Vacuum Chamber

LCLS

Stanford Linear Accelerator Center
Stanford Synchrotron Radiation Laboratory

LCLS Engineering Specification Document # ESD 1.4-118-r1 LCLS Document #	Undulator Vacuum Chamber	Revision 1

UNDULATOR VACUUM CHAMBER REQUIREMENTS

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Dave Schultz (E-Beam System Manager)	SEE ATTACHED SIGNATURE PAGE Signature	Date
Darren Marsh (Quality Assurance Manager)	SEE ATTACHED SIGNATURE PAGE Signature	Date

Bellows Module

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Brief Summary: This document defines requirements for the vacuum chambers intended to use in the Linear Coherence Light Source Undulator system.

Keywords: Undulator, Vacuum, High Vacuum (HV), Specification

Key WBS#'s: 1.4.4.2

Change History Log

Rev No.	Revision Date	Sections Affected	Description of Change
00		All	Initial Version
01	10/03/07	All	Changed for Extruded Chamber

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1. INTRODUCTION

1.1. Scope

This specification defines the requirements for the design, materials, fabrication, welding, inspection, and testing of LCLS undulator extruded aluminum vacuum chamber components.

1.2. Description

An electron beam will pass through an array of 33 separate undulator segments to produce spontaneous and FEL x-ray radiation. The total length of the undulator will be 131.52 m long, which includes 3.4-m-long undulator strongback segments, 0.470-m short breaks, and 0.898-m long breaks. The undulator vacuum chamber will be fabricated out of an aluminum extrusion and must fit into the 6.8-mm undulator pole gap. To fit into this small undulator gap, the external vertical dimension of the vacuum chamber will be nominally 6.0 mm. The chamber will be segmented in the same way as the undulator, with a diagnostics section between each undulator segment and joined by vacuum flanges. The vacuum chamber will be 3.47684 m long with explosion bonded bi-metal aluminum to stainless steel vacuum flanges and will be pumped by ion pumps at each diagnostic section. The undulator vacuum chamber aperture must have a smooth internal surface to minimize wakefields. Each individual chamber will be positioned by its own supporting structure.

1.3. Required Equipment

This specification requires surface polishing, surface roughness measurement, ultrasonic cleaning and de-ionized water rinsing, GTAW, vacuum leak detection, residual gas analysis (RGA), vacuum pumping, low temperature bake-out (150 C), and dimensional inspection. Equipment to perform these functions must be available.

1.4. Applicable Documents

The following documents form a part of this specification to the extent specified herein. The latest revisions shall apply.

- Procedure # L1440202-00040: LCLS Extruded Aluminum Vacuum Chamber Inspection Procedure
- Procedure # L1440202-00041: LCLS Inspection / Acceptance Report of Components for LCLS Assemblies
- Procedure # L1440202-00039: LCLS Machined Vacuum Chamber Extrusion Traveler
- LCLS ESD #1.4-106-r0 Undulator Vacuum System Requirements

1.5. Requirements Summary

Table 1: Machined Extruded Aluminum Vacuum Chamber Requirements

Parameter	Value	Unit
Thickness of chamber at aperture	6.00 +.15/-.05	mm
Aperture height	5.00 ± .08	mm
Overall flange to flange length	3476.84 +0/-.20	mm
Vertical straightness of mounted chamber after alignment	± 0.050	mm
Beam stay-clear radius around the chamber aperture axis	2.3	mm
Average rms slope error goal of aperture in longitudinal and transverse directions – best effort	See Table 1	mRad
Average vacuum pressure	$<10^{-6}$	Torr
RGA mass scan	Peaks ≤ 44	AMU
Outgassing rate	$\leq 2 \times 10^{-12}$	$l \cdot T/s \cdot cm^2$
Maximum pump-down time after girder replacement	1	day
Vacuum chamber material	6063 aluminum	-

2. TECHNICAL REQUIREMENTS

The Advanced Photon Source/Argonne National Laboratory (APS/ANL) shall supply the detailed drawings and procurement specifications 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.

2.1 Design Requirements

2.1.1 The extruded aluminum vacuum chambers will be designed to produce an average pressure of less than 1×10^{-6} Torr. The maximum time allowed for pump down to reach this vacuum level after the chamber is vented with dry atmospheric pressure nitrogen gas will be one day.

2.1.2 The beam-stay-clear radius around the nominal beam axis must be 2.3 mm.

2.1.3 Thickness and straightness are critical parameters to control during fabrication to enable the vacuum chamber to be inserted into the mouth of the undulator while maintaining chamber wall integrity under vacuum. The outside thickness of the vacuum chamber in the beam aperture region must be 6.00 +0.150/-0.050 mm and the straightness in the vertical direction must be ± 0.050 mm.

2.1.4 The overall length of the vacuum chamber prior to flange welding shall be 3428.6 +0.000/-0.200 mm. This dimension is critical due to the fact that there are many diagnostic components between the undulators and space is limited.

2.1.5 Of importance is the impedance that the vacuum chamber presents to the beam which is the cause of wakefields. There are three main contributors to the impedance of the vacuum chamber: its electrical surface conductivity, its surface roughness, and its geometric shape. The goal is the keep the contribution from surface roughness and geometric shape small (less than 10%) compared to the contribution from the finite electrical conductivity. In order to accomplish this, the average rms slope error of the internal aperture in both the X (transverse) and Z (longitudinal) directions will ideally fall within the green or yellow sections of table 2, and the vertical height of the inside aperture should be 5.00 ± .08 mm.

rms slope		
main [mrad]	side [mrad]	$\sigma_{W,core}$ [kV/m]
10	10	5.1
10	20	6.1
10	30	8.7
10	40	12.1
10	50	14.1
10	60	15.1
10	70	17.4
15	15	11.4
15	20	11.9
15	30	13.4
15	40	15.4
15	50	17.1
15	60	18.9
20	20	20.0

Table 2: RMS slope error table.

2.2 Material Requirements

2.2.1 The vacuum chamber will be made of 6063 alloy extruded aluminum so that its permeability is sufficiently small so as to not change the magnetic field on the beam path by more that 0.015% of the peak undulator field.

2.2.2 Vacuum-tight connections along the beamline direction will be accomplished by explosion bonded bi-metal aluminum to stainless steel blank-plate type flanges, such as EVAC CeFix Flanges and VAT Flat Seal Flanges. An oxygen free copper metal seal gasket will be used. Any other special flanges and sealing hardware, if needed, must be approved by the APS/ANL.

2.3 Fabrication Requirements

2.3.1 **Extrusion** Extrusions will be produced on a best effort basis according to drawing number L1440202-200001. Only virgin quality 6063 aluminum billets will be used in the production of these extrusions. Material certifications will be sent from the vendor and

verified by APS/ANL. The mandrel will be polished prior to extrusion in an attempt to improve the surface roughness inside the aperture.

2.3.2 Polishing Each aluminum extrusion shall have its internal aperture polished by an abrasive flow technique using a series of 220 and 400 grits. The extrusion will be flipped to yield polishing for an equal duration from each end. The total polishing time will be thirty hours. The media used will utilize an aluminum oxide grit to reduce the possibility of foreign contaminants being embedded into the vacuum surface of the extrusion. The polishing will be performed on a best effort basis with the goal of meeting the average slope error specification in section 3.1. Forty-five extrusions will be polished but only the best forty will be used to fabricate the undulator vacuum chambers.

2.3.3 Machining Machine the aluminum extrusion and bi-metal vacuum flanges per the supplied drawings. Machining shall not cause contaminants to be embedded into the vacuum surface of the component. Machining shall be performed using a water-soluble cooling fluid that is free of silicone, sulfur, phosphorus, or halogens. The recommended cutting fluid is Trim Sol.

2.3.3.1 Vacuum Chamber Identification Each vacuum chamber shall have a unique identification number. The serial number will be sequential starting with '01' and be engraved on the top side of each end, and the middle, of the vacuum chamber (see figure 1).

2.3.3.2 End Sample Identification Each vacuum chamber will have an upstream and downstream sample cut from the parent extrusion to be used for slope error measurements (see section 3.1). These sample identifications will adhere to the following format: 'Chamber Serial Number – Upstream' or 'Chamber Serial Number – Downstream' depending on sample location. On 10% of the vacuum chambers, a sample will be cut from the middle of the extrusion. These samples will be identified 'Chamber Serial Number – Middle'.

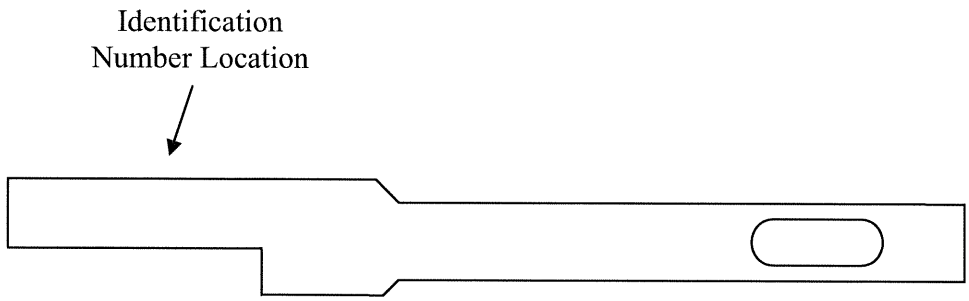

Figure 1: Identification number location

2.3.4 Pre-Weld Cleaning Before welding, the machined vacuum chamber extrusion shall be cleaned in accordance with section 2.6 from ESD #1.4-106.

2.3.5 Mechanical Inspection The vacuum chamber shall be inspected prior to welding per the requirements outlined in section 3.2 of this specification.

2.3.6 Welding The vacuum chamber shall be welded per the requirements specified in section 2.4 of this specification.

2.4 Welding Requirements

2.4.1 All parts to be welded shall be cleaned in accordance with LCLS ESD #1.4-106. Vacuum welds must be completed within 48 hours of the cleaning. Prior to and during the welding process the cleaned surface shall never be in contact with oily or greasy objects including bare hands.

2.4.2 All welding is to be performed in a clean area, and the welders must follow the guidelines specified in section 2.3.2 of LCLS ESD #1.4-106.

2.4.3 The allowable method for welding the components is Gas-Tungsten-Arc-Weld (GTAW). Filler metals must be in accordance with those specified in section 2.3.2 of LCLS ESD #1.4-106. Exceptions must be reported to APS/ANL for approval before work is started. The gas used in GTAW will be 99.95% pure with no measurable hydrocarbon contamination.

2.4.3.1 The weld will be performed manually, and due to size limitations of the aperture, must be performed on the external surface of the chamber. Additionally, underbeads, and consequently full penetration welds, are not permitted.

2.4.4 The components shall be leak tight when checked with a helium mass spectrometer leak detector with a minimum sensitivity of 2×10^{-10} Std. atm-cc/sec (helium), as described in section 2.8 of LCLS ESD #1.4-106, Undulator System Vacuum Requirements.

3. ACCEPTANCE TEST REQUIREMENTS

Before shipping the vacuum chamber assembly to SLAC, the inspection and tests listed below must be performed to meet the minimum acceptable requirements of the LCLS machined extruded aluminum vacuum chamber.

3.1. Slope Error Test The average rms slope error of two representative samples (one upstream and one downstream) from each vacuum chamber will be measured before welding. In addition, 10% of the vacuum chambers will be cut in half in order to measure the slope error at the center of the chambers. The average rms slope error of the internal aperture in both the X (transverse) and Z (longitudinal) directions should ideally fall within the green or yellow sections of table 2.

3.2. Mechanical Inspection Every machined vacuum chamber extrusion and the associated bimetal flanges must be inspected per Procedure # L1440202-00040: LCLS Extruded Aluminum Vacuum Chamber Inspection Procedure. Any rejections shall be dispositioned by ANL/LCLS Group prior to use and documented.

3.3. Pumpdown and Bakeout Test The welded vacuum chamber assembly will be baked out under vacuum before being shipped to SLAC for installation. The internal pressure shall be better than 2 x 10^{-6} Torr before heat is applied. The bakeout temperature will be 150°C and continue for at least 24 hours.

3.4. Leak Test Every welded vacuum chamber assembly must be leak tight when checked with a helium mass spectrometer leak detector with a minimum sensitivity of 2 x 10^{-10} Std. atm.-cc/sec (helium) as defined by American Vacuum Society Standards 2.1 and 2.2. More detailed requirements are defined in section 2.8 of LCLS ESD #1.4-106.

3.5. RGA Test Each vacuum chamber must have a residual gas analysis test performed prior to shipment. An RGA spectrum will be taken after cooldown when the pressure has reached at least 2 x 10^{-8} Torr. The RGA data must be included with each vacuum chamber. An acceptable RGA is defined as no peaks over 5 x 10^{-12} Torr for masses over 44 atomic mass units. Torr. There must also be no indication of residual acid or alkali cleaning residue, or halogen in the spectrum.

3.6. Outgassing Test LCLS vacuum chambers require low outgassing rates on the order of 2 x 10^{-12} Torr-liter/sec-cm^2 in order to achieve the required average vacuum pressure. The rate of rise will be recorded for thirty minutes with absence of pumping to determine the outgassing rate.

4.0 Shipping Specifications

Shipping specifications for the vacuum chamber assembly will be in accordance with Section 2.9 of LCLS ESD #1.4-106.