National Synchrotron Light Source

Five Year Plan

FY 2007 - 2011

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1. Executive Summary

The National Synchrotron Light Source (NSLS) began its operation as a dedicated user facility in 1982, and has been delivering high-brightness radiation, ranging from far- infrared to 100 keV x-rays, to a large and diverse scientific user community for more than two decades. Today, the NSLS operates 65 beamlines, with 49 beamlines on the X-ray ring and 16 beamlines on the VUV-IR ring, and supports the research of more than 2,000 scientists from over 400 academic, industrial, and government institutions. An important national and international research resource, the NSLS plays a particularly critical role for the research community in the Northeastern United States.

To ensure the continuing success of the NSLS, a five-year strategic plan has been developed with input from the user community, staff, and the NSLS Scientific Advisory Committee. The plan, summarized in this document, aims to identify the most exciting scientific opportunities; areas of vulnerability and improvements in accelerator operation and performance; upgrades for beamlines, detectors, and infrastructure to improve scientific productivity; and safety issues. Updated annually, this plan will be used to guide the allocation of resources and the development of funding proposals.

First and foremost, it is essential that we maintain the high reliability and performance of the two storage rings in order to support the large user base at the NSLS. We have identified critical vulnerabilities for the whole accelerator complex and have subjected our conclusions to external review. Their findings will be factored into our planning to assure robust NSLS Operations. We have also identified machine improvements that will have the largest impact to the user program and have developed plans for their implementation.

Scientifically, nanoscience and technology, energy research, and biomedical imaging are identified as the areas where strategic investment by the NSLS could have the largest impact. The wide range of experimental tools available at the NSLS, coupled with the unique intellectual environment of its large and diverse user community, consisting of academic, governmental and industrial researchers, presents an ideal situation to tackle interdisciplinary problems of this nature. These are also areas that support the strategic initiatives of Brookhaven National Laboratory, other major institutions of the region, and the nation as a whole.

In support of these scientific priorities and to meet the growing demand of users in other areas, we have developed a major beamline/endstation upgrade program, which is described in detail in this document. We have also outlined a plan to develop and provide state-of-the-art detectors to fully utilize the high brightness and flux from the light source. The completion of both will substantially improve the quality of the beamlines and instrumentation at the NSLS, and encourage new and exciting science.

Furthermore, we will pursue ways to enhance scientific productivity through infrastructure improvement. In particular, we will increase the level of automation for beamlines and endstations; make more efficient use of the space around the experimental floor in order to increase laboratory and setup spaces for users and allow better off-line preparation and characterization of samples; and work with the user community to support experiments with increasing complexity by providing better laboratory equipment..

It is also essential to improve user support as well as beamline management and operation to capitalize on the hardware investment. To this end, we will strive to increase the staffing of the existing facility beamlines to ensure that they are fully utilized, and to allow the facility to attract and retain the best employees.

In addition, we will continue to build partnerships with research resources. Today, six research resources, ranging from structural biology, to catalysis, to earth and environmental sciences, fully or partially support more than 20 beamlines. These resources are the focal points for the specific scientific communities they serve. They help define the scientific priorities and the needs of the communities, as well as provide unique scientific infrastructures and user training and support. Working with research resources has been an effective way to leverage the resources of the NSLS and the scientific/technical expertise of the NSLS staff. In the coming years, we will work with the research resources to enhance their capabilities to meet their scientific challenges. We will also continue to work with research resources to improve coordination and cooperation among them and with the NSLS to achieve greater efficiency and synergy.

We recognize that synchrotron research is a very dynamic enterprise. New applications of synchrotron radiation are discovered and developed constantly through advances in light sources, instrumentation, and the development of new experimental techniques, based on (1) a better understanding of the interaction between light and matter, and (2) the introduction of synchrotron tools to new scientific disciplines. The evolution of the large and diverse user base at the NSLS is clear evidence of this aspect of synchrotron research and a testament to the success of the NSLS and its user community in continually renewing itself. To continue this trend, we will enhance our education, outreach, and scientific program development effort. In particular, we will direct our effort to targeted institutions and areas of science.

The advent of the NSLS-II project and its scheduled completion by 2012-13 clearly will have profound impact on the NSLS in the coming years. The NSLS will coordinate with the NSLS-II project on all major machine upgrades, beamline/endstation construction, staff additions, and organization to ensure that (1) there is optimal utilization of NSLS resources, (2) we take advantage of the NSLS-II R&D effort, (3) the user program is positioned to explore the unique properties of the NSLS-II, and (4) there is a smooth transition for our staff and user programs.

Last but not least, we will continue to be vigilant and set the highest priority for staff and user safety as stated in the mission of the NSLS: “support our users in doing outstanding science in a safe and environmentally friendly manner.”

2. Scientific Opportunities

The scientific programs at the NSLS are best characterized by their diversity and the synergistic relationships. The following is the list of current major scientific programs at the NSLS and their fraction of the user community:

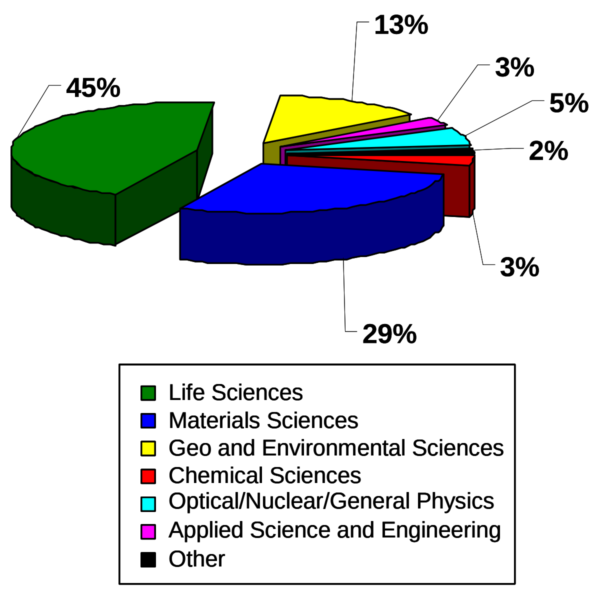
Life Sciences (45%)
- Macromolecular Crystallography
- Biomedical Imaging

Materials and Chemical Sciences (37%)
- Strongly Correlated Electron Systems and Magnetism
- Materials Growth and Synthesis
- Soft Materials and Biophysics
- Catalysis and Energy Research

Geosciences and Ecology (13%)
- Earth, Planetary, and High Pressure Materials Sciences
- Environmental Sciences

Applied Science and Engineering (3%)
- Industrial and Engineering Applications
- Materials Characterization
- Metrology

NSLS Users by Field of Research
FY 2006



These programs are healthy and expected to be very productive in the coming years. In particular, there are six research resources, including structural biology, catalysis, and earth & environmental sciences, that fully or partially support more than 20 beamlines. These resources are the focal points for the specific scientific communities they serve. They help define the scientific priorities and the needs of the communities, as well as provide unique scientific infrastructure, user training, and support. Working with research resources has been an effective way to leverage the resources of the NSLS and the scientific/technical expertise of the NSLS staff. We will work with the research resources to enhance their capabilities to meet the scientific challenges identified by these communities in the coming years. We will also continue to work with research resources to improve coordination and cooperation among them and with the NSLS to achieve greater efficiency and synergy.

Looking into the future, we believe that the most exciting scientific opportunities for the NSLS are Nanoscience and Technology, Energy Research, and Biomedical Imaging. First, the American Competitiveness Initiative (ACI), which proposes to double the federal spending in physical sciences in ten years, will ensure the large number of nanoscience initiatives across the country come to fruition. It is important that the NSLS makes strategic investments in this area to address the needs of this emerging scientific community. We will also continue to coordinate scientific programs, major instrumentation development, and other synergistic activities between the Center for Functional Nanomaterial (CFN) and the NSLS.

Second, in order to address the Nation's energy future, there are many exciting scientific opportunities and technological challenges in energy research, including catalysis, bio-fuels, solar energy conversion, fuel cells, and nuclear energy. The NSLS has the unique advantage that a significant fraction of the current scientific programs, with large teams of researchers from universities, industries and government laboratories, is already focused on this area. We will work with the user community to make investments in targeted areas to enhance the capabilities at the NSLS for energy research, and to coordinate research done by universities, industries and government laboratories.

Third, the biomedical imaging research program at the NSLS has grown steadily over the last decade. These programs are based on the development of IR, soft x-ray, hard x-ray spectromicroscopy and diffraction enhanced imaging. The time is ripe to take full advantage of the complementary nature of all these imaging tools to tackle important problems.

To realize these scientific opportunities, a beamline and endstation upgrade plan has been developed; see section 4 for details. These upgrades will also significantly benefit existing scientific programs and will provide a jump start for NSLS-II programs.

3. Accelerator Operation and Performance Improvements

3.1 Analysis of NSLS Storage Ring Complex Performance

The NSLS storage ring complex has been successfully providing light to the NSLS user community for nearly a quarter of a century. The VUV-IR ring, being the smaller of the two rings, became operational in 1982 and the larger X-Ray ring with its increased complexity required some additional commissioning time to reach full operation. During the past 20 years, significant improvements to the machine performance have resulted from the following initiatives:

- Global Orbit Feedback Systems for Beam Stability on the VUV-IR & X-Ray
- RF Beam Position Receivers for Improved Beam Position Measurement
- Longitudinal Coupled-Bunch Feedback System on the VUV-IR
- Fourth Harmonic Cavity for Increased Beam Lifetime on the VUV-IR
- Linear Optics Characterization from Closed Orbit Response Measurements (LOCO)
- Middle Layer & Accelerator Toolbox Software for Machine Modeling & Studies
- Non-achromatic Lattice for Reduced Emittance on the X-Ray
- Skew Quadrupoles for Coupling and Vertical Dispersion Control on the X-Ray ring
- Increased Linac Energy for Improved Booster Injection Efficiency
- Four New RF Cavities for the X-Ray ring.

The NSLS pioneered many of the cutting-edge technologies listed above and other facilities have adopted and expanded them. The NSLS has also played a key role in the development of novel insertion devices; in particular, the development of an in-vacuum mini-gap undulator (MGU) and a fast-switching Elliptically Polarized Wiggler (EPW). A summary of the existing VUV-IR & X-Ray ring insertion devices is given in the table below.

Table 1: Existing NSLS Insertion Devices

(W = wiggler, SCW = superconducting wiggler, MGU = mini gap undulator, EPW = elliptically polarized wiggler)

Device	Type	Period [cm]	Length [m]	Gap Range [mm]	K_{max}
U5	W	7.5	2.06	34-120	3.2
U13	W	10	2.2	33.5-120	6.7
X1	U	8	2.76	33-98	2.3
X13	MGU	1.25	0.36	3.3-	1.1
X13	EPW	16	0.48	27	12/3
X17	SCW	17.4	0.61	32	81
X21	W	12	1.69	24-120	12.3
X25	MGU	1.8	1.05	5.6-	1.5
X29	MGU	1.25	0.36	3.3-	1.1

Given the long list of improvements already made to the rings as outlined above and the physical constraints of the NSLS storage ring complex, there exist only limited opportunities to make significant improvements in the storage ring performance. This is the main reason that the NSLS-II project is being developed. For example, the x-ray ring source brightness is near its limit, top-off injection is precluded by the limited energy reach of the small circumference booster (750 MeV and 28 m) and the inherent long bunches of the 53 MHz RF systems makes a short-pulse laser-slicing source unattractive.

3.2 Operation Reliability and Improvements

The NSLS operates each of its two storage rings for roughly 5000 hours of scheduled user operations each year. For over twenty years the NSLS has provided users with scheduled beam averaging 95% availability and has led the way in producing novel insertion devices and improvements in beam stability. Indeed the NSLS paved the way for the current ‘third generation’ facilities, which used the NSLS as a template for their designs. However, as the facility enters its third decade of operation, maintaining this high level of reliability and machine performance is increasingly challenging. Two major component failures that caused significant downtime in 2003 and 2004 illustrate the kinds of vulnerabilities to which the aging NSLS storage ring complex is becoming increasingly susceptible.

To ensure the reliable operation of both storage rings, assessments were performed of the critical machine vulnerabilities and mitigation measures including special process spares. This information was presented to an external review panel for evaluation along with other machine information including operating performance, staffing and proposed upgrades. From the perspective of the machine equipment, the vulnerabilities fall into three broad categories; brash component failure, wear and performance degradation due to use, and obsolescence which makes the equipment more difficult to service.

The ceramic vacuum chambers that are part of the injection kicker system have been of particular concern, as they have elements of each of the three vulnerabilities. They are subjected to repeated thermal cycling which can lead to fatigue failure after several (3 to 5) years of service in some magnets. Our spares had been nearly exhausted and the rate at which vendors could make replacements was maddeningly slow. Recent concentrated efforts have helped build up the supply of spares while a parallel effort was initiated to develop a more robust design that would fit in the very constrained locations in the NSLS machines.

Another major concern has been the viability of the cryogenic system for the X17 SCW. It is an old system which has a substantial annual maintenance cost. It has also become sufficiently obsolete that obtaining replacement parts is becoming increasingly difficult. While its failure would not have the same ubiquitous impact as a ceramic chamber, it would bring down a very productive program. Addressing this problem is critical to ensuring the health of the high energy program at NSLS.

An overview of the most critical systems is shown in the table to the right, where they are grouped by the urgency with which they must be addressed. Systems that are near the end of their life and are critical for operations have the highest priority. Those which are important, but that are expected to come to the end of their service life in several years are assigned a lower priority. It is important to note that much of the lower cost urgent work is addressed through the operating budget allocations of the system stewards, or through the special process spares pool.

System	Basis
Critical Systems, Urgent Priority	
Ceramic Chambers	Catastrophic failure w/o spares would result in significant down time
Injection/Extraction Kickers	Pulsed magnet supplies aging and in need of updates
Linac Gun Control System	Old (but critical) system full of obsolete components
Main Magnet Regulator System	Old (but critical) system full of obsolete components
Booster Feedforward System	Prototype update in place, needs to be completed
Accelerator Control System	Becoming Obsolete (Workstations), vendor no longer supports development system (VXWorks),
Vacuum Instrumentation	IG & RGA's, Some in service 25+ years, need replacement
Utilities Spare components	Predictable wear, failure has predictable (bad) consequences
Site Chilled Water Strainers	Reduce failure of LS Hx equipment
NSLS Chiller Upgrades	Robust local capacity
X17 Cryogenic Systems	Very old cryogenic system, obsolete and expensive to maintain
Magnet Spares	Inventory of spare components nearly exhausted
Supporting Systems, High Priority	
Flag Control System	Diagnostic flags for injection system, need updating
Ion Pumps	Several ion pumps at end of operating life
Pumping stations	TMP pumping stations, many at end of service life
Linac Booster Security	Uses obsolete PLC, needs updating
Leak Detectors	Portable systems at end of service life
X-29/X-13 Motor controls retrofit	Should update to be consistent with supported components
PS Interface Boards	Potential reliability problem to be addressed
GP Valve Replacement	GP valves in service 25+ years, no longer supported
Backleg windings	Radiation damaged windings should be replaced
Survey Instrumentation	Update survey instruments to meet facility needs
Systems that will need attention, Intermediate Priority	
RF Systems	
	Build spares for the RF processor boards
	Address the ageing 3Kw amplifier system with either upgrades, spares or replacement
	Address the management of tube life in the 100KW amplifier systems.
	Spares for 100W amplifier system
	Upgrade RF controls to eliminate obsolete components and increase reliability.
	Potential replacement of VUV cavity
Power Supplies	
	Supervisory Chassis upgrade
	Booster Ramp card upgrade
	BXD, BXD5 upgrade
	Active filter for XSXD
	Replace some Kepcos
	Rebuild NWL for backup
	Power Supply Diagnostics
Tooling and Instrumentation	
	Labview based diagnostics (CARTS?)
	Longer term replacement of Vacuum Instruments

3.3 Storage Ring Lattices, Injection System and Diagnostics

Storage Ring Lattices and Closed Orbits

The NSLS pioneered the LOCO (Linear Optics from Closed Orbits) software tools for characterizing storage ring lattices through the measurement and analysis of closed-orbit response matrices. The LOCO tools were expanded at the ALS and SSRL, converted to the MATLAB environment and renamed the "Middle Layer Tools and Accelerator Toolbox". The enhanced tools have greatly improved our ability to perform machine studies and modeling of the rings. These tools will be used to perform the following analysis to enhance the performance of the rings:

- Routine lattice symmetrization of both the VUV-IR & X-Ray rings to maintain the optimum beam brightness and lifetime
- Reduction of the vertical emittance coupling on the X-Ray ring to maximize the beam brightness
- Development of a nonlinear lattice model for the X-Ray ring to explore the potential impact of introducing a new Elliptically Polarized Undulator (EPU) in place of the existing Soft X-Ray Undulator in the X1 straight section
- Explore the possibility of chicaned straight sections in the X-Ray ring to permit two insertions devices in a single straight section
- Investigation of a low vertical betatron function straight section in the VUV-IR ring to permit a mini-gap undulator in one of the straight sections
- Development of an improved closed-orbit correction scheme and algorithms to reduce the trim corrector strength in both rings
- Low momentum compaction lattices on the VUV-IR ring will be revisited to potentially provide for a coherent infrared operation mode of the VUV-IR ring
- Improved compensation schemes for the X13 Elliptically Polarized Wiggler (EPW) will be developed to yield improved orbit stability and faster polarization switching
- Potential enhancement of the stored beam lifetime by increasing the number of filled RF buckets in the rings will be studied
- Assess the impact on the beam lifetime of the limited horizontal aperture in the vicinity of the septum magnet in the VUV-IR ring

Injection System

Significant improvements in understanding the machine performance, upgrading of diagnostics and documenting the operation of the linac, booster and transport lines have been made in the last few years. These enhancements will be focused to improve the injection rate into the storage rings, in particular the X-Ray ring. The klystrons used to power the NSLS linac will be refurbished or replaced to ensure reliable operation through the life of the NSLS complex.

Diagnostics

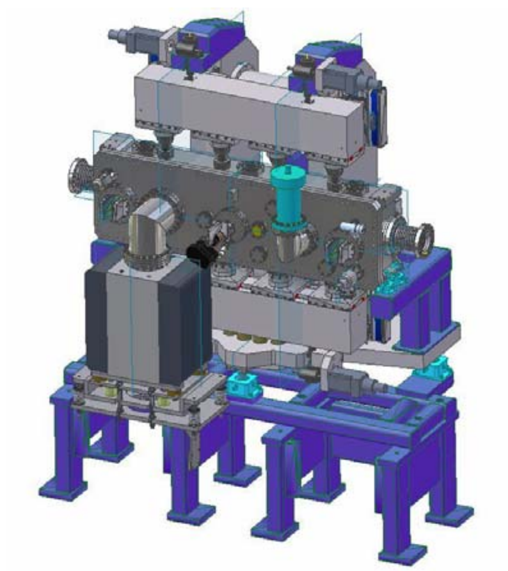
A Young's slit interferometer will be developed to complement the existing X-Ray pinhole camera for online emittance measurements. Some single-turn beam position monitors will also be implemented in the storage rings and the booster.

3.4 Insertion Devices

Construction of new, and upgrading existing, insertion devices are the most cost-effective way to improve the storage ring performance and enable new scientific programs in the next 5-7 years. The following is a summary of possible new insertion devices and insertion device upgrades envisioned for the next 5-7 years:

3.4.1 X-Ray Ring

Upgraded X25: For completeness we note that the X25 wiggler has been replaced by a one-meter-long MGU with cryogenic capabilities in January 2006. This is the first of a series of insertion device upgrades to expand the scientific programs.



A new in-vacuum undulator replaced the wiggler at beamline X25.

New X9 undulator: By locating the two pairs of RF cavities toward the edges of the straight sections in the X-ray ring, it is possible to make room for a short (~35 cm) mini gap undulator (MGU) in each of the two straight sections between the cavities. This was done in 2004 to accommodate a new MGU in the X29 straight and will be done in 2007 to accommodate a new MGU in the X9 straight.

Upgraded X17: The existing X17 superconducting wiggler (SCW) is meeting the needs of the current scientific programs; however, its cryogenic system requires very high maintenance. A replacement SCW was fabricated several years ago and its installation was held up due to concerns with the performance of the current leads. A study will be undertaken to decide the optimum path forward to maximize the SCW performance to meet the current and projected scientific programs, and at the same time, reducing the maintenance burden. The study will consider existing hardware as well as the potential of an entirely new SCW.

Upgraded X1: This beamline is the key to a number of soft x-ray scattering, spectroscopy and imaging programs. An elliptically polarized undulator (EPU) is being considered as a replacement for the existing insertion device to enhance the scientific programs at X1. Development of the nonlinear lattice modeling of the X-Ray ring will be required to insure that the EPU does not compromise the performance of the machine.

New X5 undulator: The LEGS program will be completed by the end of CY06 and this provides the opportunity to consider an insertion device in the X5 straight section where it must coexist with the electron beam injection line. With the addition of a device in X5, all eight of the straight sections would contain at least one insertion device. If cost is a concern, one can consider moving the existing MGU from the X13 straight to X5, which would double the availability of that MGU and the elliptically-polarized wiggler (EPW) that would remain in the X13 straight.

Chicaned Straight Sections: While there are presently two insertion devices in the X13 straight, only one is used at a time since the devices are "in line"; the solution to this problem would be to chicane some of the straight sections to provide some angular offset for the two insertion devices. The possibility of chicaning the straights will be explored as it will be challenging to accomplish with the limited length of the X-Ray ring straight sections (~4.5 meters). Chicanes would be the only possibility to introduce new additional insertion devices into the X-Ray ring.

Upgraded X21: Prior to January 2006 the insertion devices in the X25 and X21 straight sections were of the same type but satisfying two different scientific programs, protein crystallography and material sciences, respectively. Following the successful upgrade of X25 to an MGU, the needs of the X21 user community will be reviewed to see if a new device can expand the capabilities of this beamline.

3.4.2 VUV-IR Ring

Upgraded U5 or U13: The potential benefits of upgrading the insertion devices in the VUV-IR ring will be evaluated. The possibility to introduce an MGU into one of the straight sections will be explored to determine the impact on the VUV-IR ring performance.

3.5 Possible Machine Developments That Are Synergistic with NSLS-II

In principle, the existing NSLS accelerator complex could serve as a test bed for some systems to be deployed on the NSLS-II project in the future thereby advancing both facilities. Listed below are areas of mutual interest to both the existing NSLS and the future NSLS-II complex:

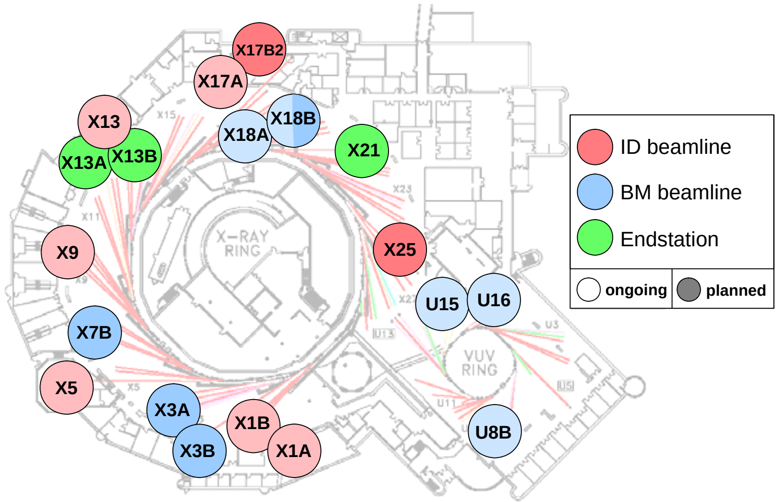
- Cryo Permanent Magnet & Superconducting Undulators and Magnet Measurement Systems
- Superconducting RF
- Diagnostics, Controls Hardware & Software
- Feedback Systems.

Developments in these areas will be pursued as the budget and timetable for the NSLS-II project evolves.

4. BEAMLINE AND ENDSTATION UPGRADES

To realize the scientific opportunities identified above and to meet the increasing user demand, a comprehensive beamline and endstation upgrade plan has been developed and is summarized in the figure to the right and detailed below.

ONGOING AND PLANNED BEAMLINE UPGRADES
APRIL 2005



4.1 ONGOING BEAMLINE AND ENDSTATION UPGRADES

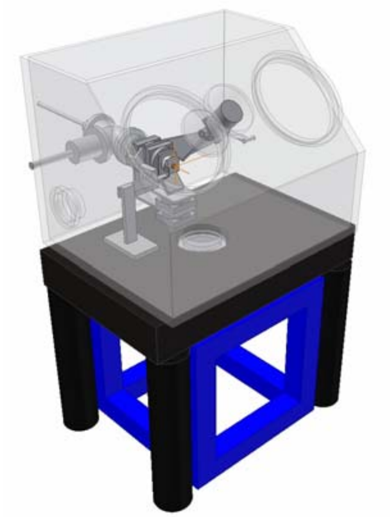
U5UA Low-energy Electron and Photoelectron Microscopy (LEEM-PEEM) Endstation

Following upon a recommendation by the 2001 DOE review, a second, refocused branch (branch II) has been installed and commissioned at beamline U5UA. The refocused beam spot has a measured diameter of approximately 15 microns, in close agreement with the predictions of ray-tracing calculations. The small spot and high flux characteristic of the U5UA branch II beamline make it ideal to perform VUV microscopy experiments. A LEEM/PEEM system has been funded by the BNL Center for Functional Nanomaterials (CFN) to utilize this new branch line. The new instrument will provide sub-10 nm structural and morphological information in the LEEM mode and ~20 nm chemical and magnetic information in the PEEM mode. This unique combination will be essential in the study of nano-catalysis and nano-magnetism.

X1B Endstation Upgrade

The scientific program on X1B is focused on the study of nanoscale electronic ordering in transition metal oxides, for both that which forms “naturally” through many-body interactions and that which can be synthesized artificially with molecular beam epitaxy techniques. Recent studies have revealed, for example, the existence of a depletion layer at the interface between epitaxial La_2CuO_{4+y} and an $SrTiO_3$ substrate, a Wigner crystal in $Sr_{14}Cu_{24}O_{41}$, and substantial hole ordering in the static stripe phase of $La_{15/8}Ba_{1/8}CuO_4$.

The planned endstation upgrade involves the installation of a 5 Tesla split-coil, superconducting magnet in the existing diffractometer to extend soft x-ray resonant scattering measurements to high magnetic field. This new capability will enable the investigation of wide–ranging, exciting new problems, including the intrinsic charge and possible Wigner crystallization in the vortex core of high T_c superconductors in the mixed state, and the melting of charge order in CMR phase manganates which sit near a ferromagnetic phase boundary.



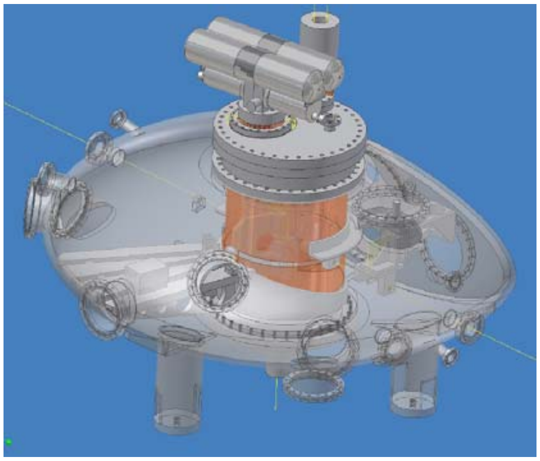
Schematic of the X1B endstation with grazing incidence diffraction and imaging capabilities. The end station sits on a table with active vibration isolation.

X7B Beamline Upgrade

In order to satisfy the growing user demand for monochromatic, focused high energy x-rays for in-situ structural studies of materials, a sagittal focusing bent Laue monochromator will be implemented to replace the existing beamline optics. This is a collaborative effort between the X7B PRT and the NSLS. The new monochromator, developed at the NSLS, is expected to provide x-ray energies from 30 to 50 keV. It will deliver flux of about 10^{11} ph/s/mm^2 at the sample position, in a spot of less than 2 mm vertical by 0.5 mm horizontal, with an energy resolution ($\delta E/E$) of 10^{-3} at 30 keV. In addition, taking advantage of the small Bragg angles, a simplified Boomerang linkage has been incorporated in the monochromator to simplify energy tunability. The new beamline will increase significantly the total capacity at the NSLS for high-energy x-ray powder/single-crystal diffraction and pair-distribution function (PDF) measurements, and will have major impact on in-situ catalysis studies, structural studies of nanomaterials and the study of materials under high temperature and pressure.

X13A Soft X-ray Magnetic Scattering Endstation

A new ultrahigh-vacuum magnetic scattering endstation for X13A is being developed to replace the existing two-circle diffractometer. The design and construction of the new instrument, plus an associated sample transfer system, is currently in progress. X13A is a soft x-ray beamline dedicated to the study of magnetism and magnetic materials, in particular the growing nanoscience research community as well as other scientific programs which can benefit from the unique fast-polarization-switching (22Hz) property of the Elliptically Polarized Wiggler (EPW). The enhanced capabilities of the new soft x-ray magnetic scattering endstation will include: a stronger magnet, based on high temperature superconductor technology, to increase the available magnetic field to 1 Tesla; the capability to cool the samples down to ~10K; full coverage of the horizontal scattering plane; and a complement of detectors to cover the full dynamical range of the scattering signals.



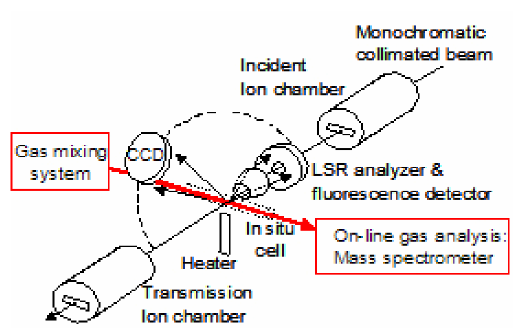
Schematic of the new high vacuum diffractometer at X13A.

X17B2 Branch Line Upgrade

High-energy x-rays are required for high-pressure experiments using a large-volume press. The X17B2 large-volume-press beamline is currently limited to energy-dispersive scattering mode with limited resolution and beamtime. A proposal to DOD by the Stony Brook PRT at X17B2 was funded in 2004 to equip an area detector and a large-volume press for a dedicated angle-dispersive scattering station. The new branch line, funded by Department of Defense, will use a side-diffracting focusing monochromator to provide 30-100 keV x-rays and a Mar3456 image-plate detector for powder diffraction and pair distribution function (PDF) measurements of samples under pressure. This new branch line will enhance the X17B2 beamline by improving the resolution for powder scattering, enabling PDF measurements, and increasing the available beamtime significantly.

X18B Beamline Upgrade for Quick-EXAFS

A new monochromator drive and a new data-collection scheme are being developed for beamline X18B to allow quick measurements of x-ray absorption spectra (QEXAFS). The micrometer on the standard NSLS tangent-arm driven monochromator is being replaced with a cam, which continuously changes the Bragg-angle of the monochromator with a simple rotation of a motor. Different positions in the cam result in different angular ranges over which the monochromator is rotated, which translates into different energy-ranges for the scans. This allows the user to concentrate on either the near-edge structure (XANES), or the extended fine structure (EXAFS). The data is collected using an analog-to-digital converter, which digitizes the voltage from the current amplifier directly. This new read-out method allows the collection of a complete EXAFS-scan in ~1 second. This new capability will enable the use of x-ray absorption spectroscopy for fast in-situ kinetic measurements in catalysis and fuel cell research.



QUICK-EXAFS AT X18B WILL ENABLE FAST, IN-SITU KINETIC MEASUREMENTS IN CATALYSIS AND FUEL CELL RESEARCH.

X25 Beamline Upgrade

X25 is one of the two insertion beamlines at the NSLS dedicated for monochromatic macromolecular crystallography. It is operated by the BNL Macromolecular Crystallography Research Resource (PXRR), a collaboration of the BNL Biology Dept. and NSLS. The beamline upgrade, funded by DOE BER and NSLS, includes replacing the existing hybrid wiggler, which has served as the radiation source for beamline X25 since its inception in 1990, by a custom-designed in-vacuum miniature gap hybrid undulator and upgrading the beamline optic in order to exploit the properties of the new source. The current double crystal monochromator will be replaced by one which incorporates cryogenic cooling of the first crystal and sagittal bending of the second crystal to permit horizontal focusing. It will be followed by a new bendable mirror, containing multiple coating stripes, to permit vertical focusing. This upgrade is critically important for the NSLS to meet the growing demand for high brightness beamlines, which are essential for tackling the most challenging problems in macromolecular crystallography.

4.2 PLANNED BEAMLINE AND ENDSTATION UPGRADES (PROJECTS LIKELY TO BE FUNDED AND UNDERTAKEN IN FY 2007-8)

X9 In-Vacuum Undulator based Small Angle Scattering Beamline

X9 will be a new undulator-based beamline optimized to provide SAXS and GISAXS capabilities for nano- and bio- science studies that require high flux and/or small beam. The beamline will use the NSLS mini-gap in-vacuum undulator (MGU) as its radiation source, providing continuous tunability from 2-20 keV. The beamline optical design will include a cryogenically-cooled Si (111) two-crystal monochromator, a primary Kirkpatrik-Baez (K-B) mirror pair, and a secondary micro-focusing K-B mirror pair to achieve either high q resolution or small beam size (~10 microns). The beamline construction is funded by NSLS project funding and a BES instrumentation grant. The BNL Center for Functional Nanomaterials (CFN) will fund the instrumentation of the X9 experimental endstation and provide staffing to support endstation operations as a Contributing User.

X17A High Energy Wiggler Beamline Side Station

The X17 wiggler is the only high-energy x-ray insertion device at the NSLS. The wiggler’s horizontal beam fan is divided into three branches, two of which (B and C) have been brought out of the shield wall. The X17B beamlines and the X17C beamline run independently of each other while the three individual X17B beamlines (X17B1, B2, and B3) share the center 5 milliradians of the wiggler’s output. The demand for beamtime at all X17 branches has been historically high and is currently growing, leading us to explore ways to use a larger fraction of the horizontal output fan. Preliminary studies have shown that a side-scattering sagittal-focusing bent Laue monochromator can be installed in the X17A path, immediately downstream of the existing X17A safety shutter. The monochromator would provide focused high-energy x-rays to a new experimental hutch to be built on the outboard side of the X17B1 hutch. An X17A side station configured in this way will be ideally suited for high-energy x-ray scattering and diffraction programs, which currently take place at X17B1. The addition of X17A will increase the beamtime available to the two high-pressure endstations (X17B2 and B3) and the strain mapping endstation (X17B1) that currently share the use of X17B. It will also allow the development of new scientific programs, such as PDF and diffuse x-ray scattering, which require high energy x-rays.

X18A and U8 Beamline/Endstation Upgrades for Synchrotron Catalysis Research

The development of techniques for the characterization of catalytic systems as they evolve in time with a changing chemical environment is one of the high priorities for future directions in catalysis. Two beamline upgrades are proposed to support the efforts of the NSLS-based, DOE-funded

Synchrotron Catalysis Consortium (SCC) which was formed initially (FY2004-5) to support x-ray spectroscopy of catalytic systems at beamlines X18B and X19A. The proposed new capabilities and beamlines are: (1) quick-scanning hard x-ray diffraction capability at beamline X18A and (2) quick-scanning high-resolution moderate-pressure XPS/NEXAFS at beamline U8. The combination of XAFS, XRD, and XPS techniques is necessary to determine the structural and electronic properties of catalysts, ranging from model single crystals to high surface-area powders, and to investigate reaction mechanisms. These two projects depend, for capital and manpower support, on successful funding of the SCC proposal submitted to the FY2006 DOE mid-scale instrumentation call for proposals.

X18B Beamline Upgrade

The ability to properly utilize the recently-commissioned quick-photon-energy-scanning (QEXAFS) capability on real samples, e.g., those systems of interest to the Synchrotron Catalysis Consortium (Contributing User group on beamline X18B), requires a focusing mirror in the X18B beamline to increase the flux density on the sample. This project consists of procurement, installation, and commissioning of such a focusing mirror, e.g., a grazing incidence toroidal mirror which can provide focusing in both the vertical and horizontal planes.

X1 Undulator Upgrade

The undulator for the X1 beamlines at the NSLS was designed and built circa 1986 and represents the state of the art of the technology available at that time. The most significant shortcoming of the existing X1 undulator is that the light emitted is limited to horizontal polarization. Undulators with the ability to produce elliptically, or near-circularly, polarized light, as well as linearly polarized light at arbitrary angles with respect to the beam propagation direction, have become commonplace. Such control over the incident polarization would enable fundamentally new research programs that examine issues such as anisotropic chemical bonding, exotic ordering phenomena in correlated electron systems, and spectroscopic and scattering studies of nano-scaled bio- and ferromagnetic materials.

U10A Far-IR microscope for materials, geological and astronomy research

There is a growing interest in far-IR microspectroscopy. For example, far-IR is needed to study collective phenomena (e.g., transport, phonons) in novel materials. However, high quality crystalline materials are often limited in size and have only small area ($\leq 1mm^2$) surfaces. There is also interest from the geological and planetary sciences communities for the identification of minerals in comets (e.g., Stardust) and other interplanetary dust particles, which are also quite small. The high brightness of synchrotron infrared makes far-IR microspectroscopy of these samples feasible, enabling an otherwise impossible (or extremely difficult) technique. Unfortunately, commercial microscopes for the mid-IR are only marginally useful for the far-IR, mostly because of the small physical size of the optics (lossy due to diffraction effects) and the strong absorption by water vapor (for which a dry nitrogen purge is not sufficient). Based on interest from the space sciences community, we anticipate participating in a proposal seeking NASA funding for the design and construction of a custom far-IR microspectrometer system for use at the NSLS. When developed, such an instrument would replace the existing microspectrometer at beamline U10A.

4.3 Future Beamline and Endstation Upgrades (beyond FY 2008)

U15/16 IR beamline suite for chemical/biological imaging and magnetism research

The study of magnetic phenomena has quickly become an important subject area for users at beamline U12IR. Electron spin resonance frequencies are typically in the very far-IR (wavelengths from 1mm to 1 cm) for magnetic fields in the 1T to 10T range. The existing U12IR beamline and spectrometer are optimized for wavelengths below 0.5 mm; at longer wavelengths, it suffers from strong spectral intensity variations due to a wall reflection inside the VUV-IR dipole chamber. Additionally, the U12IR high resolution spectrometer has low throughput at long wavelengths. This project proposes the construction of a new IR port (U16IR) to correct these deficiencies and to handle the increasing demand for THz and magnetospectroscopy. An existing spectrometer (provided by the University of Florida and optimized for 1 mm wavelengths) will be upgraded with a new control system and non-magnetic vacuum enclosure, and then combined with new beam transport optics for use with either of two 10T magnets expected to be available (NJIT and CCNY). Lastly, the U16IR port will be built on a dipole chamber modified to eliminate the internal wall reflection.

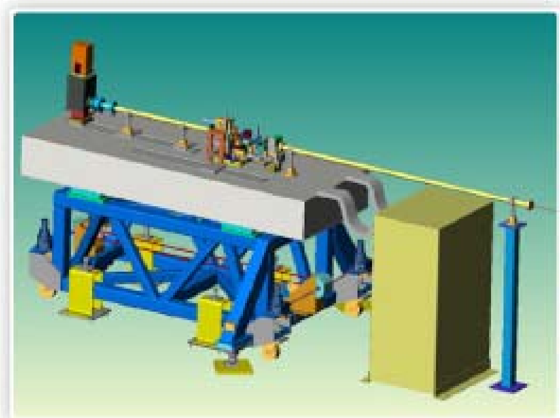
The other part of this beamline suite will be a new dipole extraction port to provide for an extended IR source. Recent developments in focal plane array (FPA) detectors have led to major improvements in the time required to collect large area chemical images. We have recently demonstrated that dipole bending magnet radiation can be formed into an extended source and matched to such an array system, enabling a unique combination of large area imaging and spatial oversampling. We expect that oversampling will allow our users to recover some of the resolution lost due to diffraction by way of image deconvolution. Like U16IR, it will be necessary to modify a dipole ring chamber to provide for the required vertical and horizontal acceptance to properly match the source to the FPA microspectrometer. Fortunately, the placement of this port upstream of U16IR, i.e., at U15/U16 will naturally solve the wall reflection problem described above.

Development of X5 Straight Section

The Laser Electron Gamma Ray Source (LEGS) program, a nuclear physics research program which focuses on sensitive tests of models describing the internal structure of protons, neutrons and light nuclei, is expected to be completed at the end of calendar year 2006. Since LEGS currently utilizes the X5 injection straight, it opens the possibility for the NSLS to develop a new insertion device beamline. Preliminary study shows a short insertion device, similar to the mini-gap undulator installed in X13 and X29 straight sections, could be accommodated. This would be a significant addition to the total number of insertion device beamlines at the NSLS and a great opportunity to develop either a new scientific program or to relieve the over-subscription on existing insertion device beamlines. A detailed study will be carried out in the near future.

Development of a Full-Field Hard X-ray Microscope Beamline

A full field hard x-ray imaging microscopy beamline is one application where the NSLS X-ray ring can remain competitive, in spite its lower brightness compared to 3rd generation sources. In the full field imaging technique, the sample field of view is illuminated incoherently and the scattered photons are collected and detected with a high resolution hard X-ray optics assembly downstream of the sample. This is equivalent to the familiar commercial optical microscope which is illuminated incoherently with a light bulb and high resolution objectives detect the scattered light. As the starting point for this effort, NSLS will purchase and implement a commercial full field microscope endstation on an X-ray bending magnet beamline. These commercial full field hard X-ray microscopes exist and have demonstrated spatial resolutions of 90nm in first order and 30nm in third order. The primary research focus of this beamline will be 3-dimensional, high-resolution imaging of intact biological cells. By using hard x-rays, the penetration depth into the sample will be dramatically improved over other imaging techniques such as electron microscopy or soft x-ray microscopy, while maintaining a high spatial resolution (<100 nm). This full-field x-ray microscope will enable the examination of cellular sub-structures, such as individual cell membranes, protein complexes, and cytoskeleton structure, which cannot easily be visualized with other methods. This type of spatial resolution will enable cellular processes, such as apoptosis and mitosis, to be studied in the native cellular environment, to provide new insight into the way cells behave as "molecular machines." Moreover, the development of this nanoscale tool will not only be applicable to biological systems, but will be valuable for the study of numerous other nanoscale structures in the chemical and materials sciences fields.



A schematic of the full-field, hard x-ray microscope beamline.

Development of a new Tender X-ray Scattering Beamline

We propose to develop a beamline optimized for resonant and anomalous scattering at tender x-ray energies (200eV – 4 keV). This energy range is important for a number of scientific communities at NSLS. It covers the K absorption edges of atoms such as C, Si, S, P, Ca, and Cl that occur in a wide variety of systems of interest to the soft and biomolecular materials research communities including liquid crystals, polymer films, semiconducting organic films, soft-core nanoparticles, micro-gels, phospholipid-protein films, and biomimetic organic-inorganic composites. This range also covers the L edges of the 3d and many 4d transition metals and the M edges of the rare earths, all of which are of interest to the materials science community for the study of magnetism, orbital order, and the formation of charge density waves (CDWs).

5. Detector Program

Detectors are an integral part of every experiment. A well-matched detector can enhance the capability of an experiment and increase the throughput of the experiment significantly. However, due to the lack of adequate investment over the last two decades, there is a critical need for better detectors to fully utilize the high flux and brightness of synchrotron radiation. To address this problem, the NSLS has established a modest research and development effort to develop new, advanced detectors for synchrotron radiation applications. This effort is leveraged by the BNL Instrumentation Division, which has a long tradition in developing large-scale detectors for high-energy and nuclear physics and has a range of relevant expertise and infrastructure which we are able to call on. This effort has led to the development of a suite of detectors, including several fast-photon counting detectors for different energy ranges and applications, linear array detectors and two-dimensional detectors. These detectors have been delivered to users with great success, and have made significant impacts on many scientific programs at the NSLS.

Here we outline a plan to expand this effort in the coming years to accelerate the upgrade of detectors for existing beamlines and to develop several new advanced detectors. The plan follows the general strategy of:

- Purchase a commercial item if something exists which fulfills the requirements.
- Optimize detectors for specific applications based on existing in-house or commercial technology.
- Initiate a full-scale in-house development project when commercial available detectors cannot meet the requirements.
- Leverage NSLS/BNL development efforts with other efforts in the U.S. and worldwide.

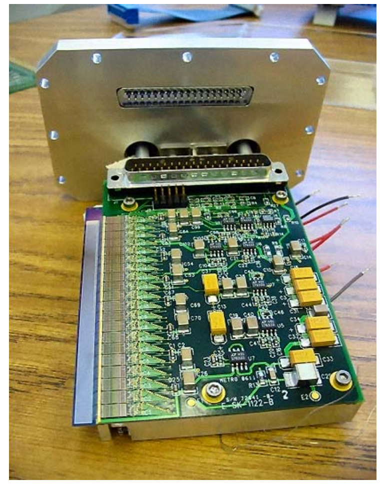
5.1 Upgrades Using Available Devices and Existing Technology

An audit of NSLS beamlines was recently undertaken to establish a common metric for beamline technical and staffing qualities across the DOE synchrotron facilities. As part of this audit, a significant number of the NSLS beamlines were found to be deficient in the capabilities of their detector systems. We will work with PRTs, CUs and the user community at large to upgrade those systems to bring them to “state of the art.”

Upgrade Detectors for NSLS Facility Beamlines

Among the NSLS Facility beamlines, those beamlines identified as deficient are the spectroscopy beamlines, X18B and X19A, and the high-energy beamlines, X17B and X17C. The spectroscopy beamlines lack modern multi-element fluorescence detectors, and the high-energy beamlines lack an efficient area detector for diffraction studies.

The spectroscopy detector needs fall into two spectral regions, 2keV - 12keV and 12keV – 50keV. The lower energy range is amenable to silicon array technology, which is an active area of research by the Detector Development group. This range is well matched to X19A, and so we would plan to install one of those detectors there. X18B is used more at higher energies, so a multi-element germanium detector would be a better choice. This is commercially available.



A BNL detector under development for diffraction applications.

There is a general need for better high-energy x-ray detectors because high-energy area detectors are not yet commercially available. The Detector Development group is working on a lens-coupled CCD system based on a 300um-thick columnar-structured CsI scintillator screen manufactured by Hamamatsu, 120mm x 120mm. This should undergo first tests before the end of FY06. If it performs satisfactorily, it will be made available.

Upgrade Detectors for PRT Beamlines

The PRT beamlines represent a larger problem for two reasons. First, they are managed by the PRTs, and so we do not have direct input to their management. Second, there are many of them in need of upgrades, and so the potential cost is large. However, we will work with the PRT management in the following ways:

- Make NSLS technology available to them at cost
- Expand the NSLS detector pool
- Assist them in acquiring funding for new detectors

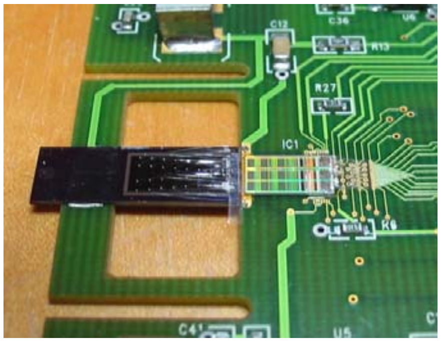
5.2 Long-Term Development Projects

Linear Coherent Light Source (LCLS) Detectors

BNL has signed a Memorandum of Understanding with SLAC to develop 2-dimensional position-sensitive detectors with fast readout for use in LCLS experiments. LCLS is the x-ray free-electron laser project currently under construction at SLAC. This is a 4-year R&D program, which aims to produce a detector having 1 million pixels with a readout time of around 1ms. Although commissioned by LCLS, this detector will be extremely attractive for synchrotron radiation applications. The device will consist of a monolithic matrix array with integrated readout in a row-serial, column-parallel manner. It is based on a novel concept from Pavel Rehak of BNL's Instrumentation Division, and the collaboration includes several members of that division in addition to NSLS staff.

Next Generation of X-ray Microprobe Detector

NSLS is working on the development of a next-generation scanning x-ray microprobe detector. This is a collaboration between the BNL/NSLS team and a group from CSIRO in Australia headed by Dr. Chris Ryan. The development makes use of high-speed parallel processing



32-channel prototype of the high-speed x-ray microprobe detector.

expertise within CSIRO, combined with sensor and readout IC expertise from BNL to develop a revolutionary imaging system capable of providing real-time quantitative elemental maps. It is also possible to operate this new detector system at a high enough speed that the raster-scanning of the sample through the microbeam will be continuous, rather than step-measure scans, which offers an enormous savings in time, and allows many new and more complete studies to be carried out. A 32-channel prototype has been successfully tested. Funding is now being sought to extend it to several hundred elements for several user programs at the NSLS.

Development of Planar Germanium Technology

The development of a planar germanium technology similar to that already used by silicon sensors will have a significant impact to a wide range of scientific programs. In particular, it will address the increasing demands for efficient detectors with good spatial and energy resolution for hard x-rays. LDRD funding has been provided to explore this possibility.

Enhancement of Existing Silicon Technology

We will explore ways to enhance BNL's existing Silicon foundry to bring it up to modern standards by acquiring modern instruments and technologies. It will permit the development of techniques for integrating more functionality directly on the high-resistivity silicon sensor wafer and hence produce more capable devices such as drift-detector arrays and integrated readout amplifiers.

6. Infrastructure, User Access, Education & Outreach

6.1 Infrastructure Improvements

We will pursue ways to enhance scientific productivity through infrastructure improvement. A high priority is to make efficient use of the space around the experimental floor to increase laboratory and setup spaces for users to allow better preparation and characterization of samples. We will work with user community, in particular research resources, to provide better laboratory equipment to enable experiments with increasing complexity. Another area of priority is beamline automation and instrumentation for high-throughput screening of samples.

With the increased use of area detectors in diffraction and scattering experiments and the growth in the microscopy and microprobe user communities, there is a clear need for better, user-friendly data analysis and visualization software to handle the large amount of data both on-line and off-line. We will coordinate beamlines with similar needs to standardize the existing software in the short term, and explore more comprehensive solutions for the long term.

6.2 Evolution of User Access

A set of 18 Facility Beamlines was established in 2005 after the completion of a major beamline/endstation upgrade program as well as significant staff additions over the last five years. This set of Facility Beamlines was chosen to provide all essential synchrotron techniques to general users on beamlines that, to the extent that resources allowed, were well staffed and maintained with state-of-the-art detectors and instrumentation. In selecting beamlines to become Facility Beamlines, higher priority was given to insertion device beamlines, IR beamlines, and beamlines with high user demands. In the next few years, we will strive to increase the staffing of the existing Facility Beamlines to improve user support. We will also continue to expand the number of Facility Beamlines to meet the evolving needs of the user community.

While Facility Beamlines enable the NSLS to maintain better control of beamline quality, this comes at the expense of potentially losing important participation in the facility by researchers from universities, industry, or other Brookhaven Departments. In order to retain and nurture these highly important research partnerships, the NSLS established Contributing User (CU) Programs on each of the Facility Beamlines. 25% of the beam time on each Facility Beamline is made available for CU Programs. Following an open call for CU Proposals, the NSLS Science Advisory Committee (SAC) approved 14 CU Programs that can be grouped into three categories. The first category of CU Program involved a consortium of researchers who optimized an endstation for a particular research community and operated this research resource for the community. There are currently three CU consortia research resources in operation that serve the catalysis, environmental sciences, and earth sciences research communities. The second category of CU Program was established with the Center for Functional Nanomaterials (CFN) to facilitate coordinated use of the fabrication and characterization facilities of the CFN together with the synchrotron characterization tools of the NSLS. Specifically, the CFN instrumented the VUV-IR undulator beamline, U5UA, with a LEEM-PEEM endstation and is providing advanced detectors for SAXS/GISAXS measurements on X6B. The CFN will also provide staffing to support use of their endstation instrumentation beginning in January 2007. The SAXS/GISAXS CU Program will be moved to the new undulator beamline, X9, when it is scheduled to be operational in 2008. The third category of CU Program was established with researchers who contributed instrumentation or technique expertise that enhanced the capabilities of the NSLS. These new capabilities included x-ray microbeam diffraction, x-ray standing wave analysis, and in-situ UHV growth chambers for real-time studies. As new Facility Beamlines are developed we will work with the SAC and user community to identify associated CU Programs to enhance the capabilities and productivity of these new beamlines.

We will also continue to improve the on-line proposal system, PASS; in particular, we will implement rapid-access and work with BNL to streamline the process for users to gain access to the NSLS.

6.3 Education and Outreach

The majority of the users at the NSLS today are relatively inexperienced with synchrotron techniques and unfamiliar with the sophisticated instrumentation at the beamline. This is a direct result of the rapid expansion of synchrotron radiation into new scientific disciplines over the last decade, with macromolecular crystallography being the most notable example. We expect this trend to continue and will enhance our education and training effort to ensure that the new and inexperienced users can make effective use of the allocated beamtime. Specifically, we will enhance our education effort by providing short courses beyond the general introduction of experimental techniques. These courses will target students or researchers who are interested in specific scientific problem, and tailor the training for them. The combination of lecture and hand-on exercises will allow the students or research meet the experts in the field and beamline staff, as well as become familiar with beamline instrumentation.

We will also explore the possibility to expand the industrial user base at the NSLS. Today, there are roughly one hundred companies actively working at the NSLS. We believe that a balanced portfolio of academic and industrial research is essential to the intellectual environment at the NSLS, and presents a unique opportunity for partnership between industries, national laboratories and academic institutions. However, in order to capitalize on this opportunity, we need to address several important issues that are unique to industrial users.

First, the importance of industrial research is gauged very differently from peer-reviewed and openly published academic research. Second, industrial users often need rapid access to a set of routine techniques for results on a timescale that suits product development and problem solving in the more business-oriented industrial setting. We will work with the NSLS scientific advisory committee to establish a metrics for determining the value and productivity of industrial research. We will explore the possibility of developing a mechanism for rapid and/or remote access to facility beamlines that provide more standard, routine techniques and instrumentation, such as XRD, SAXS, reflectivity and EXAFS.

The needs of industrial users, in particular rapid access to multiple experimental techniques, are also shared by a large number of materials scientists and nanoscience researchers who are interested in using synchrotron to characterize their samples as a way to feed back to the synthesis and growth processes, or to understand the structural-function relationship. In these cases, the availability of high-quality synchrotron data on a time scale and relative ease, similar to obtaining data from instruments in their own laboratories, would be extremely important and attractive to a large potential user base.

7. Environment, Safety, Health and Quality

7.1 Background and Present Status

The NSLS experimental floor and associated work areas represent a complex and potentially hazardous environment characterized by the following attributes:

- The facility operates 24 hours/day, 7 days a week throughout much of the year.
- Significant radiological hazards exist in accelerator enclosures and beamlines.
- Significant electrical safety and fire protection issues are created by the widespread use of high voltage and high power electrical equipment in the building.

- Significant industrial hazards (e.g. material handling, cryogens, noise, machine shops) exist in many areas of the building.
- A significant number of class 3b and 4 lasers are used in the building.
- Relatively small quantities of hazardous materials are present, but a wide diversity of chemicals is in use - occasionally high hazard materials are used in experiments (e.g., flammable or noxious chemicals, bio-toxins, radioactive substances).
- The large number of beamlines sharing the experimental floor creating very congested, and in some cases, highly restricted work locations.
- The experimental program is dynamic and includes many users from different institutions. Most of these users are not routinely at the facility. In addition, a large number of them are inexperienced and at the NSLS for the first time. Some of them may also have very different safety culture than that of the NSLS.

Overall, the ESH experience at the NSLS has been very positive and characterized by:

- Very low radiation exposures
- A marked decreased in the number of injuries in recent years
- Low frequency of reportable occurrences
- High level of compliance with regulations
- Staff that is very responsive to safety issues

However, there have been occasional occurrences and near misses that indicate the potential for more serious events. In particular, an electric shock incident in August 2004 and a series of incidents in 2002 resulted in significant attention to the NSLS from BNL and DOE management and resulted in a major commitment of resources to address incident-related issues.

7.2 Challenges to ESH&Q Program Success in the Next Five Years

The expectations by BNL and DOE management for a high level of safety performance have steadily increased over the past 10 years. These expectations are expressed in many ways ranging from reduction of injuries to strict compliance with safety requirements. There is a major emphasis on work planning to ensure that hazards are identified and controlled and that all workers are trained to conduct their work safely. This emphasis can be expected to continue to grow over the next five years. A rulemaking which applies to DOE (10CFR Part 851) will place additional requirements on the safety program and provides enforcement powers to DOE for monetary fines and penalties for non-compliance by DOE contractors. DOE has also embarked on a new program to re-vitalize the implementation of Integrated Safety Management at DOE facilities.

Consequently, it is clear that continued emphasis and attention to safety-related issues and a high level of successful safety performance is paramount to the on-going success of the NSLS through the next five years.

- A number of major initiatives in recent years have been needed to address ESH requirements established by DOE or BSA (e.g. NFPA70E, NRTL, EMS, OHSAS, ISM). These programs have created significant additional resource demands on ESH staff, as well as for operating and research staff. Additional demands that can be readily anticipated (e.g. Part 851 and the planned re-invigoration of ISM) will only add to this burden. These resources must be addressed and provided to ensure the on-going implementation of ESH expectations. However, it is equally vital to ensure the most effective implementation processes to optimize the effort required to ensure a successful program.

- A combination of several factors suggests that the greatest vulnerability in the ESH program will continue on the experimental floor. We have many users who come from other institutions, which may not appreciate the high safety expectations that are present at the NSLS. In addition, the number of inexperienced users continues to grow, resulting in users who work in unfamiliar quarters with unfamiliar equipment. These factors, coupled with the 24-hour-per-day operation of the facility and the potential time and programmatic pressures experienced by the user community, strongly suggests that high priority will be needed for issues relating to (1) beamline and ESH training, and (2) the level of support and oversight provided to the short-term users by facility and PRT staff.

- The aging infrastructure of the facility and poorly documented equipment and facility design from the construction and initial operating periods of the facility will continue to create on-going challenges to the operating and ESH programs. The recent need to remove many of the lifting hoists from service because of undocumented load tests is a good example of this problem. Critical vulnerabilities which may compromise the operating capability of the facility should be identified and corrected as feasible to provide for a safe and effective operation over the next five years.

7.3 Approaches to Addressing ESH&Q Challenges

The mission of the NSLS is to support our users in doing outstanding science in a safe and environmentally friendly manner. Safety of users and staff is the highest priority of the facility. In order to address the ESH challenges of the coming years:

- We will provide additional staffing, in particular at the facility beam lines, to improve safety through increased user support and oversight. We will also continue to work with our PRTs and CUs to ensure a strong commitment on their part to our shared responsibility for safety on the experimental floor.

- We will improve the effectiveness of training for staff and users. Particular emphasis will be focused on streamlining the training program, improving the content of training program, and improving beam line-specific training.

- We will develop a comprehensive plan to address the safety issues related to the safe handling of nanomaterials in anticipation of the growing usage of the NSLS by nanoscience research community.

- We will continue to be vigilant on ESH through tier-1 inspections, safety observations by facility management, staff and user surveys, and regular discussion of safety issues at all department meetings. Lessons-learned of important issues to the department will be routinely distributed to all NSLS staff as well as PRT and CU staff to ensure awareness of problems and solutions impacting department activities.

- We will provide resources to meet all ESH requirements established by DOE or BSA. Particular emphasis will be focused on the scheduled Integrated Safety Management assessment and the impact of Part 851 requirements on NSLS programs. We will also ensure smooth integration of new ESH requirements into the existing ESH program and user experimental program.

- We will also identify and correct critical vulnerabilities which may compromise the safe operation of the facility to ensure safe and effective operation of the NSLS accelerator complex. In conjunction with the analysis of Part 851 and the study of machine operational vulnerabilities, a separate report addressing critical ESH vulnerabilities will be prepared.