The APS Upgrade

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APS Upgrade

Classe Seminar at Cornell University
April 3, 2013
Advanced Photon Source in 2012: The Nation's Largest User Facility

- 63 simultaneously operating beamlines, 5000 hours per year, >100 hour MTBF
- 4000 unique onsite users plus 1600 remote users, 4900 experiments in FY12
- 1500 total publications in CY2011
- 1600 protein structure deposits per year, plus drug discovery programs
- 2012 Nobel Prize
- Industrial users from ~150 companies in pharma, energy, electronics, materials ...
Worldwide Context for APS Upgrade

ESRF, France: upgrading
PETRA-III, Germany: new
SPring-8, Japan: upgrading

The world of synchrotrons

- 4th generation
- “3.5” generation
- 3rd generation, high energy
- 3rd generation
- 2nd generation
- Includes facilities under construction

ESRF, France: 6 GeV, 1992
PETRA-III, Germany: 6.5 GeV, 2009
SPring-8, Japan: 8 GeV, 1997

ESRF, France: upgrading
National Context for APS Upgrade

APS is complementary to other advanced x-ray sources in the US:
- Higher flux and brightness at x-ray energies above 10-20 keV than NSLS-II
- Short pulses with higher repetition rate than LCLS
APS Strengths

- High brightness and flux at high energies
- Fast pulses, high rep rate, flexible bunch structure
- Wide array of beamlines, beamtime available for complex experiments
- Large and diverse community

APS Strategy

- Drive advances in accelerators, undulators, optics, and detectors that build upon these strengths
- Make them available to the broad user community through optimized beamlines and strong groups of staff
- Bring forefront synchrotron capabilities to priority DOE and user programs
Transformational RIXS Instrumentation Upgrade Objectives

Components of the RIXS Beamline/Instrument Upgrade:

- Doubling monochromator throughput
- Two orders of magnitude focusing improvement from \((50 \ \mu m)^2\) to \((5 \ \mu m)^2\)
- Order of magnitude energy resolution improvement from \(\sim 200 \ \text{meV}\) to \(20 \ \text{meV}\)
- Order of magnitude detection improvement from 1 to 8-10 analyzers
- New sample environments for high P, high and low T, electric and magnetic fields and laser excitations

Components of the RIXS Beamline/Instrument:
- High-resolution monochromator
- Undulator source
- High-heat load monochromator
- Focusing mirrors
- Monochromatic, polarized micro-focused incident beam
- diced, spherical, near-backscattering analyzer system
- (strip-) detector
APS Upgrade Enables Breakthroughs in Science

Real materials under real conditions in real time

Mastering hierarchical structures through imaging

Can we harness photosynthesis for solar fuels?

Can we discover exotic new states of matter under extreme conditions?

Can we control nucleation and growth to make better functional energy materials?

Can we design drugs that will effectively target disease?
Main Features of the APS Upgrade

- The APS Upgrade will be transformational, providing a dozen new or upgraded beamlines with improvement in areas such as high-energy diffraction, *in situ* studies of materials synthesis, wide-field imaging, ultrafast diffraction and spectroscopy.

- Insertion devices optimized for brightness at high energies (e.g., superconducting or revolver), long straight sections, superconducting rf cavities to produce picosecond x-ray pulses, higher electron current, and beam stability.

- Upgrade machine with minimal loss of operating hours to ongoing programs.
SCU: Superconducting Undulators for High Energy X-rays

- Provide high brightness and flux at high energies (> 15 keV)
- The APS Upgrade will push the forefront of this new technology, which provides a long-term path forward to even higher flux and brightness (e.g. 100X improvement from typical U33 today at 100 keV)
SCU: Superconducting Undulators for High Energy X-rays

APS Upgrade News

First Light from the First High-Energy Superconducting Undulator

January 21, 2013

More than eight years of effort by Advanced Photon Source (APS) physicists, engineers, and technicians culminated on January 21, 2013, with the production of the first x-rays from the prototype of a novel superconducting undulator (SCU), which has been installed in the APS electron accelerator and storage ring at Argonne National Laboratory. It is the first such SCU operated at a third-generation synchrotron x-ray facility. {...}

SPX: Superconducting RF for Picosecond Pulses

Provide ~2 ps FWHM X-ray pulses at 6.5 MHz rep. rate for time-resolved studies at several beamlines, with path forward to ~1 ps.
APS Strategy: Surrounding and Beyond the Upgrade

The APS Upgrade is the lead component in the overall strategy for improvements to APS, that also includes:

- Additional beamlines funded by BES, NIH, BER, NSF, NNSA, industry
- New, neighboring facilities, e.g. the Advanced Protein Crystallization Facility of ANL Biosciences
- Expansion of lab and office space for users and user support
- Continued development of superconducting undulator and short-pulse technologies pioneered by the Upgrade
APS Upgrade Enclosures and Control Rooms
RIXS Sector 27 - Overall View

- Interface Points
- Storage Ring Components - Insertion Devices and Vacuum Chambers
- Front End
- Enclosures and Beamline Equipment
- View from Inside Ring
Enclosure installation can produce shock, vibrations and environmental disturbances for adjacent beamlines.
Once enclosures are installed, beamline equipment installation can proceed
  – Independent of maintenance periods
RIXS Sector 27 - Second Shutdown

Install Insertion Devices, ID Vacuum Chamber

Install Front End
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<th>New</th>
<th>Upgrade Relocation</th>
<th>WBS</th>
<th>Description</th>
<th>Sector</th>
<th>Front End</th>
<th>Planar ID</th>
<th>Revolver ID</th>
<th>Polarizing Devices</th>
<th>Superconducting Device</th>
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<th>ID Vacuum Chamber</th>
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| 8   | 6                  | 6        |                                                                | 22     | 19        | 3          | 5           | 3                 | 2                      | 8             | 3           | 12            | 2             |             |
## Proposed Funding Profile and Schedule

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- **Research & Development**
  - FY10: Approve Mission Need
  - FY11: Approve Alternative Selection and Cost Range
  - FY12: Approve LLP
  - FY13: Approve Performance Baseline
  - FY14: Approve Start of Fabrication

- **Conceptual Design**
  - FY11: CD-1
  - FY12: CD-2
  - FY13: CD-3

- **Preliminary Design**
  - FY12: CD-3

- **Final Design**
  - FY13: CD-3
  - FY14: CD-3

- **Fabrication/Procurement**
  - FY14: CD-3

- **Installation/Checkout**
  - FY15: CD-3

- **Float**

### Timeline
- **2010**
  - Apr-10: CD-0
  - Sep-11: CD-1

- **2011**
  - Aug-12: CD-3A
  - Sep-11: CD-1

- **2012**
  - Apr-13: CD-2
  - Aug-12: CD-3A

- **2013**
  - Apr-14: CD-3
  - Sep-11: CD-1

- **2014**
  - May-15: CD-3
  - Jun-13: CD-1

- **2015**
  - Aug-14: CD-3
  - Jul-15: SCU1 Design Complete
  - Sep-16: 4th Beamline Transfer to Operations Complete

- **2016**
  - Sep-17: 5th Beamline Transfer to Operations Complete
  - Apr-16: SPX Design Complete

- **2017**
  - May-17: SPX Installation Start
  - Sep-17: 5th Beamline Transfer to Operations Complete

- **2018**
  - Jan-18: 12th Beamline Transfer to Operations Complete
  - Sep-18: 6th Beamline Transfer to Operations Complete

- **2019**
  - Jan-19: 16th Beamline Transfer to Operations Complete

- **2020**
  - Feb-20: Last Beamline Transfer to Operations Complete
Summary

- The APS Upgrade opens new venues of research at the APS, all the while providing increased brightness and improved performance for our 5000 existing users.
- With the Upgrade, the APS will remain a leading light source in the world, supplying unique capabilities for the next several decades.
- Accelerator improvements include updates of existing technology, but also the installation of exciting new technologies, including superconducting undulators and the SPX superconducting RF deflecting cavity system.