The ALS Upgrade

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Mounting global competition was recognized by BESAC

The July 2013 BESAC Report highlighted the urgent need to revitalize storage ring light sources:

• “...the Office of Basic Energy Sciences should ensure that U.S. storage ring x-ray sources reclaim their world leadership position…”

• “The very large, diverse U.S. user population presently utilizing U.S. storage rings represents a major national resource... It is essential that the facilities this science community relies on remain internationally competitive in the face of the innovative developments...in other countries.”

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ALS-U Mission Need: An ultra-bright storage-ring-based light source providing soft x-ray light with high coherent flux

Source need: Highest possible coherent soft x-ray (50–2,000 eV) flux with quasi-continuous operation and high stability

- Upgrade the ALS with an MBA lattice design that will provide a soft x-ray source that is orders of magnitudes brighter than today’s ALS—up to a 10–1000x increase in brightness and coherent flux
- Produce longer pulses at high repetition rate to achieve 5–10% duty cycle
- Provide a set of experimental capabilities to preserve and exploit the high brightness and coherent flux
ALS-U accelerator conceptual design

Small round **insertion-device** vacuum apertures are possible that allow new high-performance undulators.

New **accumulator ring** for full-energy swap-out injection and recovery of bunch trains.

New **9BA storage ring** in existing tunnel optimized for low emittance and high soft x-ray brightness and coherent flux.

Transfer lines
ALS-U conceptual design enables the ALS’s leadership in soft x-ray science

**Features**

- World-leading soft x-ray brightness and capabilities
- More than 100x increase in soft x-ray brightness and coherent flux compared with today’s ALS
- Excellent IR and hard x-ray performance

**Impact**

- Enable scientific advances in a diverse range of fields, improving our economy, healthcare, and national security
- Continue the ALS tradition of serving a large and scientifically diverse user community
BES Basic Research Needs reports identified need to understand, predict, and control emergent material and chemical properties

Quantum materials & information  
Catalysis; synthesis science  
Earth & environmental systems
A combination of technical capabilities is required to understand emergent properties

1. High chemical and material contrast
2. Nanoscale spatial sensitivity
3. Broad temporal sensitivity to nanoscale motion

Today’s light sources lack this combination of capabilities
High soft x-ray brightness and coherent flux are needed to provide these capabilities

Tune spectral contrast with incident energy
Lensless imaging at the nanoscale
Spontaneous nanoscale motion with correlation spectroscopy

Studying heterogeneous systems requires coherent wave fronts

Brightness is the metric of a source that determines the achievable spectral, spatial, and temporal resolution

ALS-U is needed to address BES Basic Research Needs
ALS-U source brightness is essential to accomplish science goals

**Materials Discovery**

100x brightness increase = 100x faster materials discovery & optimization, e.g., for quantum information science and beyond

**Chemical Kinetics**

100x brightness increase = 10,000x faster chemical kinetics, e.g., for energy and water applications and beyond
Cross-cutting challenges addressed by ALS-U: Energy materials

- Spectral Mapping of Nano-Objects
- Designing Functional Interfaces
- Harnessing Entropy for Material and Chemical Design
- Measuring & Manipulating Nanoscale Currents & Flows
- Materials Chemistry and Physics in Confined Spaces

Optimized electrocatalysts

Helmholtz layer structure & stability

Electrochemical storage systems
W. Chueh, D. Shapiro (2016)
ALS is already building beamlines that will take advantage of improved capabilities

MAESTRO: nanoARPES
Mapping electrons, with the Molecular Foundry

COSMIC Ptychography:
Mapping chemistry, with CAMERA/CRD, ESNET, NERSC

These and other existing ALS instruments will benefit directly from the higher brightness provided by the ALS-U
Impact of high brightness and coherence on ALS instruments

<table>
<thead>
<tr>
<th>Requirement/Benefit</th>
<th>ALS in 2016</th>
<th>Today’s ALS</th>
<th>Upgraded ALS</th>
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<tbody>
<tr>
<td>Instruments requiring smooth wave fronts</td>
<td>5</td>
<td>7</td>
<td>12</td>
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<tr>
<td>Instruments benefitting from a small round source</td>
<td>24</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Instruments not dependent on source brightness</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>34</strong></td>
<td><strong>38</strong></td>
<td><strong>43</strong></td>
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Most instruments will benefit from the ALS-U, and the upgraded ALS will serve vibrant existing and new communities.
ALS urgently needs ALS-U to maintain US leadership in soft x-ray science and to address critical needs outlined in recent BES/BRN reports.

Revolutionary “ALS-U ready” tools are already being planned, designed, constructed, and commissioned and will provide an unprecedented combination of spectral, spatial, and temporal resolution.

A combination of ground-breaking early science activities and longer-range aspirational science goals will ensure a world-leading ALS science program for decades to come.

Most existing ALS user communities will benefit from ALS-U, either by a modest increase in flux or by a large increase in source brightness.
ALS accelerator, scientific, and operations staff deserve much credit for our innovative and productive 25-year history.

The ALS upgrade, coupled to emerging experimental tools, will ensure 25 more years of leadership.

Thank you!