

Stanford Synchrotron Radiation Laboratory

Alignment Plan for the LCLS Undulator

Catherine LeCocq, SLAC

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- LCLS Overview
- Undulator Component Alignment Tolerances
- Support Undulator Hall Construction
- Plan Assembly of Girders
- Plan Tunnel Installation Sequence
- Alignment Possibilities after Installation

09-27-06 Alignment Plan for the LCLS Undulator

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Undulator Layout



Parameter	Symbol	Value	Unit
min. fundamental wavelength	λ_r	1.5	Å
undulator period length	λ_{u}	3.0	cm
nom. undulator parameter	K	3.5	
peak field	B- _{pk}	1.25	Т
undulator segment length	L _s	3.4	m
number of segments	N _s	33	
full undulator length	L _s	132	m
nom. undulator full pole gap	g	6.8	mm
long break length	L _l	0.898	m
short break length	L _s	0.470	m
number of quadrupoles	NQ	33	
number of BPMs	N _{BPM}	33+3	

From Heinz-Dieter Nuhn

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One Segment- Wall Side



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One Segment- Aisle Side



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Physics Requirements

The x-ray FEL process requires:

- Straightness of the electron beam trajectory:
 2 μm rms through the LCLS undulator system
- 2. Alignment of the individual undulator segment with respect to the beam axis:
 80 µm rms vertically
 140 µm rms horizontally

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Quadrupole Alignment Tolerance Budget

Quadrupala Fiduciala	Vertical [µm]	Horizontal [µm]
Pulsed Wire Center Definition	▲ 10	10
Wire to Wire Finder (WF) Fiducial	$\leftarrow 20$	10 20
WE Fiducial to Quadrupole Fiducial	4	20
WT Tradelar to Quadrupole Tradelar		10 25
	25	25
Quadrupole BBA Offset	20	20
Undulator Fiducials		
Hall Probe Resolution/Positioning	← 20	20
Needle Hall Probe Resolution	← 15	30
Needle Center to Fiducial	← 20	30
Fixture Fiducial to Undulator Fiducial	← 20	20
	→ 40	50 →
Undulator Segment Roll-Away Repeatability	10	10
Alignment Quadrupole to Undulator	60	125
Grand Total	80	140

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BFW Alignment Tolerance Budget

	Vertical [µm]	Horizontal [µm]
BFW Fiducials	▲ 20	20
Dr w whe to Reference Stop	× 20	20
Reference Stop Definition		10
Reference stop to Flutchar		20
	→ 30	30 -
Undulator Fiducials		
Hall Probe Resolution/Positioning	▲ 20	20
Needle to Hall Probe Resolution	↓ 15	30
Needle Center to Fiducial	↓ 20	30
Fixture Fiducial to Undulator Fiducial	↓ 20	20
	→ 40	50
X-Wire Positioning Repeatability	-	80
Y-Wire Positioning Repeatability	30	>
CAM Positioning Repeatability	4	4 →
Undulator Segment Roll-Away Repeatability	10	10
Alignment BFW to Undulator	55	100
Grand Total [Beam-to-Undulator]	80	140 🚽

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LCLS Construction Support





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Magnetic Measurement Facility



- Floor plan divided into three functional areas
 - Magnetic Measurements (± 0.1° C)
 - Fiducialization and Assembly (± 1° C)
 - Storage (± 2.5° C)

<u>LCLS-TN-04-1</u> "Requirements for the Construction of the LCLS Magnetic Measurements Laboratory" by Z. Wolf and R. Ruland.

<u>LCLS-TN-05-4</u> "Earth's Magnetic Field Measurements for the LCLS Undulators." by K. Hacker and Z. Wolf.

- Test Stand #1
 Test Stand #2
 Fiducialization CMM
 Cradle Assembly
 Quad Fiducialization
 Quad Field Meas.
 Hall Probe Calibration
- 8 BPM Fiducialization
- 9 Needle Fixture Calibr.

- 10 Und. Seg. / Cradle on Transport Cart
- 11 Inspection Tools
- (12 Und. Segment Storage (3 x 4)
- 13 Vacuum Chamber Storage
- 14 Quad. / BPM Storage
- 15 Cradle Storage
- 16 CMM Tools Storage
- 17 Office
- 18 Tuning Platform
- 19 HVAC Equipment

 4/3/06: MMF Beneficial Occupancy
 7/3/06: MMF Qualified & Ready to Measure Production Undulators.

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Kugler Bench for Undulator Tuning



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Undulator Measurement Steps

from Zack Wolf, Head of the Magnetic Measurement Group

- 1) Place undulator
- 2) Mechanically align undulator to bench
- 3) Magnetically align Hall probe to undulator
- 4) Perform any required large gap adjustments and re-align
- 5) Straighten the X and Y trajectories
- 6) Minimize phase errors
- 7) Perform phase matching
- 8) Determine K vs X, move probe to the X value which gives the specified K
- 9) Add fiducialization magnets to undulator ends, locate center of fiducialization magnets
- 10) Move undulator to CMM, finish fiducialization
- LCLS-TN-03-07: "ANL and DESY Undulator Tuning Procedures" by Z. Wolf.
- LCLS-TN-05-10: "Test of Coordinate Transfer from Magnetic to Mechanical Reference for LCLS Undulator Fiducialization." by Y. Levashov and Z. Wolf.



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Leitz Reference Model 45129 CMM



Facts:

Measuring range is 0.9 x 1.5 x 4.5 m Weight capacity is 3000 kg Resolution is 0.1 µm Repeatability is 1 µm **Test for qualification:** Accuracy formula:1.5µm+d(mm)/350 Weight test (2400 kg) Magnetic test (50 Gauss)

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Tunnel Installation Sequence

- Establish survey network in empty UH
- Mark bolt-hole floor positions for pedestals
- Align pedestals
- Align girder without undulator segment
- Map all girder components including undulator segment
- Measure with portable HLS and WPM
- Perform the required moves
- Final map & initialization of ADS: ready for BBA

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Undulator Hall Monument Layout



From Brian Fuss

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Tunnel Network Simulation



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Alignment Diagnostic System (ADS)

Goal: Monitoring of

X, Y Position of each Quadruple

Roll, Pitch and Yaw of each Undulator Segment

Component Monitoring Tolerance	Value	Unit
Horizontal / Vertical Quadrupole and BPM Positions	0.7	μm
Roll of Undulator Segment	1000	µrad
Pitch of Undulator Segment	16	µrad
Yaw of Undulator Segment	30	µrad

Composition:

- 2 wires spanning the whole undulator hall
- 1 water level system

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Alignment Diagnostics System – Sensors

Wire Position Monitor System (WPM)

- Resolution < 100 nm in X & Y Direction
- Instrument Drift < 100 nm per day
- Moving Range ±1.5 mm in X & Y Direction
- Accuracy
- 0.1 % of full Scale
- Availability Permanent, no Interrupts

X and Y can be measured

Owner: Franz Peters

Hydrostatic Leveling System (HLS)



- **Precision** < 1 μm
- Instrument Drift ~1-2 μm / month
- Accuracy < 0.1 % of full Scale

Ultrasound Sensor

- *Precision* < 0.1 μm
- Instrument Drift potentially no drift
- Accuracy < 0.1 % of full Scale
- *Availability:* 10 minutes settling period after movement

Owner: Georg Gassner

Y can be measured

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ADS Installation - Hardware

HLS

• Piping

•CPVC (FM4910) 2" and 1" schedule 40 •Pipe is supported by Unistrut® to avoid sag

•Bellows

- •Gortiflex® GF-100B •Small: max length 2", min 1"
- •Long: max length 10", min 2"

Bracket

•Nickel plated steel, machined out of standard angle 0.5" thickness



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End of Presentation

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