefield shield, which maintains the wall current continuity and minimizes wakefield effects on the beam. The detailed design of this shield will be specified at a later date. SLAC is responsible for establishing general guideline for acceptable geometries. ANL will submit all proposed designs to SLAC for final approval before fabrication.

3.2 Equipment Protection Interlock

The design is based on the assumption that, when the wire scanner is inserted and removed from the beam, the LINAC beam will be turned off or parked upstream of the undulator line to avoid damage due to beam scattering on the wire scanner components by LCLS equipment protection system interlocks.

The wire scanner will not be used in the region of high x-ray power.