User Science Report

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Organization and Mission

The User Science Division coordinates major facility activities related to users so that we can be more effective in communicating with the user community, strengthening existing scientific programs, fostering the growth of new scientific programs, and raising the visibility of the exciting science produced by our users. The division consists of five sections: User Administration (Mary Anne Corwin), Information and Outreach (Lisa Miller), Beamline Development and Support (Steve Hulbert), Scientific Program Support (Ron Pindak), and Detectors and Controls (Peter Siddons). The major initiatives and accomplishments of the User Science Division and the NSLS user community for 2004 are summarized below.

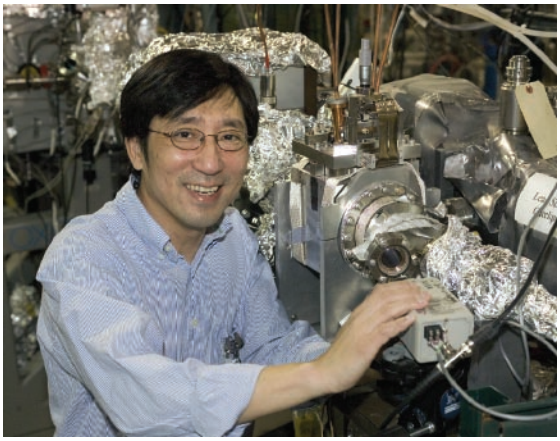
2004 Activities

With the help of a large number of users and staff, a major NSLS-II workshop was organized in March 2004 to summarize the outcome of more than a dozen focused workshops where the grand challenges in the individual fields of research, and the impact of NSLS-II on those challenges, as well as the technical challenges in the accelerator, insertion devices, optics, and detectors, were discussed. The workshop was well attended and provided additional support to the NSLS-II scientific case. Following the workshop, the NSLS-II proposal was officially submitted to the Department of Energy (DOE).

The general user proposal system was switched to the new online proposal system (PASS) in the May-August cycle of 2004, after extensive testing by the User Administration office and representative users. The transition has been very smooth, with only minor problems. Additional new features, in particular rapid access, will be implemented in 2005. As always, we welcome comments and input from users to continue improving the system.

This year was also a particularly busy year because, as part of the overall plan to enhance the experimental capabilities at the NSLS, we have completed a large number of beamline construction and upgrade projects, including beamline upgrades for the U12IR beamline, the X1A undulator beamline, the X13A elliptically polarizing wiggler beamline, and the X21 wiggler beamline, as well as the construction of the X27A x-ray microprobe beamline and the X29 undulator beamline. Some of the highlights are described below, and more detailed descriptions can be found in the pages following this article.

- **U12IR beamline upgrade:** The U12IR far-infrared beamline was upgraded to accommodate a Bruker IFS-125HR spectrometer with a resolution capability of 0.001 cm^{-1} (125 nV or 30 MHz), making U12IR the highest resolution IR beamline of any synchrotron facility. This new capability, in combination with the ex isting high-field magnet and Ti-sapphire laser, provides a unique facility for the study of THz spectroscopy, electron spin resonances, and time-resolved magneto-spectroscopy.



- **X1A beamline upgrade:** The X1A1 beamline is dedicated to scanning transmission soft x-ray spectromicroscopy in the 200-600 eV range, which includes the carbon, nitrogen, and oxygen K-edges. A new four-position in terchangeable grating chamber with state-of-the-art soft x-ray laminar gratings optimized for specific portions of the X1A1 photon energy range was implemented to improve the throughput and energy resolution of the beamline.
- **X13A beamline upgrade:** A new motorized and water-cooled mirror system was installed in the X13A elliptically polarizing wiggler beamline. The larger collecting angle and improved mirror figure have resulted in an order of

magnitude increase in flux. The increased flux and temperature stability of the mirror will be particularly important for the detection of small magnetic circular dichroism signals.

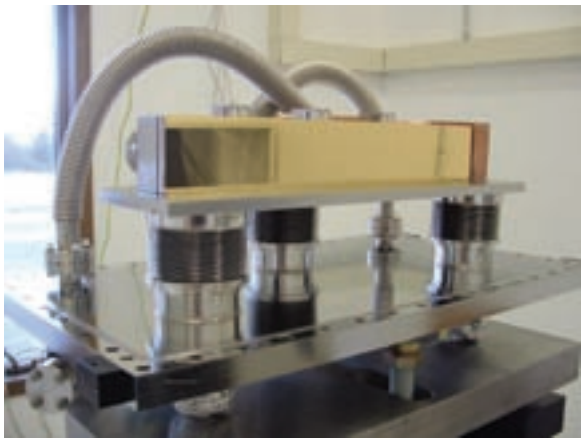
- **X21 beamline upgrade:** The X21 wiggler beamline was upgraded for research programs in materials sciences, including x-ray scattering studies of materials under high magnetic fields, in-situ study of materials growth, and small angle x-ray scattering. An important feature of the new beamline is the non-dispersive double silicon crystal or multilayer monochromator, which contains selectable pairs of silicon crystals or multilayer elements that can be chosen in-situ to suit the experiment at hand.
- **X27A beamline construction:** A new hard x-ray microprobe beamline, X27A, has been completed to provide much-needed additional x-ray microprobe capacity and enhanced x-ray microspectroscopy capabilities to the NSLS. In particular, the beamline is optimized for the environmental science user community.
- **X29 beamline construction:** A new mini-gap in-vacuum undulator beamline, X29, dedicated for macromolecular crystallography, has been completed. The beamline was funded by various divisions of DOE (Offices of Basic Energy Sciences and Biological and Environmental Research within the Office of Science) and the National Institutes of Health (National Center for Research Resources, National Institute for Biomedical Imaging and Bioengineering, and National Institute of General Medical Sciences) in order to meet the increasing demand at the NSLS for high-brightness x-ray beamlines for the study of the most challenging problems in macromolecular crystallography.

In the areas of computer control and detector development, the major effort in the development of a multi-element Si detector was completed this year. Extensive testing of the detector with users has begun. Using the same technology, a linear array Si detector was constructed and used by users in real-time x-ray scattering experiments with great success. In addition, we have extended the fast avalanche photodiode (APD) detector-electronics unit to soft x-ray scattering experiments, and are working with outside vendors to make NSLS-designed APD-based detectors commercially available. We also continued the upgrade of EPICS-based beamline control system and PLC-based user interlock system on NSLS and PRT beamlines.

Finally, we continue to take more immediate steps to enhance user science, education, and outreach at NSLS. The annual short course on EXAFS "graduated" 32 students this summer. This hands-on workshop was organized by NSLS users Bruce Ravel (Naval Research Laboratory), Simon Bare (UOP LLC), and Lisa Tranquada (SFA, Inc.), and provided both new and experienced users with exposure to EXAFS theory, data collection, and analysis. A regular series of science highlight articles is now published on the NSLS website to help inform the NSLS user community and the broader scientific community of the exciting scientific results obtained at NSLS. The symposium series continues at the NSLS to give staff and users an opportunity to hear about cutting-edge synchrotron research that is performed worldwide. Upcoming seminars are listed on the NSLS homepage for easy access to the schedule. Finally, outreach events such as the NSLS Summer Sunday, "Take Our Sons and Daughters to Work" Day, and tours (more than 50 tours of the facility were conducted in 2004) continue to bring hundreds of members of the community to the NSLS to hear about the exciting science ongoing at the NSLS and how this research impacts their everyday lives.

X13A Magnetic Circular Dichroism Beamline Upgrade

Two insertion devices are installed in the X13 straight section: the mini gap undulator (MGU) and the fast-switching (22 Hz) elliptically polarizing wiggler (EPW). The X13A beamline, which utilizes the EPW source, is dedicated to the study of magnetic materials and their properties. The EPW provides alternately left- and right-handed elliptically polarized soft x-rays, which enables magnetic circular dichroism (MCD) measurements to be performed at a fixed magnetic field on the sample. The fast-switching capability simplifies the detection of small magnetic signals via the use of lock-in techniques.



The new X13A M0 mirror before installation at the beamline. Only the bottom flange of the ultra-high vacuum chamber is shown in this photograph. The flexible bellows behind the mirror surrounds and vacuum-isolates the water-cooling plumbing. The mirror itself is gold-coated electroless nickel deposited on glidcop, which is explosion-bonded to a stainless steel substrate. The water-cooling channels are milled in the stainless steel/glidcop substrate, and then a stainless steel plate containing mechanical and plumbing fittings is welded to the mirror substrate. The three bellows underneath the mirror allow motor-driven adjustments of the mirror in the x and z translations and in rho and tilt rotations, while the surrounding chamber remains fixed.

The first optical element in the X13A beamline is a horizontally deflecting mirror (M0) that collects the central ~1 mrad of the EPW source, directs it to the X13A branch, and focuses it horizontally at the entrance slit of a horizontally dispersing spherical grating monochromator (SGM). The original (1980s) M0 mirror was too short, not well cooled, and suffered from mechanical stability problems and inadequate adjustment controls. We have replaced this mirror with a new one that remedies all of these problems. The new M0 mirror has twice the length of the old one, is integrally water-cooled, and is outfitted with a robust mounting and motor-driven mirror alignment system. These features have significantly improved the stability of the signal ratio between left and right elliptically polarized soft x-rays. Very often, the magnetic signals measured at X13A are quite small, such that an improvement in beam stability results in a significant improvement in data quality. In order to maximize beamline performance for demanding soft x-ray MCD measurements, the M0 mirror position for X13A operations has been centered on the EPW beam fan. This geometry necessarily blocks any output from the MGU, and results in a 50/50 scheduling split of X13 beamtime between X13A and X13B operations.

The new position of the X13A M0 mirror, both horizontally and along the beamline, required realigning the entire X13A beamline: the X13A SGM monochromator, I0 chamber, 22 Hz chopper, and diffractometer endstation. During initial commissioning of the newly rebuilt X13A beamline, it became clear that the EPW beam was not quite level, so we requested a vertical orbit correction for X13A. The new orbit bump was eventually made permanent, and contributed most of the factor-of-ten increase in intensity measured at the sample in the X13A endstation. (The doubled mirror length contributed only a factor of two.) The stability of the new mirror mounting system has also resulted in an improvement in stability of the left/right signal ratio. The flux and stability improvements combine to provide a significant increase in sensitivity, i.e. the ability to detect small magnetic signals. The newly renovated X13A beamline was tested by users during the fall 2004 scheduling cycle.

Principal thanks for the installation of this mirror, including the large amount of lead shielding required around the mirror chamber, go to the User Science Division technical group led by Tony Lenhard. In particular, Shu Cheung performed most of the mechanical assembly and installation work on this mirror chamber, once the vendor (Advanced Design Consulting, Lansing, NY) completed delivery. Thanks also go to the Operations and Engineering Division for mechanical survey work and control-room assistance during commissioning, as well as to the Accelerator Division for the X13 orbit bump work. —Cecilia Sanchez-Hanke, BNL-NSLS

A Unique Spectrometer for High-Resolution Inelastic X-ray Scattering

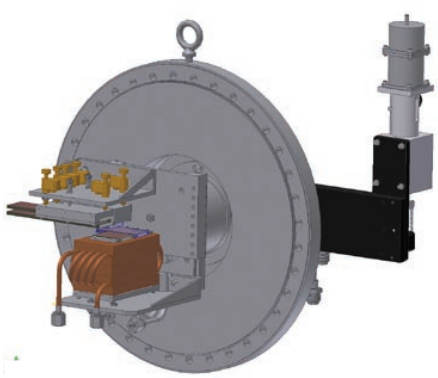
(Top) Picture of the IXS-spectrometer. The nine individual inverse joystick goniometers for each analyzer crystal are mounted on a two-circle goniometer, which in turn is mounted on a translation stage. The detector mounted on the two theta can move along the two-theta arm to stay on the Rowland circle. (Bottom) A close-up picture of the nine-crystal (10 cm each) analyzer array.

A nine-element, two-dimensional crystal array analyzer system for inelastic x-ray scattering (IXS) has been designed and built at the NSLS. Each individual crystal analyzer is aligned with an inverse joystick goniometer. The energy of the scattered photons is measured with a conventional double-circle goniometer mounted on a translation stage, which allows the maintenance of the sample, analyzers, and detector in a Rowland-circle geometry. The spherically bent crystal analyzers play the key role in this spectrometer. We chose a diameter of about 10 cm for a 500 μm thick Si(440) wafer, and bent it to radius of 1 m. We realized an adequate compromise between energy resolution (1.5 eV) and the solid angle (about 4% with nine analyzer crystals). At a Bragg-angle close to backscattering ($\theta = 88^{\circ}$), we obtained an energy resolution of 0.5 eV.

The instrument can be used to probe the metal site valence, spin polarized charge density, and local magnetic ordering in transition-metal systems. In addition, it can be used to obtain light-element x-ray absorption spectra by the use of inelastic scattering with bulk sensitivity without the need for vacuum conditions. The light-element sensitivity utilizing a hard x-ray incident beam makes the spectrometer useful for studying in-situ processes. The multi-element analyzer development was funded by a National Science Foundation Instrumentation for Materials Research (NSF-IMR) grant.

For more information on applications of this instrument see: Qian, Q., Tyson, T., Savrassov, S., Kao, C., and Croft, M., *Phys. Rev. B*, **68**, 014429 (2003). —Trevor Tyson, NJIT

A Renovated X-Ray Wiggler Beamline for Materials Science



The new X21 monochromator internal assembly contains silicon crystal and multilayer pairs that can be selected in-situ via transverse alignment of the appropriate pair in the beam path. The first pair is mounted on a cryogenic copper support. The second silicon crystal and multilayer element are mounted on their own motor-driven kinematic supports. The entire assembly is mounted on a rotary vacuum feedthrough, which is driven by the motorized assembly shown behind the mounting flange.

The X21 hybrid wiggler x-ray beamline and its endstations are devoted to inelastic x-ray scattering for materials science research. To meet the increasing needs of these programs, the beamline optics and endstations have been upgraded.

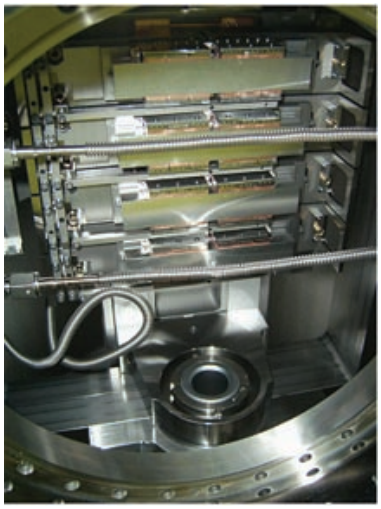
The first optical component is a new non-dispersive double silicon crystal or multilayer monochromator, which contains selectable pairs of silicon crystals or multilayer elements that can be chosen in-situ to suit the experiment at hand. The first silicon crystal and multilayer element are mounted side-by-side on a helium-gas-cooled cryogenic support that suppresses thermal distortions of the crystal or multilayer when subjected to the 500 W wiggler beam.

The monochromatic beam that emanates can be used as is, or can be further conditioned by the original high-resolution four-reflection Si(220) monochromator, which remains installed in the beamline, if high energy resolution is desired.

Finally, the beam is then focused and delivered to the appropriate experimental setup by one of two bent cylindrical mirrors, each of which is shaped to focus the beam into one of the two experimental stations.

The X21 experimental endstations have been rebuilt to accommodate new experimental programs that address elastic x-ray scattering studies of materials under high magnetic fields, thin films grown *in-situ*, and materials studied with small angle x-ray scattering, with appropriate setups permanently installed in the endstations. The renovated beamline and both experimental endstations, including their dedicated instruments, are now in operation.

X1A Monochromator and Laser Interferometer Upgrades



The new monochromator at beamline X1A1. It will provide for exchangeable gratings with higher diffraction efficiency, integrated water-cooling, and improved vacuum performance to minimize carbon contamination. It includes four selectable in-situ side-cooled grating holders, and provides for micro-radian angular precision and repeatability.

The X1A1 beamline received a new monochromator in May 2004. The purpose of this monochromator upgrade was to provide for exchangeable gratings with higher calculated diffraction efficiency, integrated water-cooling (such as will be required for NSLS-II), and improved vacuum performance to minimize carbon contamination. Due to constraints of the beamline length, the optical configuration could not be changed; it continues to be a spherical grating with a fixed exit arm and a resolving power of about 5000 at 290 eV. The monochromator was specified by Steve Hulbert of the NSLS, and manufactured by Physical Science Laboratories. It was installed by NSLS personnel during the May shutdown, and the electronic interfacing and alignment was done by the Stony Brook X1A group in late May and early June. The monochromator offers a significant improvement in ease of alignment, and the possibility of extending the operating energy range of X1A1. Two of the new gratings (Horiba Jobin-Yvon, Inc., Edison, NJ) are optimized for operation near the carbon K-edge (calculated diffraction efficiency 16% at 290 eV) and one is optimized for the oxygen K-edge (calculated diffraction efficiency 27% at 505 eV). At present it has been used primarily for carbon edge studies, and as the vacuum gradually improves we hope to see a reduction in the rate of carbon contamination. Thanks to Chi-Chang Kao, Steve Hulbert, Qing-Yi Dong, Gary Nintzel, and Dennis Carlson, along with many others from the NSLS, as well as Bjorg Larson, Mirna Lerotic, and Sue Wirick from Stony Brook, for their efforts with this system.

We are also in the middle of installing a laser interferometer upgrade to the scanning transmission x-ray microscope at X1A2, and then, at a later date, the one at X1A1. This will follow impressive developments at the Advanced Light Source by David Kilcoyne and others to use laser interferometer information on scanning stage position in a closed-loop feedback system to improve position stability in spectromicroscopy. The laser interferometer upgrade is also accompanied by a complete redesign of the control electronics and software, which will improve throughput of the microscope. This effort has included Holger Fleckenstein, Dan Flickinger, Benjamin Hornberger, and Mirna Lerotic from Stony Brook, and it is a key element to NASA-funded research performed by George Flynn of SUNY Plattsburgh in partnership with Stony Brook. —Chris Jacobsen, Stony Brook University

Ultrahigh Resolution Infrared Spectroscopy Moves In at Beamline U12IR

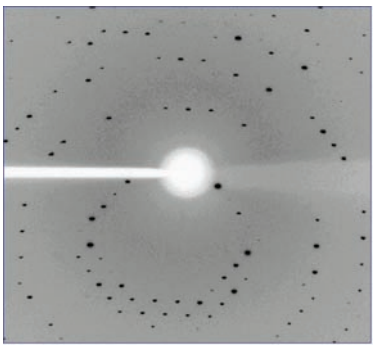
The ultrahigh resolution infrared spectrometer at beamline U12IR.

In a collaboration between Stony Brook and UCLA researchers and funded by the Defense Advanced Research Projects Agency (DARPA), a new high-resolution infrared spectrometer has been acquired for the U12IR beamline. It is hard to miss the long vacuum box next to the entrance to the NSLS VUV-IR floor, running approximately parallel to the walkway.

The key component of the instrument is a mirror that is mounted on a high precision motion stage and runs inside the box. The exceptionally long range of motion results in a high spectral resolution (on the order of 0.001 cm^{-1}); in fact, this Bruker Instruments spectrometer (Bruker IFS-125HR) has the highest possible resolution available today.

The spectrometer will be used to investigate low energy (<1 eV) vibrational and electronic excitations in gases, liquids, and solids. A particularly unique application is the study of electron spin resonance (ESR) with infrared light; this becomes possible when the light from the spectrometer is fed to the 16 Tesla superconducting magnet at the beamline, purchased earlier with support from the National Science Foundation.
—Laszlo Mihaly, Stony Brook University

A New X-ray Undulator Beamline for Macromolecular Crystallography



This is an example of the central region of a diffraction pattern recorded at X29. One can see that the undulator, the x-ray optics, and the detector provide excellent sensitivity and resolution. The system will work quite well for study of the largest and most difficult molecular systems.

A new experimental station dedicated to macromolecular crystallography has been completed and has commenced operation at beamline X29. The mini-gap in-vacuum undulator beamline was built in a collaboration between the BNL Biology Department, the Center for Synchrotron Biosciences at Albert Einstein College of Medicine, and the NSLS.

The funding for construction and operation comes from the Department of Energy's offices of Basic Energy Sciences and Biological & Environmental Research, and the National Institutes of Health (specifically, the National Center for Research Resources, the National Institute for Biomedical Imaging and Bioengineering, and the National Institute of General Medical Sciences).

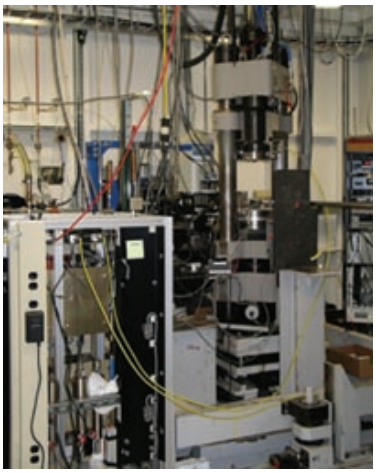
The beamline was constructed especially to meet the increasing demand at the NSLS for a high-brightness x-ray beam for state-of-the-art macromolecular crystallography research, which had previously been served by a single beamline, X25.

The new diffractometer and detector system in the X29 x-ray hutch. This device is equipped with a high-speed and high-precision crystal axis suitable for operation with a robotic specimen changer.

The x-ray optics for the beamline consists of a Si(111) double crystal monochromator, with the first crystal being cryogenically cooled and second crystal bendable to provide sagittal focusing of the horizontal beam fan, followed by a vertically focusing mirror. The experimental station includes a Crystal Logic diffractometer, an ADSC Q315 CCD x-ray area detector, and an Oxford Instruments Cryojet sample conditioner. Already in heavy use by conventional means, the focus of this facility will be automation and high throughput operation. A fraction of this new beamline's use will be devoted to both "FedEx" (mail-in) crystallography and structural genomics.

Two New Facilities for High-Pressure Research

The X17 wiggler is the only high-energy x-ray insertion device at the NSLS. Over the years, user demand in high pressure, materials, and medical research has increased significantly. In order to meet the needs of these growing user communities, two new experimental hutches (X17B2 and X17B3), funded by the NSLS and NSF through COMPRES (Consortium for Materials Properties Research in Earth Sciences), were built and commissioned this year. In addition, a beam splitter/filter unit was installed in the upstream X17 transport hutch to allow x-ray beams to be relayed through the B1, B2, and B3 hutches in a manner that allows experiments to run in the three hutches simultaneously.

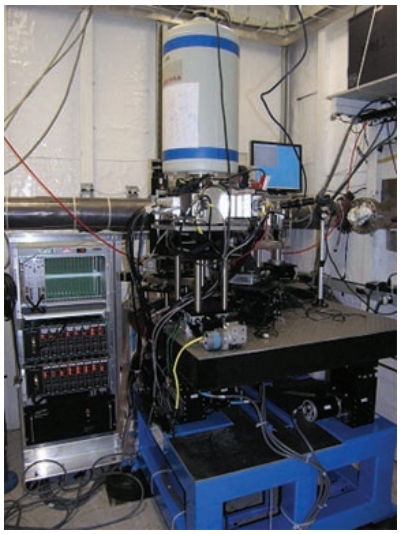


High-pressure, high-energy research occupies beamlines X17B2 and X17B3.

The new hutches are dedicated to high-pressure, earth, and mineral science research. The X17B2 hutch is utilized by the COMPRES consortium from Stony Brook University, led by Professor Don Weidner, to accommodate a multi-anvil large-volume press. White beam is currently used for experiments on this press. A multi-element Ge detector is used to collect energy-dispersive x-ray diffraction data. Radiographic imaging of the sample in the press can also be taken during all experiments. The development of a sagittal-focusing, side-diffracting Laue monochromator and a separate new large-volume press is underway for angle-dispersive diffraction. The X17B3 hutch, downstream of X17B2, is utilized by the diamond anvil cell group led by Dr. David Mao (Carnegie Institution of Washington, also a member of COMPRES). In this beamline, white beam is focused by Kirkpatrick-Baez mirrors onto the sample in the diamond anvil cell. Ongoing projects include the commissioning of an in-hutch, sagittal-focusing, 30 keV monochromator at X17B1 to provide monochromatic beam to X17B3, and safety and interlock approvals to include laser-heating capabilities.

—Zhong Zhong, BNL-NSLS

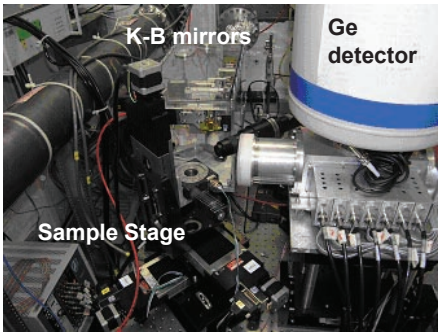
X27A: A New Hard X-Ray Microprobe Beamline for Environmental Research



The new X27A hard x-ray microprobe shown within the experimental hutch.

A new and advanced hard x-ray microprobe facility has been installed at NSLS bending-magnet beamline X27A. This beamline was constructed to meet the increasing demand of environmental molecular science users for state-of-the-art x-ray microprobe research, only previously served by the highly productive X26A beamline. Operated as a microprobe since 1986 by the University of Chicago's Consortium for Advanced Radiation Sources, the Savannah River Ecology Laboratory, and BNL's Environmental Sciences Department, X26A's research mission has been to provide a national facility for micro-spectroscopy to the environmental sciences and geosciences community. However, as the only dedicated hard x-ray microprobe at the NSLS, beamline X26A has been consistently oversubscribed. X27A will allow the NSLS to meet the demand of this ever increasing and vibrant user base.

The new X27A microprobe facility consists of a newly designed monochromator and slit system, which is installed between the X27A & X27B hutches and enables both monochromatic and white-beam modes of operation. Si(111) and Si(311) channel-cut crystals are employed, enabling an energy accessible range from below 4 keV up to 32 keV. To micro-focus the incoming x-rays, a Kirkpatrick-Baez (K-B) bender system is used to form the required elliptical shapes from flat tapered rhodium-coated trapezoids. The x-ray beam is focused to a spot size of ~ 5 µm [vertical] x 15 µm [horizontal] at the sample location, which is ~ 9 cm from the end of the helium-filled mirror enclosure box. A 13-element, liquid-nitrogen cooled germanium detector is used to collect the fluorescence photons emitted from the sample. Transmission is collected with a photodiode. Spatially resolved information is obtained by raster-scanning the sample through the micro-focused x-ray beam with a high-resolution motorized sample stage.

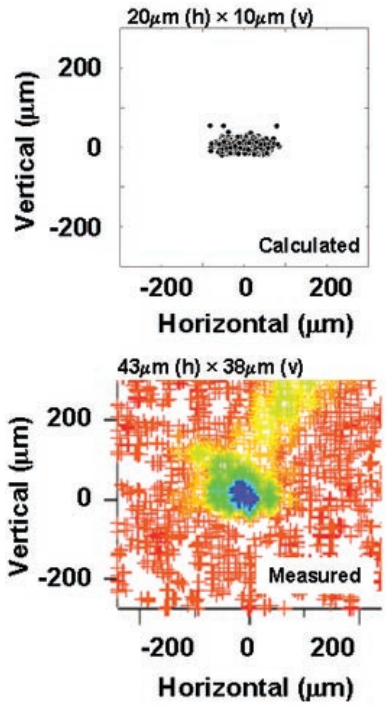


Close-up of the microprobe setup: The K-B mirror system is located towards the top center, the high-resolution sample stage is towards the bottom center, and the 13-element fluorescence detector is on the right of the photograph.

Beamline control is VME-based EPICS through the SPEC and IDL (using X26A IDL routines) software programs.

The X27A microprobe facility involves a collaboration between the NSLS, EnviroSuite, and CEMS. EnviroSuite is a strategic initiative within BNL's Environmental Sciences Department that facilitates environmental molecular science research at the NSLS, and CEMS is the Center for Environmental Molecular Science, based at Stony Brook University. The funding for construction of the X27A facility, the detector system, and operation comes from the Offices of Basic Energy Sciences and Biological & Environmental Research within the Department of Energy's Office of Science, and CEMS is supported by grants from the National Science Foundation and the Department of Energy. —James Ablett, BNL-NSLS

A New Micro-Focused Branch is Added to the U5UA Beamline



The new micro-focused branch at the U5UA undulator beamline meets the increasing demand of nanoscience users. The small spot will be of major importance in microscopy studies. In the figure the calculated spot-size is compared with direct measurements, obtained by scanning the light-beam with a 5 μm pinhole.

The U5UA beamline is an intense undulator beamline operating in the 15 to 200 eV photon energy range. It can excite valence bands electrons as well as shallow core levels from solid surfaces, and is also equipped with a four-reflection circular polarizer that operates in the 15 to 70 eV range.

U5UA has been upgraded with a new branch (#2) added downstream from the existing branch (#1). The new branch consists of a pair of ellipsoidal mirrors that demagnify the U5UA #1 sub-mm-sized beam by a factor of approximately 10, forming a micro-focused spot.

The new micro-focused branch is therefore particularly appropriate because it can be used as an intense excitation source in LEEM/PEEM experiments.

Furthermore, even conventional VUV spectroscopy techniques, such as angle-resolved photoemission, are currently spot-size limited in their quest for better and better energy resolution.

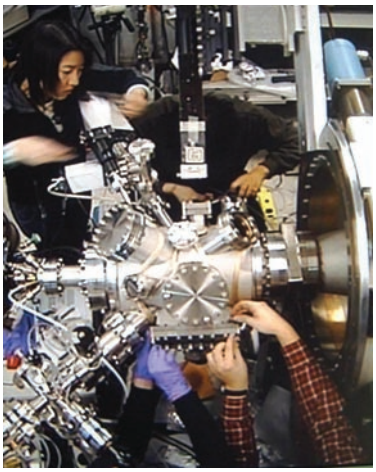
The U5UA beamline optics are capable of delivering very high photon energy resolution light. For example, a resolving power of 10,000 has been demonstrated at ~30 eV. However, in order to match this source ideally to a high-resolution electron spectrometer, a micro-focused light spot is required.

The new branch was constructed to meet the increasing demand of nanoscience users. The small spot will be of major importance in microscopy studies, such as LEEM/PEEM, where combining a small spot size with tunable synchrotron photon energy enables VUV spectromicroscopy experiments to be performed. The micro-spot will also benefit ultra-high resolution photoemission and emission experiments.

The new branch is now operational and available to users. Presently the performance of the new beamline is being characterized, and preliminary results indicate a spot-size of approximately 25 microns in diameter at fwhm.

A New Facility for Real-Time X-Ray Studies of Materials Processing

Formation of the advanced materials that are at the forefront of science and technology requires increasingly sophisticated thin film growth techniques and surface modification regimens. To better understand in real time the atomic-level changes occurring during such processing, a new facility is being developed at beamline X21 – the X-ray Studies of Materials with Analysis in Real Time (XSMART) facility. Funded with the National Science Foundation (NSF) Major Research Instrumentation (MRI), and Instrumentation for Materials Research (IMR) support to Boston University (K. Ludwig and T. Moustakas) and the University of Vermont (R. Headrick), the XSMART collaboration also includes C. Eddy of the Naval Research Laboratory. To promote flexibility, the x-ray spectrometer is designed so that modest-sized processing/vacuum chambers can be rolled onto a base diffractometer system. This design allows multiple specialized chambers to be constructed, optimized for processing, and then moved onto the diffractometer for x-ray experimentation. Thus, the base diffractometer system will be available for scientists in the community to design processing chambers to meet their individual needs.



Real-time sample characterization is now available at beamline X21.

Initially, two UHV chambers have been constructed. First studies with these are focusing on surface evolution during several distinct processes: ion bombardment and plasma processing, growth of novel thin films by pulsed laser deposition (PLD), formation of ultra-thin silicide films, and growth of III-V nitrides by molecular beam epitaxy (MBE).
—Karl Ludwig, Boston University