The ALS Upgrade

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BESAC Meeting

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BERKELEY LAB

U.S. DEPARTMENT OF ENERGY | Office of Science

ALS-U ADVANCED LIGHT SOURCE

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."
- "Developments include **diffraction-limited storage rings** with…**10^2–10^3 increase in brightness**…"

Report of the BESAC Subcommittee on Future X-ray Light Sources

Approved by the Basic Energy Sciences Advisory Committee on July 25, 2013

In a January 2, 2013 letter, then Director of the DOE Office of Science (SC), Dr. William Brinkman, asked the Basic Energy Sciences Advisory Committee (BESAC) to provide him with objective, independent advice in the following areas:

- Assessment of the grand science challenges that could best be explored with current and possible future SC light sources. The assessment should cover the disciplines supported by Basic Energy Sciences (BES) and other fields that benefit from intense light sources.
- Evaluation of the effectiveness of the present SC light source portfolio to meet these grand science challenges.
- Enumeration of future light source performance specifications that would maximize the impact on grand science challenges.
- Prioritized recommendations on which future light source concepts and the technology behind them are best suited to achieve these performance specifications.
- Identification of prioritized research and development initiatives to accelerate the realization of these future light source facilities in a cost effective manner.

It is important to note that the Future Light Source charge was provided to BESAC shortly after the Office of Science requested BESAC to provide a prioritization of the BES existing and planned major facilities. In the BESAC facilities prioritization report provided to the Office of Science on March 21, 2013, BESAC made the clear statement that "***the BESAC urges DOE to aggressively pursue a new future light source with unprecedented beam characteristics and thus unprecedented opportunities for world-leading science***".

The BESAC facilities prioritization report, in concert with the outstanding success story of construction and early experiments of the Linac Coherent Light Source sets the stage for the present discussion and report.

Executive Summary

The world leadership that the U.S. has provided in accelerator-based x-ray light source user facilities over the last 40 years has generated broad and far-reaching advances in diverse fields of science and technology. The unprecedented success of the U.S. x-ray light sources, under the stewardship of BES, has resulted in an extensive international activity in the development of innovative, and ever more advanced x-ray sources for discovery science and technological development. In spite of the present intensely

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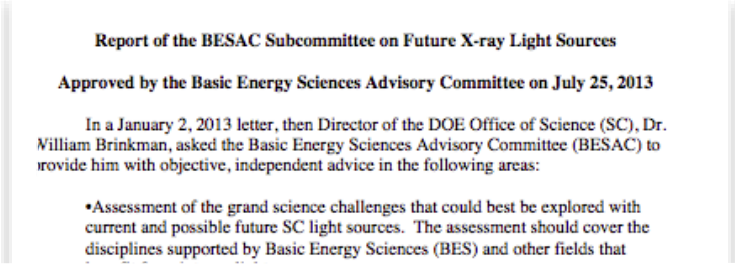

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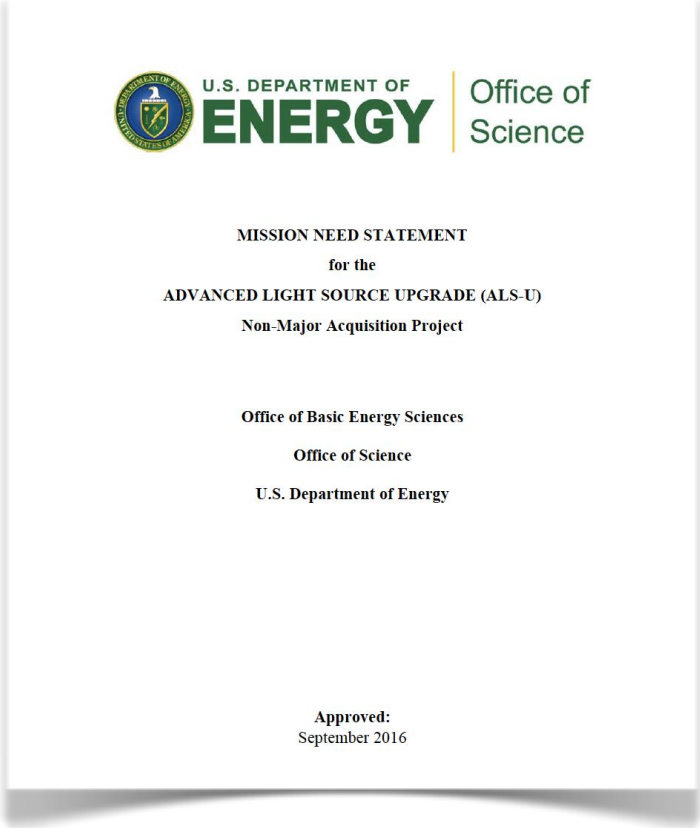
ALS-U Mission Need: An ultra-bright storage-ring-based light source providing soft x-ray light with high coherent flux

ALS-U Mission Need Statement
Approved Sept. 2016



U.S. DEPARTMENT OF ENERGY | Office of Science

MISSION NEED STATEMENT
for the
ADVANCED LIGHT SOURCE UPGRADE (ALS-U)
Non-Major Acquisition Project

Office of Basic Energy Sciences
Office of Science
U.S. Department of Energy

Approved:
September 2016

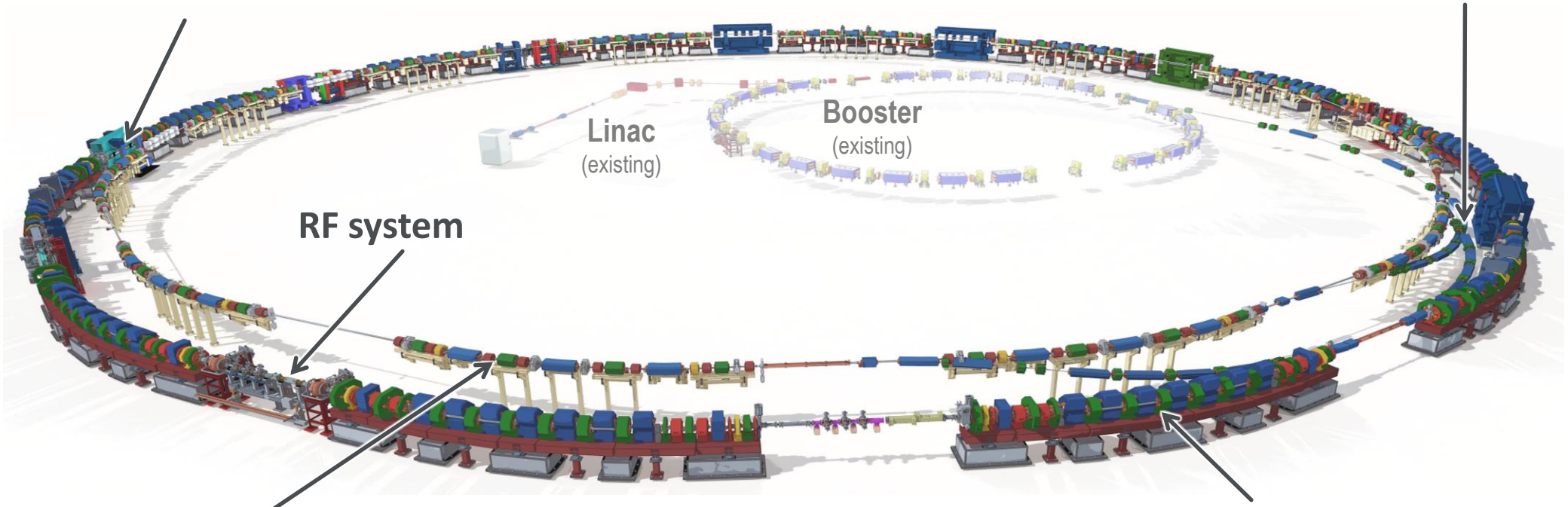
Source need: Highest possible coherent soft x-ray (50–2,000 eV) flux with quasi-continuous operation and high stability

- 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

Transfer lines

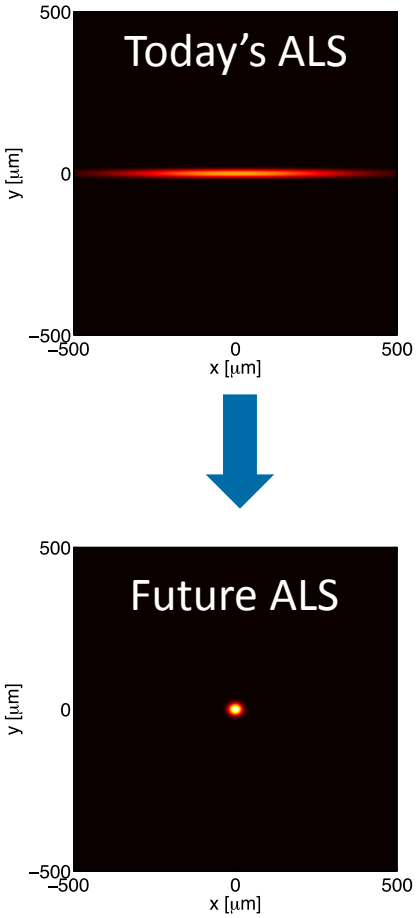


New **accumulator ring** for full-energy swap-out injection and recovery of bunch trains

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

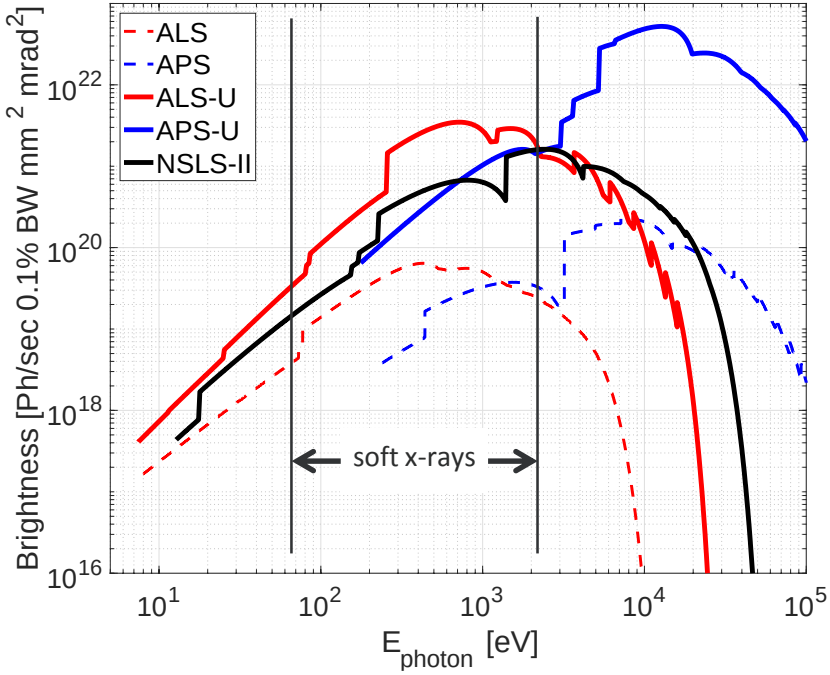
ALS-U conceptual design enables the ALS's leadership in soft x-ray science

Electron Beam Profiles



Features

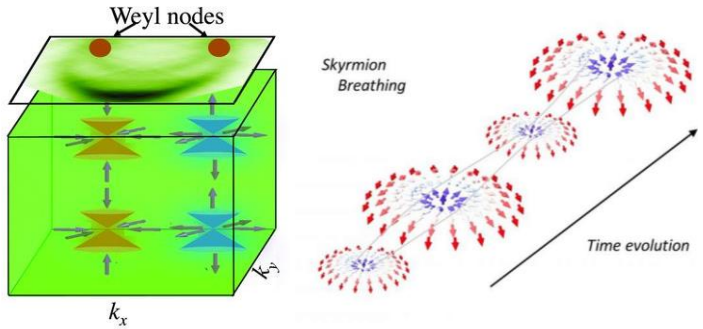
- World-leading soft x-ray brightness and capabilities
- More than 100x increase in soft x-ray brightness and coherent flux compared with today's ALS
- Excellent IR and hard x-ray performance



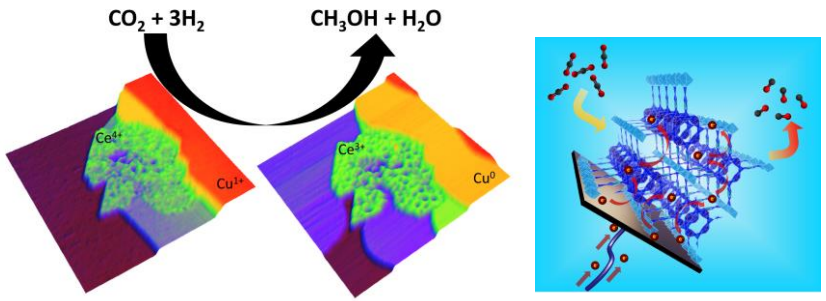
Impact

- 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

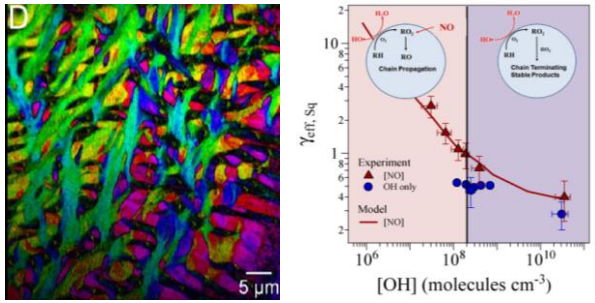
BES Basic Research Needs reports identified need to understand, predict, and control emergent material and chemical properties



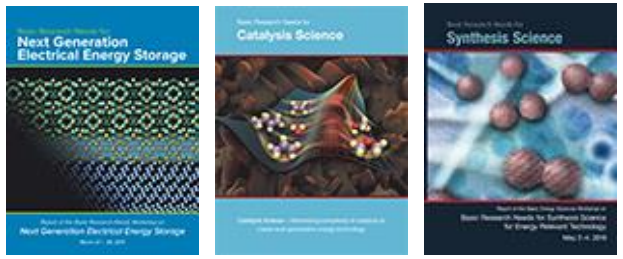
Quantum materials & information

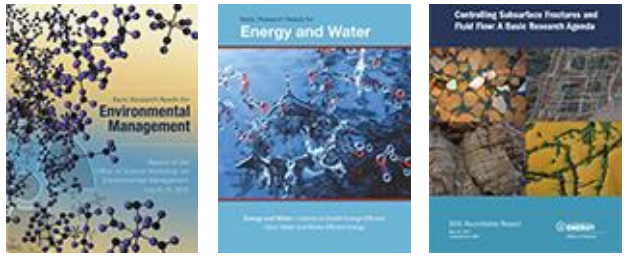


Catalysis; synthesis science

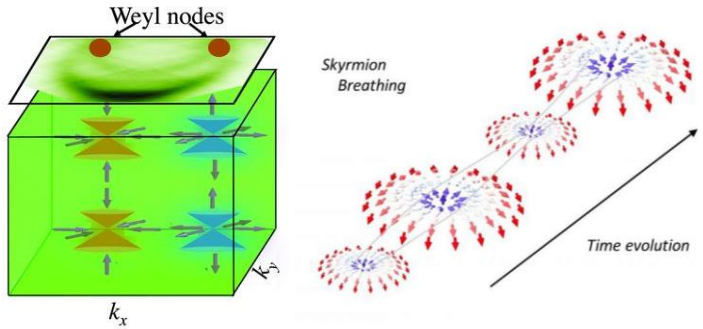


Earth & environmental systems





A combination of technical capabilities is required to understand emergent properties



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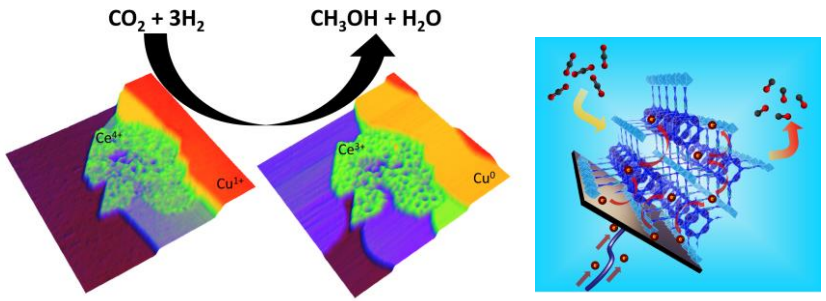
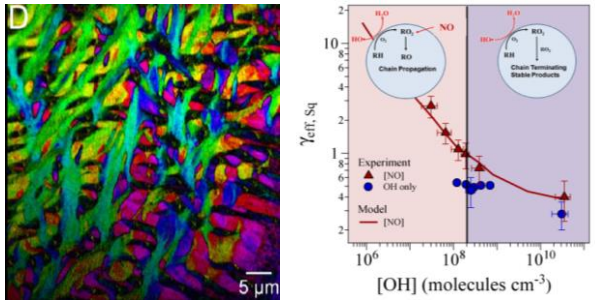


Catalysis; synthesis science

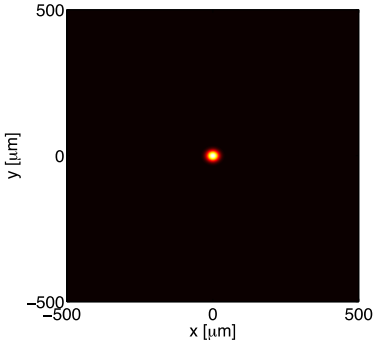


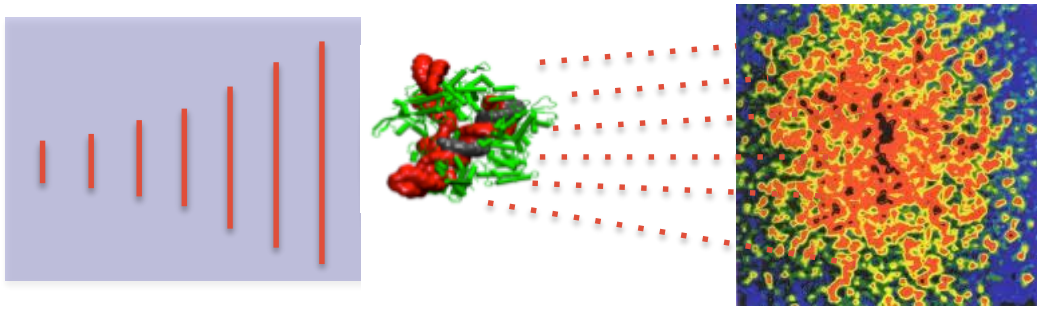
Earth & environmental systems

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





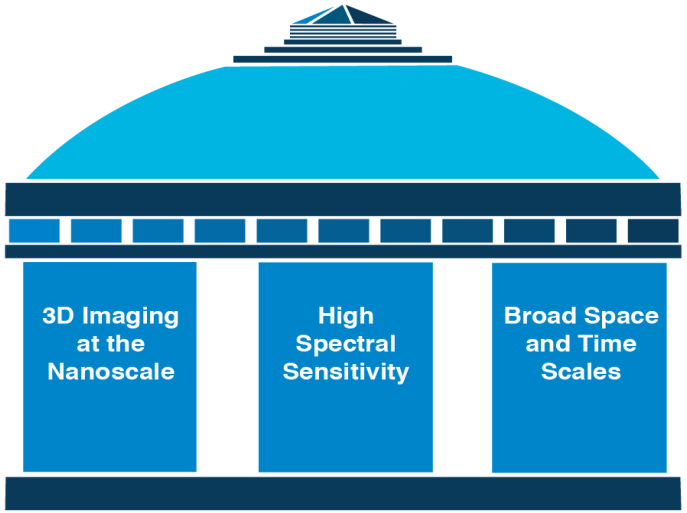
Tune spectral contrast with incident energy

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

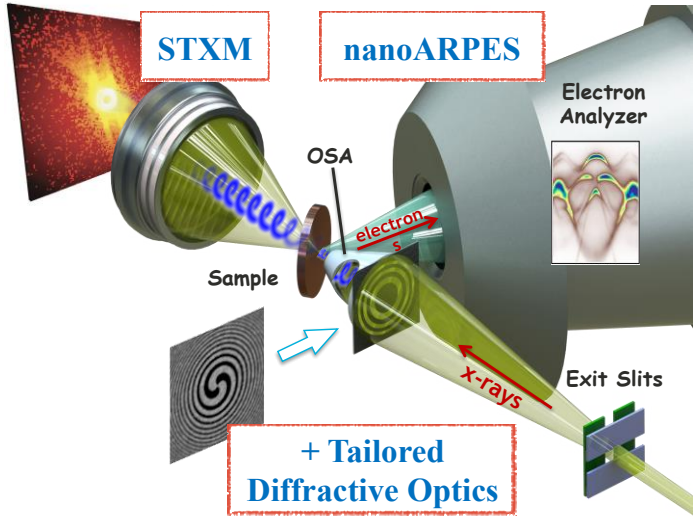


ALS-U is needed to address BES Basic Research Needs

ALS-U source brightness is essential to accomplish science goals

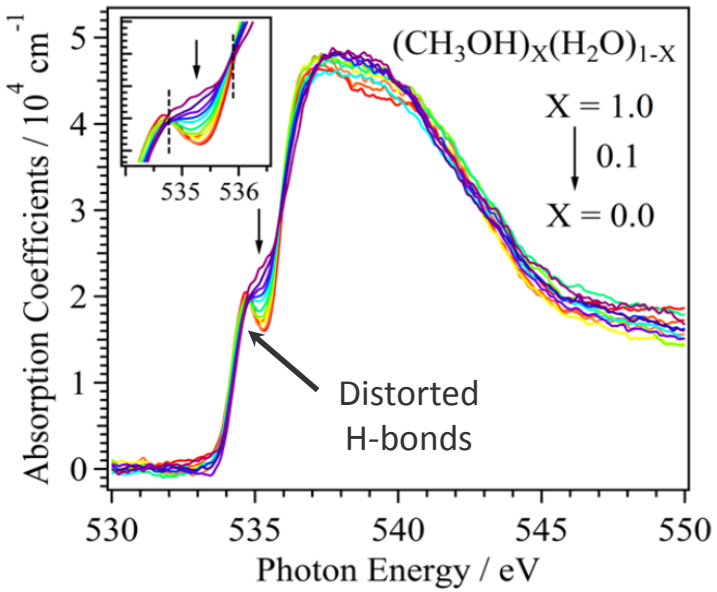
Materials Discovery

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

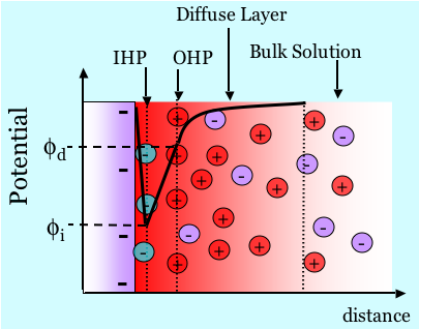
Harnessing Entropy for Material and Chemical Design

Measuring & Manipulating Nanoscale Currents & Flows

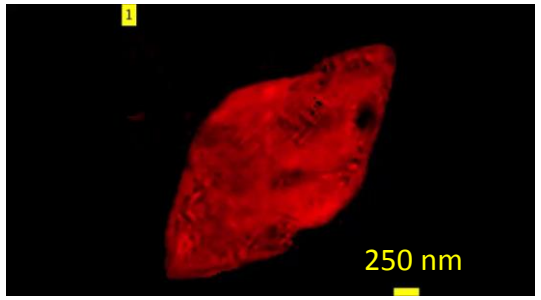
Materials Chemistry and Physics in Confined Spaces

Optimized electrocatalysts

C. Chen, et. al., Science **343**, 1339 (2014).



Helmholtz layer structure & stability



Electrochemical storage systems

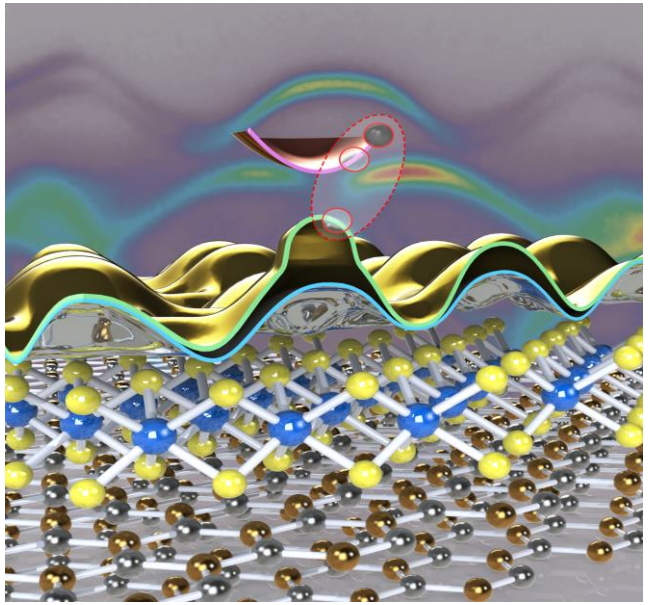
W. Chueh, D. Shapiro (2016)

Building blocks

Fluctuations & motion

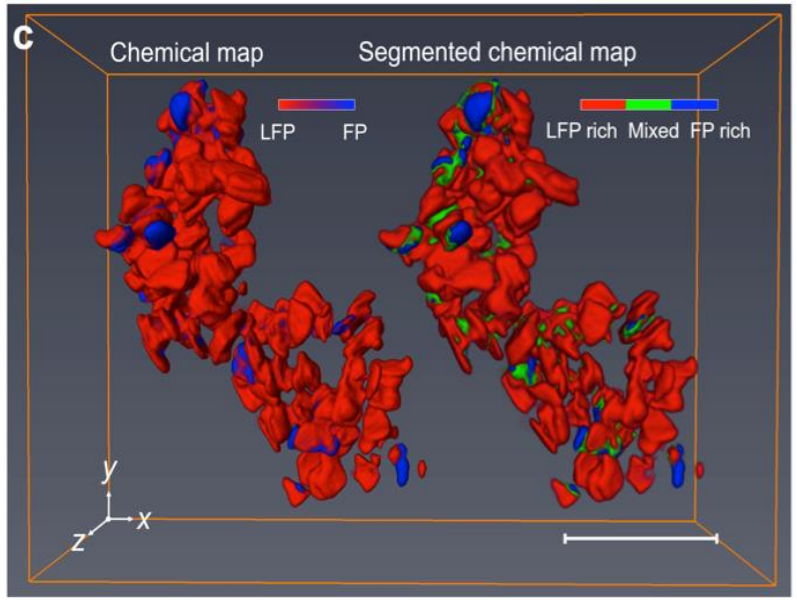
Integration & function

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

Requirement/Benefit	ALS in 2016	Today's ALS	Upgraded ALS
Instruments requiring smooth wave fronts	5	7	12
Instruments benefitting from a small round source	24	26	26
Instruments not dependent on source brightness	5	5	5
Total	**34**	**38**	**43**

Most instruments will benefit from the ALS-U, and the upgraded ALS will serve vibrant existing and new communities

Summary: ALS is working hard to enable ALS-U success

- 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.