Alignment activities for the LCLS-II project at SLAC
IWAA2022 – CERN, November 2022

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LCLS-II

1. **New Injector and New Superconducting Linac**
2. **New Cryoplant**
3. **Existing Bypass Line**
4. **New Transport Line**
5. **Two New Undulators And X-Ray Transport**
6. **Exploit Existing Experimental Stations**
7. **Remove SLAC Linac from Sectors 0-10**
LCLSII

- LCLS-II adds a 4 GeV SC linac to the first kilometer of the SLAC linac tunnel.
- The copper linac in that region will be removed
- The new beam will run CW at up to 1 MHz
- The LCLS-I linac is not altered, retains performance
- The new beam can be directed at either of two new undulators
- The LCLS-I beam can be directed to the new Hard X-ray Undulator

Key Performance Parameters for LCLS-II:

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Threshold</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable Gap Undulators</td>
<td>2 (SXR &amp; HXR)</td>
<td>2 (SXR &amp; HXR)</td>
</tr>
<tr>
<td>Super Conducting Linac Based FEL System</td>
<td></td>
<td></td>
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<tr>
<td>Super Conducting Linac Energy</td>
<td>3.5 GeV</td>
<td>≥ 4 GeV</td>
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<tr>
<td>Electron Bunch Repetition Rate</td>
<td>93 kHz</td>
<td>929 kHz</td>
</tr>
<tr>
<td>Super Conducting Linac Charge per Bunch</td>
<td>0.02 nC</td>
<td>0.1 nC</td>
</tr>
<tr>
<td>Photon Beam Energy Range</td>
<td>250-3,800 eV</td>
<td>200-5,000 eV</td>
</tr>
<tr>
<td>High Repetition Rate Capable End Stations</td>
<td>≥ 1</td>
<td>≥ 2</td>
</tr>
<tr>
<td>FEL Average Power (10^-3 BW)</td>
<td>5x10^8 (10x spontaneous @2,500 eV)</td>
<td>&gt;10^11 @ 3,800 eV</td>
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</tbody>
</table>

| Normal Conducting Linac Based FEL System   |                                  |                            |
| Normal Conducting Linac Electron Beam Energy| 13.6 GeV                         | 15 GeV                    |
| Electron Bunch Repetition Rate             | 120 Hz                           | 120 Hz                    |
| Normal Conducting Linac Charge per Bunch   | 0.1 nC                           | 0.25 nC                   |
| Photon Beam Energy Range                   | 1,000-15,000 eV                  | 1,000-25,000 eV           |
| Low Repetition Rate Capable End Stations   | ≥ 2                               | ≥ 3                       |
| FEL Photon Energy (10^-3 BW^2)             | 10^10 (lasing @ 15,000 eV)       | > 10^12 @ 15,000 eV       |
Alignment Activities

Aligned cold beamline

Aligned 2km bypass

Aligned x-ray Distribution and Experimental stations

Aligned 50 undulators
Alignment Network S0-S30 – Layout

S0-S10 no longer has a light pipe and bypass lines are not tied to girders -> Monument based network
Opposing wall monuments to mitigate effect of refraction.
Transferred light pipe information to monument network

3km
3.3m
12m

Cryomodule
Wall Monument
Floor Monument

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Cryomodule Alignment

After receiving inspection by mapping all fiducials on the inside and outside, the Cryomodules were transported into the tunnel and aligned relative to monument network.
Cryoplant

Mapped anchor locations on devices at vendors and marked location at SLAC. Delivery straight to installation site. High consequence work, no issues.
Alignment Activities – Linac Middle

Re-alignment of existing bypass

Alignment of spreader area
Linac Middle - BTH

- Re-alignment of the old bypass line.
- New spreader area with up to 5 beamlines in a 3.3m x 3m tunnel.
- Newly designed dump area with “coffin” design that allows swap of dump without alignment personal at the dump.
- New SXR beamline through the LTU (Linac to Undulator)
Support production of undulators
Alignment of 50 new undulator on two beamlines
Undulator alignment

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• Before removal of the LCLS undulators we re-measured the alignment network in the undulator hall.

• The walls move by about 100µm/year.

• The quadrupoles were aligned with beam-based alignment to micrometer accuracy.

• Mapping all the quadrupoles allowed us to correct our alignment network.
Alignment Network

- Comparing the free net adjustment to the adjustment with the quadrupole locations fixed (weighted +/- 50µm).
Alignment Activities – Experimental Hutches

Floor stability measurements
Concrete drilling

Scope to align core drill on 1st floor to point at mirror on 2nd floor. Drilling through 90cm concrete at a 7 deg angle.
Concrete Drilling

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Concrete Drilling

Max. $\Delta$Vertical: 27mm
Max. $\Delta$Horizontal: 6mm
Mirror Alignment

Laser Tracker (Leica AT403) is used to align the roll on vertically reflecting mirror by direct measurement through window (optical grade window)

For vertically reflecting mirror we use an Autocollimator (Moeller Wedel Elcomat 3000) with a calibrated Pentaprism. Estimated accuracy is below 10μrad.
Mirror Alignment

Laser Tracker → Autocollimator

Autocollimator → Laser Tracker

Laser Tracker → Autocollimator

Autocollimator → Laser Tracker
Experimental Halls

- Aligned Front End Enclosure, mirrors to steer the x-ray beam to the different experimental hutches.
- 3 new Experimental Hutches for Soft X-Ray Experiments.
- This included the alignment of 20 mirrors.
Alignment of LCLSII project has been mostly completed.
- We aligned over 5km of beam line
- Marked around 6000 anchors
- Checked and aligned 37 Cryomodules
- Fiducialized and aligned 50 undulators
- Aligned 20 mirrors

So far everything was aligned correctly.