NSLS-II Update

Steve Dierker
Associate Laboratory Director for Photon Sciences
NSLS-II Proposal Review Panel Meeting
February 4, 2014

U.S. DEPARTMENT OF ENERGY | Office of Science

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

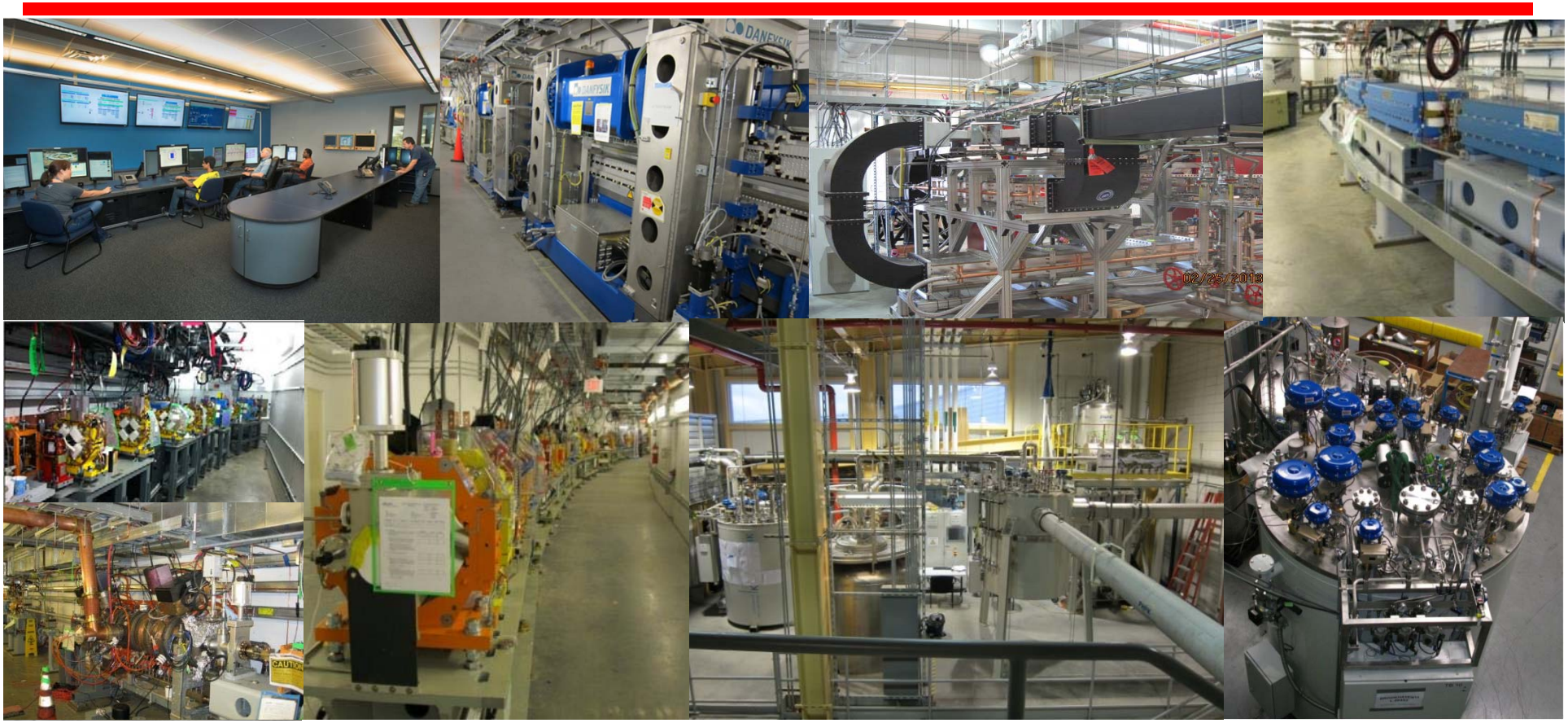
Status of NSLS-II Project

- Excellent progress
- Project is 94% complete as of end of Dec 2013

	Current baseline	% complete
Conventional Facilities	$310M	99%
Accelerator Systems	$295M	95%
Experimental Facilities	$84M	77%
Pre-Ops	$55M	58%
Project Management	$68M	98%
R&D	$61M	100%

- On schedule and on budget
  - Excellent technical, cost & schedule performance to date
  - Substantial scope (~ $60M) added to maximize science
  - Sound cost baseline with sound remaining contingency

Accelerator Systems Status



- Accelerator Systems are 95% complete
- Installation of injector complex is complete
- Accelerator installation is 97% complete
- Injector commissioning Underway: Nov 27, 2013
- Start of storage ring commissioning: Mar 21, 2014
- Completion of accelerator scope: Sep 2014

Conventional Facilities Status

- Ring building complete
- HXN satellite building complete
- All 5 LOBs fully or partially complete
  - Occupied LOB3 in Jan and LOBs 4 & 5 in March
  - LOB1 to be occupied in 2QFY14
- Contract awarded for new satellite building (SIX) in May, construction underway, to be complete by June 2014

Celebrating moving into LOB3

Aerial View of NSLS-II

June, 2013

NSLS-II Project Beamline Status

- 18 Hutch Structures Erected at NSLS-II
- Utility installations 95% complete
- Beamline optics installation underway
- Last optics due in February 2014
- 77% complete overall
- On track for early finish

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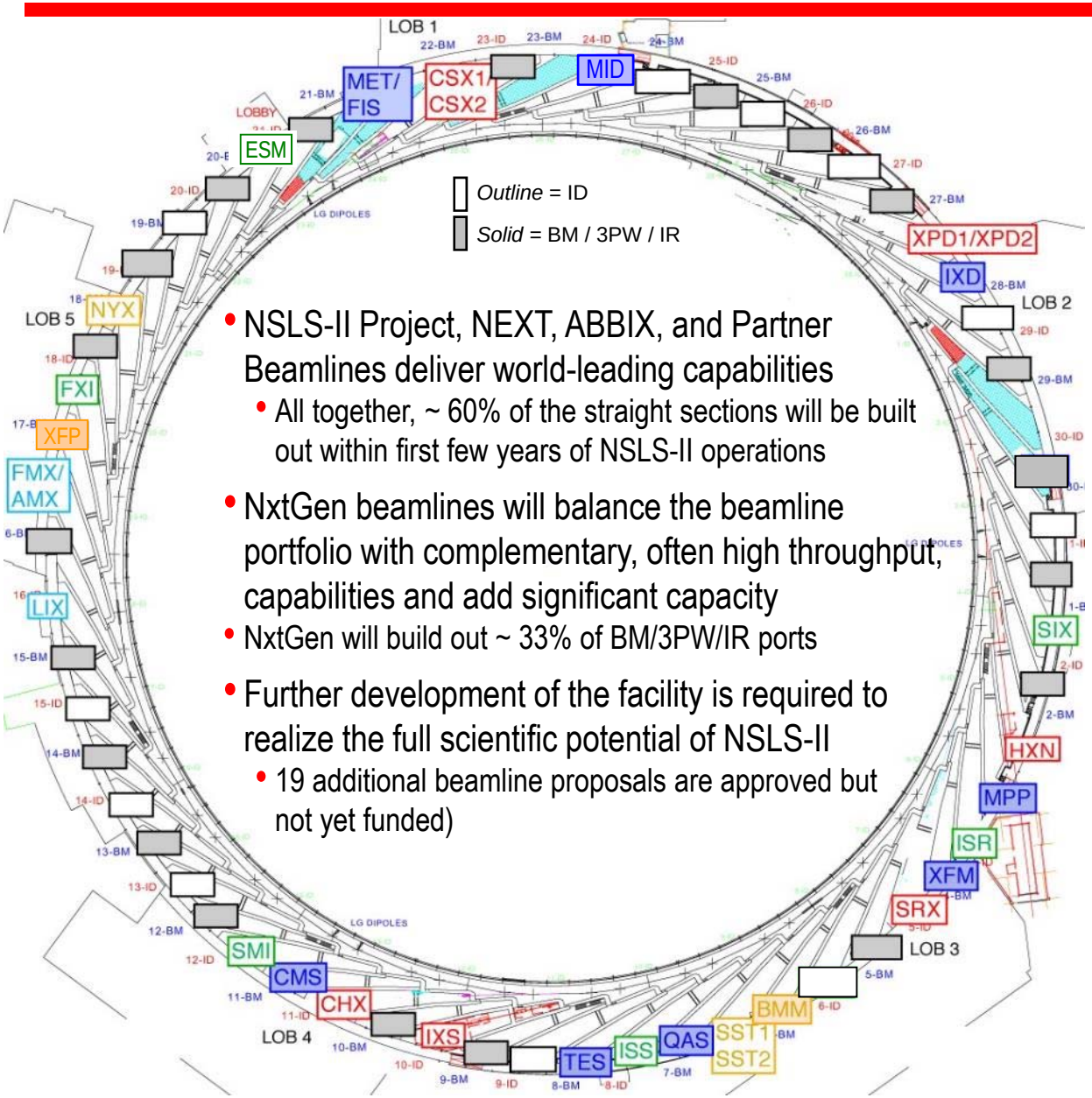
Developing the NSLS-II Beamline Portfolio

30 Beamlines are Underway



- NSLS-II Project, NEXT, ABBIX, and Partner Beamlines deliver world-leading capabilities
  - All together, ~ 60% of the straight sections will be built out within first few years of NSLS-II operations
- NxtGen beamlines will balance the beamline portfolio with complementary, often high throughput, capabilities and add significant capacity
- NxtGen will build out ~ 33% of BM/3PW/IR ports
- Further development of the facility is required to realize the full scientific potential of NSLS-II
  - 19 additional beamline proposals are approved but not yet funded)

8 NSLS-II Project Beamlines

Inelastic X-ray Scattering (IXS)
Hard X-ray Nanoprobe (HXN)
Coherent Hard X-ray Scattering (CHX)
Coherent Soft X-ray Scat & Pol (CSX1, CSX2)
Sub-micron Res X-ray Spec (SRX)
X-ray Powder Diffraction (XPD1, XPD2)

6 NEXT Beamlines

Photoemission-Microscopy Facility (ESM)
Full-field X-ray Imaging (FXI)
In-Situ & Resonant X-Ray Studies (ISR)
Inner Shell Spectroscopy (ISS)
Soft Inelastic X-ray Scattering (SIX)
Soft Matter Interfaces (SMI)

3 ABBIX Beamlines

Frontier Macromolecular Cryst (FMX)
Flexible Access Macromolecular Cryst (AMX)
X-ray Scattering for Biology (LIX)

5 Partner Beamlines

Spectroscopy Soft and Tender (SST1, SST2)
Beamline for Mater. Measurements (BMM)
Microdiffraction Beamline (NYX)
X-ray Footprinting (XFP)

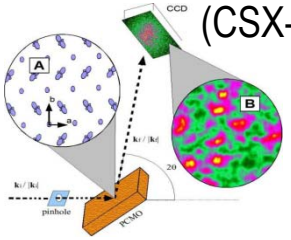
8 NxtGen Beamlines

Complex Materials Scattering (CMS)
Magneto, Ellipso, High Pressure IR (MET/FIS)
Metrology & Instrum Development (MID)
In-situ X-ray Diffraction Studies (IXD)
Materials Physics & Processing (MPP)
Quick X-ray Absorption and Scattering (QAS)
Tender X-ray Absorption Spectroscopy (TES)
X-ray Fluorescence Microscopy (XFM)

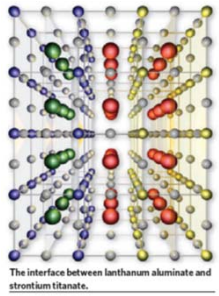
NSLS-II Project Beamlines

Operations Begin in 4QFY14

Coherent Soft X-ray Scattering (CSX-1)



World-leading coherent flux XPCS, CDI

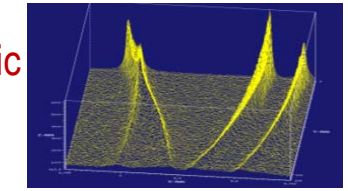


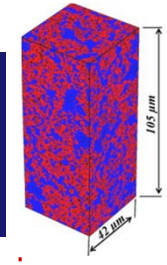
Fast Switching Polarization (CSX-2)

Resonant magnetic scattering, spectroscopy, XMCD

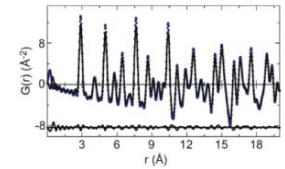
Imaging & dynamics in strongly correlated and magnetic materials

X-ray Powder Diffraction (XPD-1)





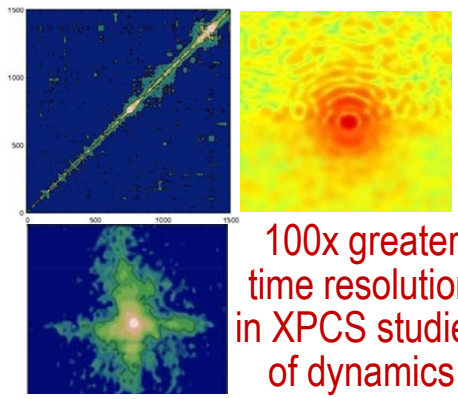
Provision for PDF (XPD-2)



Powder diffraction, scattering, PDF 30-80 keV

Time-resolved in-situ in-operando extreme conditions
Understanding complex nanostructured materials

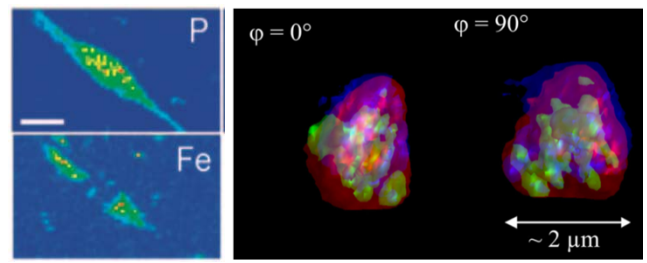
Coherent Hard X-ray Scattering (CHX)



100x greater time resolution in XPCS studies of dynamics

Non-equilibrium and heterogeneous dynamics in soft matter, at buried interfaces, biomaterials, glasses, driven systems

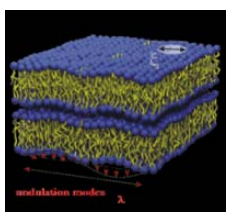
Sub-um Resolution X-ray Spectroscopy (SRX)

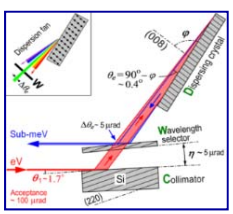


World-leading spectroscopy in sub-100 nm spot

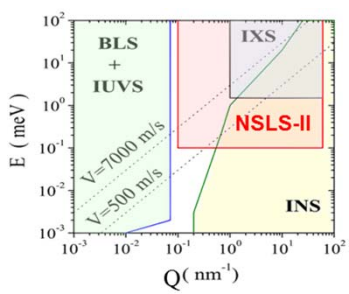
3D chemical imaging and speciation at the nanoscale

Inelastic X-ray Scattering (IXS)



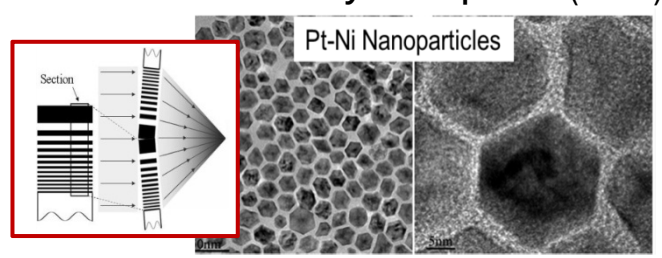


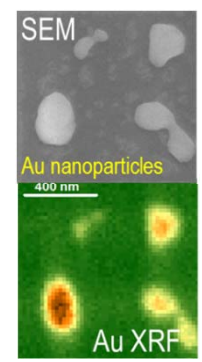
~1 meV baseline
~0.1 meV ultimate goal



THz dynamics in liquid, glassy, and crystalline materials with nanoscale inhomogeneities

Hard X-ray Nanoprobe (HXN)





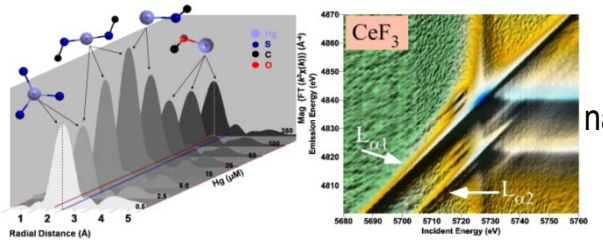
100m long beamline
~10 nm baseline
~1 nm ultimate goal

Nanoscale imaging with fluorescence and diffraction

NSLS-II Experimental Tools (NEXT) Beamlines

DOE-BES funded $90M MIE project - Operations to begin 1QFY17

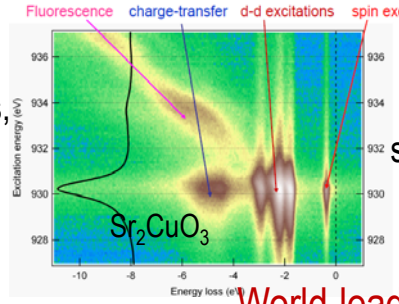
Inner Shell Spectroscopy (ISS)



In-situ, time-resolved, element specific studies of nanocatalysts, mettalloenzymes, environmental contaminants, batteries, and fuel cells

Time resolved XAS with high E-resolution and at ultra-dilute concentrations

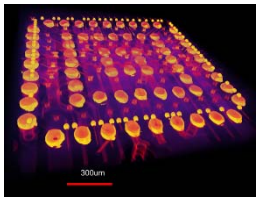
Soft Inelastic X-ray Scattering (SIX)



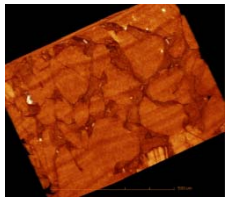
Elementary excitations (magnons, phonons and orbitons) in nanoscale samples $(100\ nm)^3$ w/ applications to superconductivity, nanocatalysts, energy storage materials

World-leading soft x-ray energy resolution

Full-field X-ray Imaging (FXI)



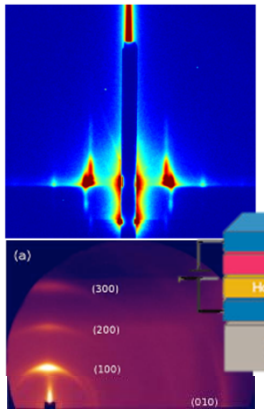
semiconductor failures



$CaCO_3$ drilling

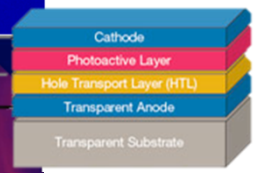
Real-time 3D imaging of natural and man-made materials in working environments

High speed TXM w/ 30 nm resolution



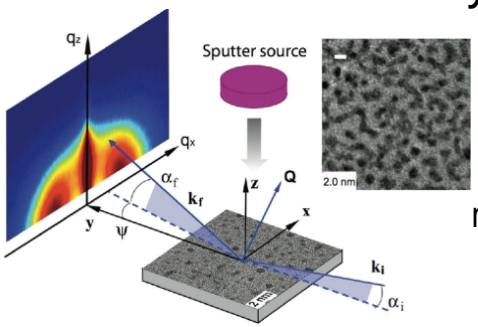
Soft Matter Interfaces (SMI)

Understanding self-assembly of nanomaterials in order to create new hierarchical materials with tailored functionality



In-situ real-time studies of solid/liquid/vapor interfaces of complex materials

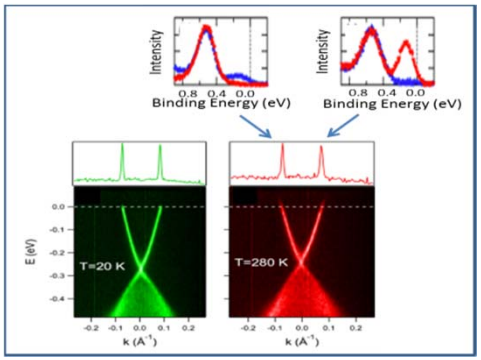
In-Situ & Resonant X-Ray Studies (ISR)



Powerful capabilities for in-situ, real-time growth, atomic structure of surface and interfaces, magnetic/orbital scattering, domain imaging, high magnetic fields

Integrated materials physics studies

Electron Spectro-Microscopy (ESM)



Advancing photoemission to characterize electronic structure of functional materials w/ high spatial resolution

Sub-meV nano-ARPES

Advanced Beamlines for Biological Investigations with X-rays

ABBIX Project - NIH funded $45M - Operations to begin 1QFY16

Frontier Macromolecular Crystallography (FMX)

Studies of enzymatic pathways of cellular and microbiological processes

Studies of drug-target interactions of new and improved pharmacologically effective compounds

Tunable 1µm beam of high intensity for micro-crystallographic studies of small crystals and large unit cells

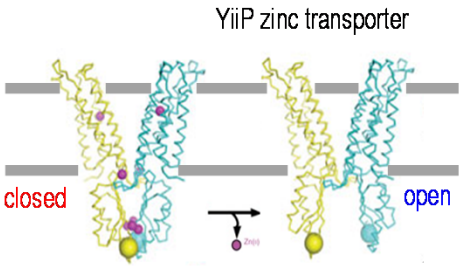
Highly Automated Beamline for Macromolecular Crystallography (AMX)

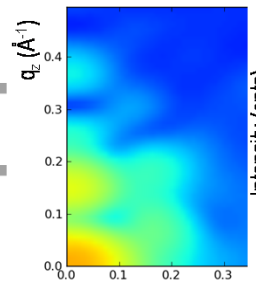
Atomic structure of large protein and nucleic acid complexes, including membrane proteins

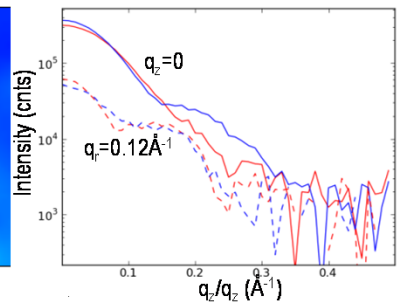
Highly automated to support remote access and extensive experimental searches

Precise structure determinations with unprecedented throughput

High Brightness X-ray Scattering for Life Sciences (LIX)







Grazing incidence scattering from 2D solutions of proteins embedded in near-native membranes

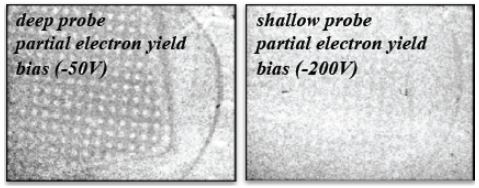
1µm beam scanning probe imaging and tomography of biological tissues

Time-resolved solution scattering down to 10µs

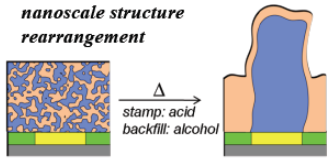
Partner Beamlines

Operations to begin FY16

Spectroscopy Soft & Tender (SST-1, SST-2) - NIST



Nanoscale imaging of the structure and chemistry of buried layers and interfaces of real device architectures



6 unique world class NEXAFS/XPS stations (2 full field microscopes, 2 automated high-throughput, and 2 in-situ high pressure) with two undulators covering soft (100 eV – 2.2 keV) and tender (1 – 7.5 keV) x-rays

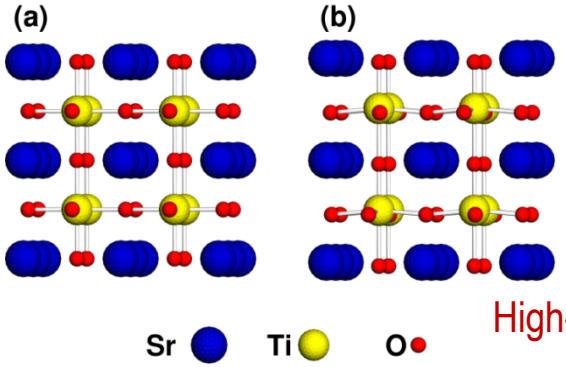
New X-ray Photoelectron Spectroscopy Microscope being developed for SST

NYSBC Microdiffraction Beamline (NYX) - NYSBC

Membrane proteins relevant to neurobiology and metabolic disorders, and protein-protein interactions in signaling complexes and protein-nucleic acid complexes in transcription or replication

Diffraction from micron sized crystals and optimized for anomalous scattering with high energy resolution at low energies (3.5 – 17.5 keV)

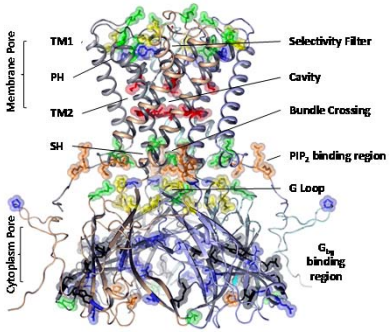
Beamline for Materials Measurements (BMM) - NIST



Strain engineering studies of electronic thin films, high throughput XAFS studies of chemical reactions and catalysts, phase transitions under controlled environmental conditions

High-throughput, high-quality hard x-ray absorption and diffraction

X-ray Footprinting (XFP) - CWRU



Steady state and time-resolved X-ray hydroxyl-radical mediated Protein and Nucleic Acid Footprinting

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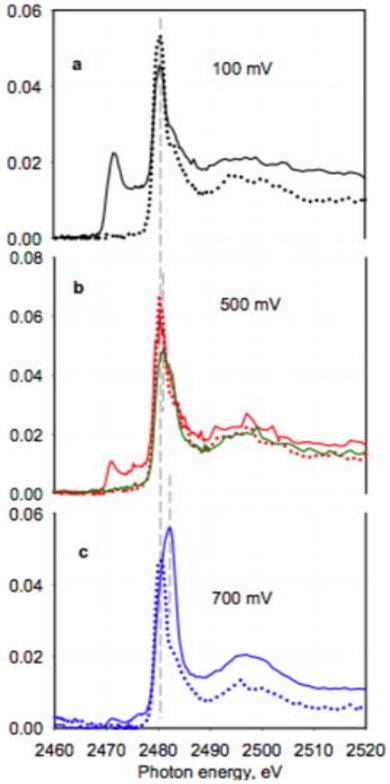
NxtGen Beamlines

Operations to begin FY15-FY17

- Bending magnet, three pole wiggler, and infrared beamlines are needed at NSLS-II to provide complementary capabilities, including high throughput, and add significant capacity
- These will also serve to transition much of the existing NSLS user community & their scientific programs to NSLS-II
- We are working to cost effectively transfer eight such beamlines from NSLS to NSLS-II as an activity called "NxtGen" using NSLS and NSLS-II operations funds
- The NxtGen beamlines are currently anticipated to go into operation in the FY15-FY17 timeframe but achieving this depends on the level of annual operations funding

- Combined *in-situ* XAS and electrochemistry examines Sulfur speciation during poisoning of fuel-cell catalyst
- TES will enable fast-scanning high-quality EXAFS and XANES at tunable spatial resolution to better address these and other real systems



Complex Materials Scattering (CMS)
Magneto, Ellipso, High Pressure IR (MET/FIS)
Metrology & Instrum Development (MID)
In-situ X-ray Diffraction Studies (IXD)

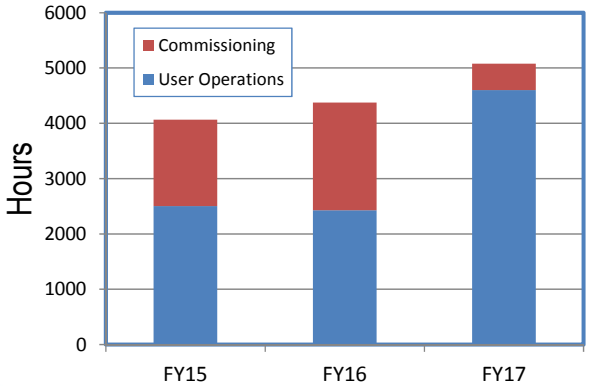
Materials Physics & Processing (MPP)
Quick X-ray Absorption Spectroscopy (QAS)
Tender X-ray Absorption Spectroscopy (TES)
X-ray Fluorescence Microscopy (XFM)

Early Storage Ring Operations

	FY15	FY16	FY17
Insertion Device, Front-end and Beamline	1563	1947	480
Accelerator Studies [h] (49-60/fortnight)	850	946	1046
Maintenance [h] (12h/week)	425	473	523
Shut downs [h]	2160	2160	1440
High current commissioning [h]	565	320	202

Scheduled User Beamtime [h]	2943	2698	4842
Operations reliability (overall)	0.85	0.9	0.95
Actual User Time w/Beam [h]	2502	2428	4600

Maximum Beam Current [mA]	300	400	500



- Challenge: Significant time will be required in FY15 & FY16 to install and commission insertion devices, front ends, and beamlines
- Mitigation: Optimize installation schedule and coordinate with beamline operations

Science Readiness Planning Review

- NSLS-II Beamlines Science Readiness Planning Review, Oct 25-26, 2012
  - Conducted based on SAC recommendation to evaluate detailed commissioning plans for readiness of each beamline
  - External committee consisting of experts with recent beamline commissioning experience at leading synchrotron facilities (ESRF, PETRA-III/DESY, Diamond, APS)
  - Endorsed strategy of phased commissioning, including definition of high priority techniques for each beamline to enable high-impact early science applications
  - Recommended careful analysis of labor resources, continued use of NSLS as test bed, and close coordination between accelerator and beamlines

Beamline Commissioning Steps

- NSLS-II beamline commissioning will proceed in three steps:
  - Integrated Testing (construction), technical commissioning, and science commissioning.
- **Integrated Testing** (construction) will be dedicated to installation and systematic testing without beam of all mechanical and control functions of installed beamline subsystems required to meet the project beamline installation criteria.

NSLS-II Project

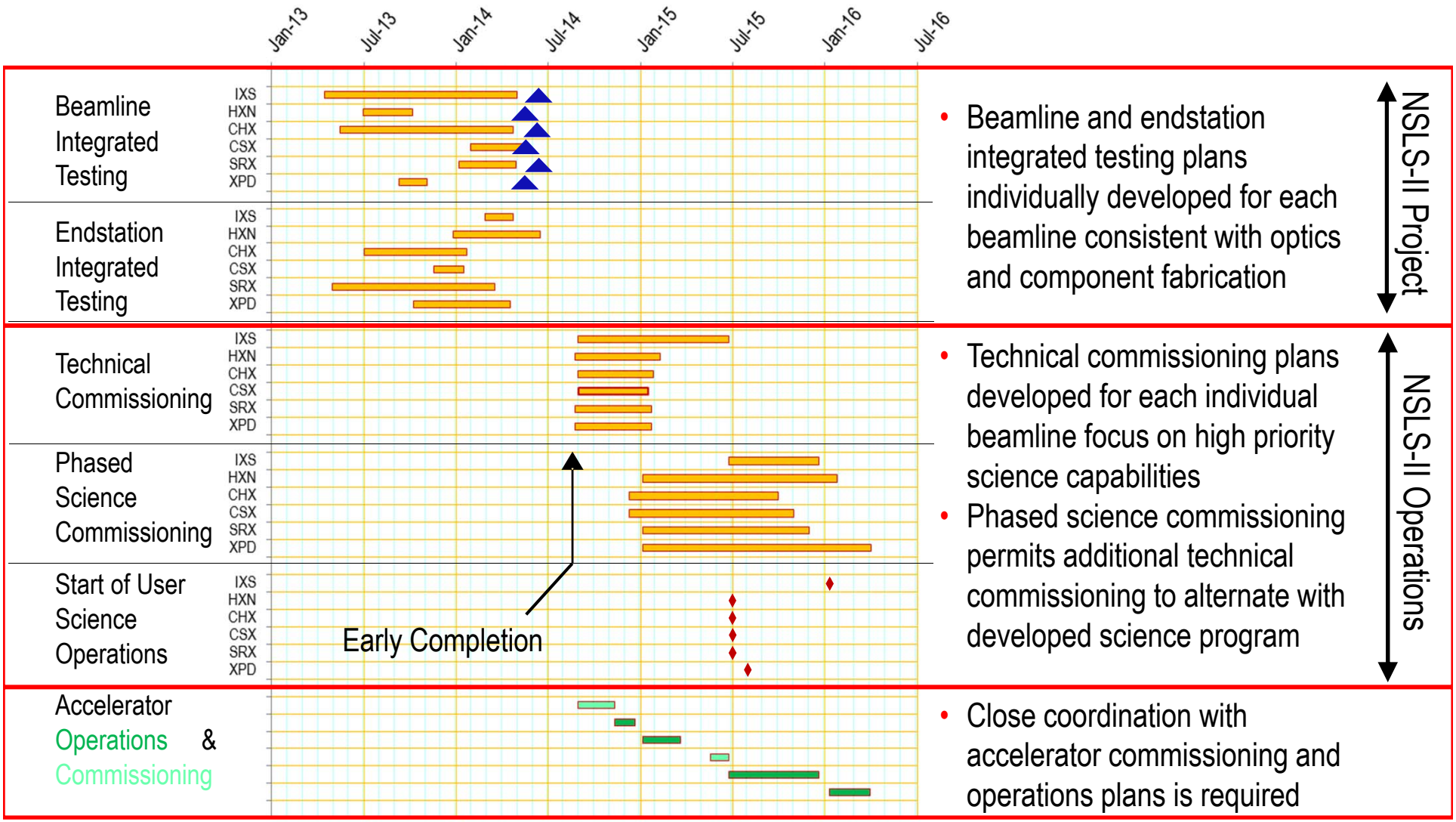
- **Technical Commissioning** will focus on beam delivery into the experimental endstation, with emphasis on characterizing the beamline performance parameters, including flux, focus, energy resolution & calibration, energy range, stability, etc…
- **Science Commissioning** will evaluate the beamline instruments and data acquisition systems for the planned science experiments, and may require measurements on standard systems or calibrated standards, followed by commissioning experiments selected through a review process.

NSLS-II Operations

Phased Science Commissioning Approach

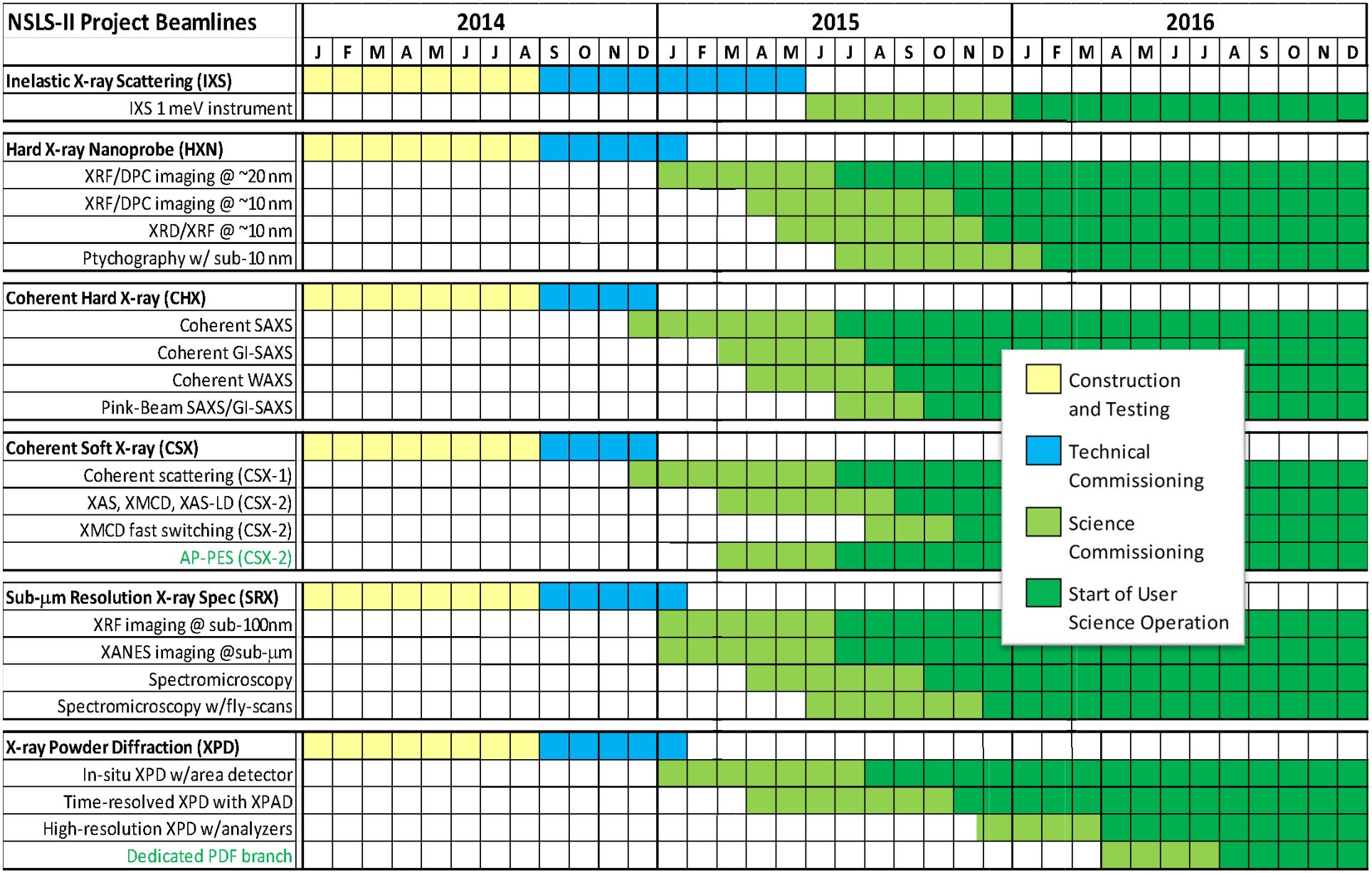
- Each beamline has more than one capability or technique
- Scientific capabilities most likely to produce early science results will be commissioned first based on scientific priorities determined through interactions with the BATs and user community
- User science program will begin once a scientific capability or technique is commissioned, and additional commissioning will alternate with previously commissioned science capabilities
- This “Phased Commissioning” approach, will permit thorough technical commissioning of all planned science capabilities and will achieve early, high impact scientific productivity

Beamline Commissioning Readiness



▲ *Instrument Readiness Reviews for each beamline to be held after all safety components are installed and integrated*

Phased Ramp-up of Science Capabilities



First Experiments Workshop

August 12-13, 2013

- Update community about NSLS-II, operations ramp-up, and anticipated beam parameters
- Identify key research projects and first experiments for NSLS-II project beamlines, emphasizing those that need NSLS-II properties
- Facilitate formation of teams and identify key additional members needed to achieve science goals (e.g., theory and analysis, ancillary measurements, specimen preparation, etc)
- Excellent turnout
  - 305 registered attendees (incl IXS session on Oct 1, 2013
  - >75% of attendees from outside of BNL-PS
  - ~58% of attendees from outside of BNL
  - A dozen other user workshops also held in FY13

August
12–13, 2013
Berkner Hall
Bldg. 488
Brookhaven National Laboratory
Upton, NY, 11973, USA

NSLS-II First Experiments Workshop

3 µm

Monday: Morning Plenary Session

Afternoon Breakout Sessions

"Coherence, Dynamics, and Polarization" (CHX, CSX-1, CSX-2)
- Hard material and condensed matter physics science focus
- Soft matter, biology, chemistry science focus

"Combined Multi-length Scale Techniques for 21st Century Science" (HXN, SRX, XPD)
- Soft matter, biology, chemistry science focus
- Hard material and condensed matter physics science focus

Tuesday: 6 Parallel Sessions

Hard X-ray Nanoprobe (HXN)
Submicron Resolution X-ray Spectroscopy (SRX)
Coherent Hard X-ray Scattering (CHX)
Coherent Soft X-ray Scattering (CSX-1)
Full Polarization Control Soft X-rays (CSX-2)
X-ray Powder Diffraction (XPD)
Inelastic X-ray Scattering (IXS) focus session – Fall 2013

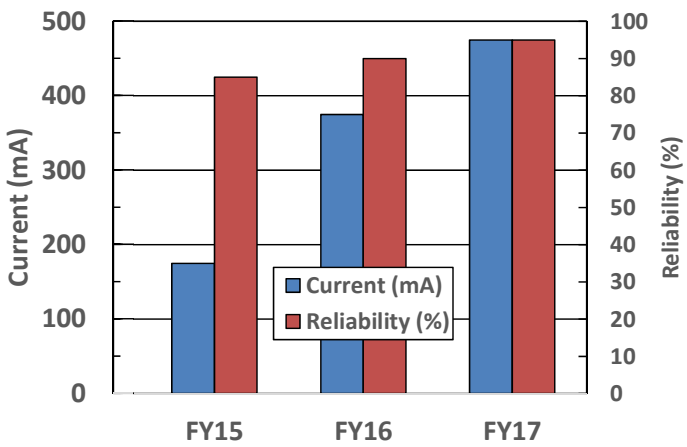
Late Afternoon Plenary Session

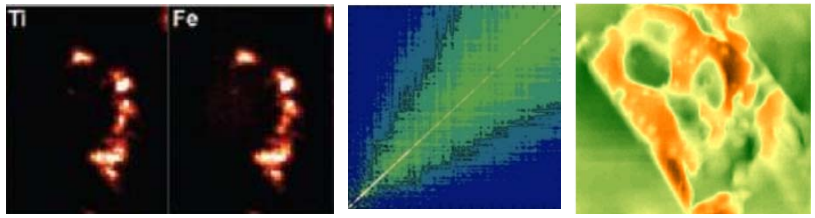
BROOKHAVEN NATIONAL LABORATORY

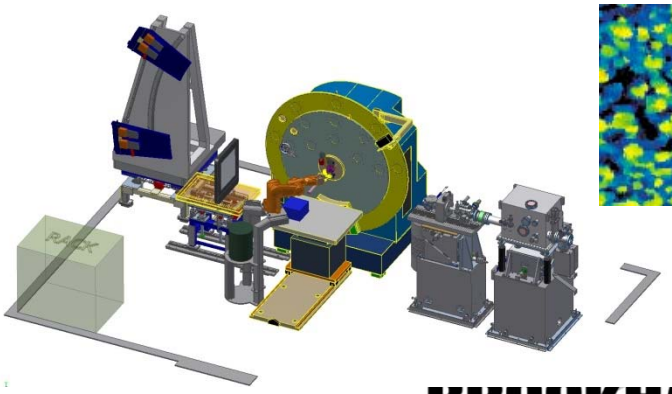
http://workshops.ps.bnl.gov/default.aspx?w=NSLS-II

Discussions at the 1st Experiments Workshop

- Communicating realistic expectations of NSLS-II accelerator & beamline performance ramp-up during science commissioning
- Many interesting presentations outlining how NSLS-II beamlines will potentially help address grand challenge problems in science and technology
- Active participations in discussions on possible experiments at NSLS-II beamlines among interested community members
- Wide-range of dialogs and discussions: ranging from fundamental physics ideas on XPCS and CDI to basic needs for advanced characterization of functional materials systems e.g. energy storage and fuel cells





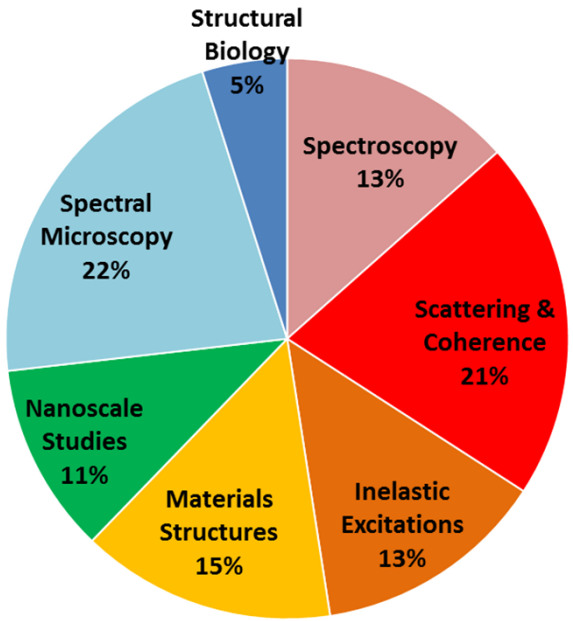


Additional Messages to the Community

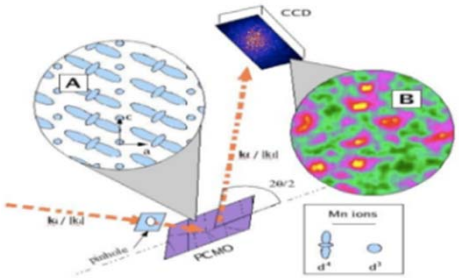
- Performing the first science experiments during the science-commissioning period is an important part of the science readiness 'commissioning' activity at the beamline, which follows a technical readiness commissioning period
- It will be a high priority to provide as much scientific and technical support to these first science experiments as possible, including tailoring the operating modes and schedule for the NSLS-II storage ring to suit their needs to the maximum extent practical
- On the other hand, it is also understood that unexpected beam conditions could happen during these commissioning experiments
- The allocated beam time will be more flexible than usual and will take into account all factors that may affect the success of the early science experiment

Outcomes of the First Round Calls for Proposals

- Photon Sciences has received total of 82 proposals during the first round calls,
  - 61 First Experiments Proposals
  - 21 Partner User Proposals
- Consistent with *NSLS-II User Access Policy*, these submitted First Experiment and Partner User proposals will be reviewed by the NSLS-II Proposal Review Panel (PRP)
- NSLS-II PRP has been formed, consisting of 24 scientists from the international scientific community, distributed among 7 sub-panels
- We will work with the user community to develop the successful proposals to ensure their success



Distribution of the 82 Proposals in the 7 PRP Sub-panels



NSLS-II: A Bright Future

- NSLS-II Project continues to make excellent progress
- 30 beamlines under development
- Accelerator commissioning & early operations plans well developed
- Early science planning underway for NSLS-II Project Beamlines
- Users engaged in science commissioning process
- Looking forward to fast ramp up to an exciting science program