LCLS-II-HE Project
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BESAC, March 2019
LCLS-II-HE will upgrade LCLS-II and deliver photon energies beyond 12 keV (< 1Å) in a continuous pulse train up to 1 MHz.

LCLS-II currently 80% complete. Users online in 2021

LCLS-II-HE CD-1 approved Sept 2018. Targeting mid-decade users
LCLS-II-HE Scope

Double the electron energy of the accelerator (4 → 8 GeV)
• Extends X-ray energy limit from 5 keV to 12.8 keV

Install a second bypass line to provide a dual source
• Delivers simultaneous soft X-ray and hard X-ray beams at high rep-rate

Provide specialized instruments for unique new source
• Delivers optimized measurement capabilities and enables science immediately from the onset of commissioning

This provides a qualitatively new capability, unique in the world, delivering ultrafast, Ångström performance at high average power.
LCLS-II-HE accelerator upgrades will enable hard X-rays at high rep-rate and increase the experimental capacity.

1. Add 20 additional cryomodules (L4 linac) to increase the LCLS-II accelerator energy to 8 GeV.
2. Install new cryogenic distribution box and transfer line between the cryoplant and the new L4 linac.
3. Add low-energy extraction point at 3.8 GeV to enable quasi-independent operation of the soft-X-ray and hard-X-ray programs.
4. Use existing transport line to bypass downstream linacs and install new dump in the beam switch yard.
5. Install high rep-rate Hard X-ray Self Seeding capability in the hard X-ray undulator.
New and upgraded instruments will address the science needs and take advantage of the transformative nature of LCLS-II-HE.

<table>
<thead>
<tr>
<th>Instr.</th>
<th>Upgrade Plan</th>
<th>Science Opportunities</th>
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</table>
| XPP    | New detector Upgraded diagnostics | • Understand coupled dynamics of molecular structure and charge & their role in energy flow  
• Characterize materials heterogeneity, fluctuations & link to function |
| DXS    | Repetition rate enhancement IXS capability | • Map collective excitations & understand their relation to emergent phenomena in complex materials  
• Characterize materials heterogeneity, fluctuations & link to function |
| CXI    | New optics & detector Enhanced DAQ | • Reveal the role of structural dynamics in biological function  
• Catalysis: Reveal the correlation between chemical reactivity & structural dynamics |

- **Key Performance Parameter**
  - 3 upgraded endstations

- **Objective KPP**
  - 5 upgraded endstations
## Preliminary Threshold and Objective KPPs

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Threshold</th>
<th>Objective</th>
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<tbody>
<tr>
<td>Superconducting linac electron energy</td>
<td>7 GeV</td>
<td>8 GeV</td>
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<tr>
<td>Electron bunch repetition rate in linac</td>
<td>93 kHz</td>
<td>929 kHz</td>
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<tr>
<td>Charge per bunch in SC- linac</td>
<td>0.02 nC</td>
<td>0.1 nC</td>
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<tr>
<td>Photon energy range</td>
<td>200 – 8,000 eV</td>
<td>200 to ≥ 12,800 eV</td>
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<tr>
<td>High rep-rate-capable HXR end stations</td>
<td>≥ 3</td>
<td>≥ 5</td>
</tr>
<tr>
<td>FEL photon quantity (10⁻³ BW)</td>
<td>5×10⁸ (50× spont. @ 8 keV)</td>
<td>&gt; 10¹¹ @ 8 keV (200 μJ) or &gt; 10¹⁰ @ 12.8 keV (20 μJ)</td>
</tr>
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LCLS-II-HE Project Collaboration (proposed)

- Accelerator and FEL Design
- Cryomodule and accelerator installation
- Cryoplant modifications & Helium distribution installation
- High Power RF, low-level RF, and Controls
- X-ray instruments design & installation

- High Q0 & High Gradient R&D
- Cryomodule design
- 50% of cryomodule production
- Processing for high Q
- Helium distribution system design and procurement

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- Accelerator Physics
LCLS-II-HE was awarded CD-1 in September 2018.

<table>
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<tr>
<th>Level 1 Baseline Milestones</th>
<th>Schedule</th>
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<tr>
<td>CD-0 - Approve Mission Need</td>
<td>December 5, 2016</td>
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<tr>
<td>CD-1 - Approve Alt. Select. &amp; Cost Range</td>
<td>September 21, 2018</td>
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<tr>
<td>CD-2 - Approve Performance Baseline</td>
<td>January 2023</td>
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<td>CD-3 - Approve Construction Start</td>
<td>January 2023</td>
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<tr>
<td>CD-4 - Project Complete/Start of Operations</td>
<td>October 2028</td>
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Estimated TPC at CD-1: $368M

Favorable appropriations in FY18 and FY19 enables LCLS-II-HE to minimize the cryomodule production gap following LCLS-II.
Significant progress has been made on SRF High-Gradient/High-Q0 cavity R&D. Two cavity processing methods have demonstrated HE performance requirements on single cells. The 2/0 cavity processing method can produce cells that meet LCLS-II HE spec! R&D now transitioning to 9-cells.

9-Cell with 2/0 N$_2$-doping

2/0 cavity processing method can produce 9-cells that meet LCLS-II HE spec!

BESAC Meeting, March 7-8, 2019
Favorable appropriations have enabled a fast project launch!

- The Project collaboration is now being formed and will be codified under a new Memorandum of Agreement.
- Cavity R&D will culminate this year with 9-cells ready for prototype cryomodule demonstration.
- Construction of the HE Prototype cryomodule will begin after LCLS-II production ceases in late 2019.
- CD-3A review for cryomodule production is planned Q4FY19.
- Cryomodule supply chain procurements will commence following CD-3A ESAAB approval.