LCLS Engineering Specifications Document # 1.3-108 Linac Revision 0

LCLS Electron Stopper

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Brief Summary: Describes the basis for design of the stopper TDUND located in the LCLS Linac-to-Undulator region just up-beam of the Undulator, which must be capable of stopping the electron beam at full charge and energy at 10 Hz repetition rate.

Change History Log:

<table>
<thead>
<tr>
<th>Rev Number</th>
<th>Revision Date</th>
<th>Sections Affected</th>
<th>Description of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>11-21-2007</td>
<td>All</td>
<td>Initial Version</td>
</tr>
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</table>
1.0 Introduction

The Linac Coherent Light Source (LCLS) project at the Stanford Linear Accelerator Center (SLAC) is intended to create an x-ray free electron laser source of unprecedented brightness and short-time pulse duration.

Just up-beam of the LCLS Undulator, the electron beam must be stopped to allow tune-up of the electron beam prior to launching electrons into the undulator channel. To minimize damage of the undulator permanent magnet blocks, and to minimize radiation in this section, the beam repetition rate will be held at a maximum of 10 Hz when the stopper is in use. The physics requirements are specified in PRD 1.3-021.

1.1 General

The TDUND stopper is not part of the Personal Protection System (PPS). TDUND is a diagnostics stopper controlled through the LCLS EPICS control system. Status signals from the stopper must be made available to controls subsystems, such as the Beam Containment System, BCS, and the Machine Protection System, MPS.

1.2 Scope

The parameters required to design and fabricate the photon/electron stopper must be established to meet beam tune-up requirements. The design parameters described herein only apply to the LCLS electron stopper TDUND located immediately up-stream of the LCLS Undulator.

2.0 Beam Line Device

Many stoppers have been built at SLAC, and are still in use in every beam line. For ease of maintenance and reliability, the vertical actuator design built for the PEPII injection beamlines will be used. The stopper block however, will be redesigned for the specific needs of LCLS. The actuator is shown in Figure 1.
To conserve LCLS project funds by re-using existing designs, the stopper block design developed for the LCLS ST1 will be used. The ST1 stopper has similar single pulse beam intercept requirements but must handle larger average current. Further information may be found in the ST1 Engineering Specification Document LCLS ESD-1.6-100.

The Stopper block will be made of multiple segments. The Burn Through Monitors (BTM) in the ST1 design will not be monitored in TDUND. Although the TDUND does not require a Boron Carbide (B₄C) segment, the stopper slug will be fabricated identically to ST1 and will include the B₄C wafer. A thick Titanium alloy wafer will spoil the beam size to decrease the density of energy deposition in the copper segment. A Tungsten segment will follow the copper segment to minimize irradiation of downstream equipment (see Figure 2). The stopper block will be water-cooled.
3.0 Device Control

The stopper is actuated via a solenoid valve and must have a pair each of “in” and “out” limit switches. The beamline device will be equipped with a panel mount cable connector. Specific cable connector types must be negotiated between mechanical and controls engineering and recorded in the cable plant database. The control hardware should be the same as other LCLS in/out air actuated devices. Indications of in/out status must be made available to other controls such as BCS.

4.0 Design Parameters

The basic design parameters of the stopper are shown in Tables 1 & 2. Electron beam parameters are taken from PRD 1.3-021 “Insert-able Beam Dumps in the Linac and LTU.” Maximum single pulse temperature rise was calculated for ST1 by the Radiation Physics (RP) group using input parameters of 20 micron round, 2 kW beam (120 Hz). The average temperature rise in the stopper block materials at 10 Hz is negligible. The estimated maximum average allowable beam power on this stopper is 2 kW, assuming a 14 GeV beam, with 1 nC charge and a 40 X 30 μm spot size. RP may impose a maximum allowable time averaged power loss at this stopper to limit residual and/or prompt dose rates at this location.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
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<tbody>
<tr>
<td>Beamline location (in ‘LCLS’ coordinates)*</td>
<td>512.9874</td>
<td>m</td>
</tr>
<tr>
<td>Nominal electron energy</td>
<td>4.3 to 14</td>
<td>GeV</td>
</tr>
<tr>
<td>Nominal beam horizontal size range (rms)</td>
<td>0.04 to 0.08</td>
<td>mm</td>
</tr>
<tr>
<td>Nominal beam vertical size range (rms)</td>
<td>0.03 to 0.06</td>
<td>mm</td>
</tr>
<tr>
<td>Bunch charge range</td>
<td>0.2 to 1</td>
<td>nC</td>
</tr>
<tr>
<td>Maximum beam rate via MPS interlock</td>
<td>10</td>
<td>Hz</td>
</tr>
<tr>
<td>Max. average beam power</td>
<td>140</td>
<td>W</td>
</tr>
<tr>
<td>Max. reasonable insertion/extraction time</td>
<td>5</td>
<td>sec</td>
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</table>

* ‘LCLS’ coordinates are defined in the LTU with \( z = 0 \) at station-100.

Table 1: Electron Beam Parameters for the Electron Stopper TDUND.

<table>
<thead>
<tr>
<th>Stopper Stack Materials</th>
<th>Value</th>
<th>Units</th>
</tr>
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<tbody>
<tr>
<td>Photon Absorber Material</td>
<td>B4C</td>
<td></td>
</tr>
<tr>
<td>Photon Absorber Length</td>
<td>10</td>
<td>mm</td>
</tr>
<tr>
<td>Electron Absorber Materials</td>
<td>Ti, W &amp; Cu</td>
<td></td>
</tr>
<tr>
<td>Electron Absorber Length (Radiation Lengths)</td>
<td>25 ( X_0 )</td>
<td></td>
</tr>
<tr>
<td>Maximum Single Pulse Temperature Rise in B4C</td>
<td>152</td>
<td>°C</td>
</tr>
<tr>
<td>Maximum Single Pulse Temperature Rise in Ti</td>
<td>277</td>
<td>°C</td>
</tr>
<tr>
<td>Maximum Single Pulse Temperature Rise in Cu</td>
<td>52</td>
<td>°C</td>
</tr>
</tbody>
</table>

Table 2: Stopper Block Materials.

### 5.0 Procurement/Fabrication/Assembly

The basis of estimate indicates that the stopper mechanical parts will be machined by an outside vendor and the final assembly will be performed at SLAC. Alternatives to the basis are allowed to reduce schedule and/or cost.

The stopper controls hardware is anticipated to be identical to stoppers installed in the up-stream areas of LCLS.

### 5.1 Materials

All parts to be installed inside the vacuum enclosure must conform to the SLAC vacuum standard for machined components including materials requirements including materials source data and machining lubricant restrictions. See the latest revision of SLAC FP-202-631-14 for details. All test results shall be recorded in the stopper traveler.
5.2 Machined Components

All vacuum enclosure parts must leak checked prior to assembly. All in-vacuum parts must be fabricated in accordance to SLAC vacuum standard SLAC FP-202-631-14. All machined parts must be inspected for conformance to drawing dimensions and tolerances. Acceptance of parts is to be recorded on the component traveler.

5.2 Purchased Components

All purchased components including controls hardware must conform to applicable SLAC safety policies and practices. Controls hardware must be acceptably rated by a nationally recognized testing laboratory or pass internal SLAC electrical safety inspections.

5.3 Vacuum Assembly

Assembly of in-vacuum parts must be performed in a SLAC Clean Room. Leak testing of components and sub-assemblies shall be performed in such a manner to identify leaks at as early a time as possible.

5.3 Alignment Fiducials

Included in the design of the stopper vacuum chambers are provisions for tooling ball sockets. Each stopper vacuum chamber must have the tooling ball sockets fiducialized on a CMM with respect to the vacuum chamber beam axis.

5.4 Identification

Each stopper assembly shall have affixed to the outer surface on both sides

- The identifier “LCLS Electron Stopper TDUND”
- Total weight of magnet in pounds.

Each stopper shall also have a white painted arrow on each side pointing in the direction shown in the drawing, with ‘Beam Direction” lettered on the shaft of the arrow (with at least 1 cm high characters) as illustrated in Figure
3.

![Beam Direction](image)

Figure 3: Beam direction arrow.

6.0 Tests and Measurements

Tests and measurements must be performed to assure that the installed stopper system will perform as designed. Tests and measurements shall include part and assembly qualification, electrical safety inspection, actuation testing, limit switch tests, BTM pressure tests, leak checks, assembly fiducialization and vacuum qualification bake-out. Tests shall be performed in the laboratory to qualify the device prior to installation. Additional tests shall be performed after installation to qualify the system prior to delivery of electron beams to the installed region. All tests and measurements shall be recorded on a device traveler which corresponds to the unique device serial number.

7.0 Installation

Installation of the Photon/Electron stoppers and control system shall conform to the Davis Bacon Act where required.

Precision alignment of the beamline device is required; to be performed by the SLAC Metrology group.

Interconnection and testing of controls shall be performed following vacuum interconnection.

Additional field testing may be performed by SLAC Radiation Physics.
8.0 Applicable Standards and Codes

Design, fabrication, testing and acceptance must be in conformance to the following codes and SLAC standards.

1. SLAC — SLAC Guidelines for Operations  *SLAC-I-010-00100-000*
2. SLAC – ES&H Manual
5. SLAC – SLAC Radiation Safety Systems Technical Basis Document