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The Advanced Photon Source looks to the future

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Abstract

The Advanced Photon Source (APS) at Argonne National Laboratory is in its 12th year since producing first light. With an eye on the next 10 years, facility management have developed plans that address priorities for new and/or improved beamlines over the next 5–10 years with a strong evolution toward a greater number of dedicated beamlines. In addition, options, including an energy-recovery linac, are being evaluated for a planned upgrade of the APS.

Keywords: Argonne; Synchrotron; X-ray; Beamline; Energy-recovery linac

1. Future directions and new beamlines at the APS

The Advanced Photon Source (APS) at Argonne National Laboratory is in its 12th year since producing first light. Over that time, the user base has grown to more than 3000 individual scientists visiting the APS per year. Today, the APS has 49 instrumented beamlines on 30 sectors, with another nine beamlines in construction and/or commissioning phases, leaving four uncommitted sectors and about a dozen bending magnet lines remaining to be developed.

With an eye on the next 10 years, facility management brought together synchrotron users and non-synchrotron communities in a series of workshops on "Future Scientific Directions for the APS" (http://www.aps.anl.gov/Future/index.html) to look at scientific opportunities where synchrotron radiation can play new roles. This resulted in a wide range of ideas for unique investigative opportunities, including the development of a short-pulse X-ray source and construction at the APS of the largest high-field magnet beamline facility in the world. Based, in part, on these workshops, the APS and its Scientific Advisory Committee have developed plans that address priorities for new and/or improved beamlines over the next 5–10 years with a strong evolution toward a greater number of dedicated beamlines.

2. New and/or reprogrammed APS beamlines

2.1. Sector 1: High-Energy X-ray Scattering—Operational

X-ray Operations and Research (XOR) sector 1 is being reprogrammed as a dedicated, high-brilliance, high-energy beamline for applied materials research. The instrumentation for the high-energy (45–130 keV) monochromator and three-dimensional X-ray diffraction microscope were upgraded as the first phase of a planned three-phase program. Phases II (two white-beam stations and associated transport) and III (installation of a side-bounce monochromator and monochromatic side station and transport) of the 1-ID upgrade will be pursued when funding is available.

2.2. Sector 11: Powder Diffraction at 11-BM—Operational

XOR beamline 11-BM is a high-resolution powder diffractometer with 12 analyzer/detectors (Fig. 1) and a

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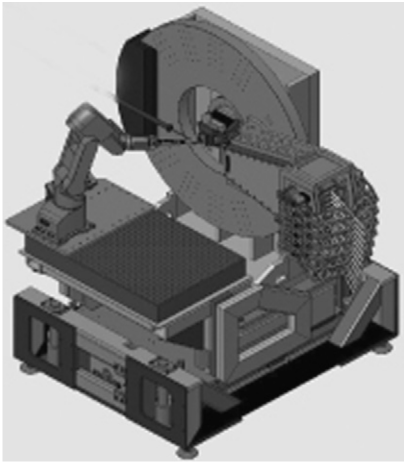

Fig. 1. Rendering of 1 of 12 analyzer/detectors developed for use at the powder diffraction beamline 11-BM.

robotic sample changer designed for high-throughput operation. 11-BM began operation as a mail-in sample user operation in run cycle 2007–3. Mail-in data can be collected a temperature range from 100 K to ambient room temperature. The operating energy range is ~10 keV (1.2 A) to ~40 keV (0.3 A).

2.3. Sector 26: The Hard X-ray Nanoprobe—Commissioning

The hard X-ray Nanoprobe beamline (Fig. 2) at APS sector 26 began commissioning in July 2007 and will support full user operations in 2008. The Hard X-ray Nanoprobe beamline utilizes X-ray energies from 3 to 30 keV to produce the world's highest-resolution hard X-ray images. The beamline will provide a diffraction-limited focal spot for scanning probe microscopy, with an initial spatial resolution of 30 nm—the size of 100 atoms. Instrumentation provides the first combination of scanning-probe and full-field transmission imaging.

2.4. Sector 30: Inelastic X-ray Scattering—Operational

The High-Energy Resolution Inelastic X-ray Spectrometer (HERIX, Fig. 3) at XOR sector 30 is now a user instrument with beam time allocated for general users. It works with up to nine analyzers in parallel, with an energy resolution of ~1.6 meV. HERIX will predominantly be used to study phonon excitations in solids. The flux at the sample position is 10^9 photons/s in a spot of $30 \times 10\,\mu$m.

The Medium-Energy Resolution Inelastic X-ray Scattering (MERIX) Spectrometer will be used to study collective valence electron excitations in correlated electron systems, primarily of transition-metal oxides. The X-ray photon energy range of MERIX is 5–12 keV and the targeted energy resolution is ~100 meV, covering the K-absorption of vanadium to zinc. The MERIX monochromator delivers to the sample X-ray photons in the 70 or 120 meV energy bandwidths.

2.5. Sector 32: X-ray Imaging and USAXS at 32-ID—Operational

XOR sector 32 is a dedicated full-field imaging beamline. At present, it is home for the temporary ultra-small-angle X-ray scattering (USAXS) setup as well. Sector 32 supports in-line phase-contrast and absorption imaging and tomography, USAXS, USAXS imaging, ultra-high-speed imaging, and hard X-ray transmission microscopy. The beamline consists of two experiment stations: the B station at ~35 m and the C station at ~65 m from the source. The beamline is equipped with millisecond and microsecond shutters for use in ultra-high-speed imaging. The transmission (hard) X-ray microscope (TXM, Fig. 4), which is part of a partner user program in collaboration with Xradia Inc. and Yeukuang Hwu of Academia Sinica, operates in the 8–18 keV range and has sub-50-nm resolution at 10 keV. It can be operated in both absorption or phase contrast modes.

3. Possible future APS beamlines

3.1. Diffraction in a high field

Materials subjected to extreme conditions such as high-magnetic fields are of great interest in contemporary condensed matter physics and materials science. The high-magnetic field beamline at the APS will be unique in the world: a steady-state 30–40 T magnet. The magnet will be developed in collaboration with the National High Magnetic Field Laboratory in Tallahassee, Florida, USA.

Construction of this beamline is envisioned as happening in two phases. Phase I encompasses the diffraction beamline with field capabilities up to 13 T. Phase II is the extension of the beamline outside the experiment hall floor and incorporates the 30–40 T magnet facility and required support utilities.

3.2. Intermediate Energy X-ray Spectroscopy and Scattering

One of the grand challenges in the 21st century is to understand the physics of materials that exhibit competing interactions, specifically materials in which the energy scales of valence bonding, Coulomb repulsion, and the kinetic energy of mobile electrons are similar in size, and the resulting ground state is a subtle compromise among these effects. Such materials exhibit a startling array of electronic phases and a heightened sensitivity to extrinsic perturbations such as changes in temperature, applied electric or magnetic fields, pressure, or nanopatterning.

The intermediate-energy X-ray beamline at the APS will operate in the regime from 0.2 to 2.0 keV to attack some of these intriguing scientific problems. This facility will serve