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## APS Renewal Instrumentation Part II

*Dennis Mills*

*APS Scientific Advisory Committee (SAC) Meeting*

*January 20-22, 2009*

### *Areas Covered in My Talk*

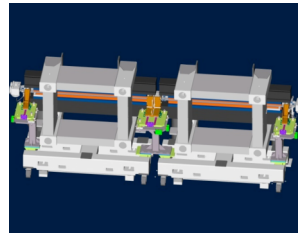
- **Techniques**
  - Imaging instruments
  - Time-resolved tools
- **Sample Environments**
- **Technical support**
  - Optics
  - Detectors
  - Software
  - Computing and Networks
  - Conventional Facilities/Infrastructure
- **Summary**

## Imaging Instruments

- Some Comments
  - X-ray imaging will be an important direction for future growth
  - It is an integral part of *both* central themes of the Science Cases
- Summary of Beamline Renewal Proposals and Sector LOIs/Proposals
  - Presently have the equivalent of about **8 imaging beamlines**
    - Microprobe beamlines (2.25)
    - Nanoprobe beamlines (3)
    - Full field imaging with micron resolution (1.75)
    - Full field imaging with nanometer resolution (1.25)
  - With beamline renewals and new LOIs/Proposals that number would more than double to about **18 beamlines**
    - Microprobe beamlines (4.5)
    - Nanoprobe beamlines (6.75)
    - Full field imaging with micron resolution (2.75)
    - Full field imaging with nanometer resolution (3.5)

## Beamline Renewals and New Sector LOIs/Proposals

- Most of the growth of imaging beamlines is due to requests for canted IDs
  - Increases capacity
  - Allows better performance of *each* beamline through
    - Optimized insertion devices
    - Technique- specific optics
- One renewal proposal submitted by our staff was for a new BM beamline for high energy work, a fraction of which would be for high energy tomography.
- We also have in hand Sector LOIs/Proposals for imaging beamlines
  - [Bionanoprobe Collaborative Development Team](#) (BNP CDT)
    - Requesting a straight section
  - [Advanced X-ray Imaging Collaborative Development Team](#) (AXI CDT)
    - Requesting a (long) straight section for a 200m beamline with 2 IDs



More canted insertion devices

## Microprobe Beamlines

Existing BL Operator (% currently)	Upgrade Proposal or LOI/New Proposal (% future)	Techniques and Disciplines	Expected Beam Properties/ Unique?
7-ID-C XOR (25%)	Upgrade will put 7-ID to nanoprobe (0%)		–
8-BM XOR (0%)	Currently under construction (100%)	High throughput trace element analysis life sciences -	30 μm
13-ID-C GSE-CARS (50%)	Canted ID to expand capacity (100%)	Microprobe (2.3-23 keV) geosciences and environmental sciences	0.25 - 4.0 μm
16-ID HP CAT (50%)	Canted ID to expand capacity and improved focusing optics (100%)	Microprobe/high pressure studies materials and geosciences	0.5 - 1.0 μm
18-ID BioCAT (50%)	2nd (tandem) undulator for increased flux (no capacity increase) (50%)	Fiber diffraction (SAXS/WAXS) and XRF life sciences	1 μm
20-ID: XOR (50%)	Canted ID and dedicate beamline to XAFS (need to move some programs) (100%)	Micro-XAFS environmental science, geoscience, materials science	0.5 - 10 μm
<b>2.25</b> (equivalent)	<b>4.5</b> (equivalent)	<b>Canted and Tandem IDs no new BLs</b>	

## Nanoprobe Beamlines

Existing BL Operator (% currently)	Upgrade Proposal or LOI/New Proposal (% future)	Techniques and Disciplines	Expected Beam Properties/ Unique?
2-ID XOR (150%)	Canted IDs for 3 parallel operating nanoprobes (300%)	Nanoprobes life/environmental science, materials science	50 nm (2-20 keV) XRF (5-30 keV)
7-ID-C XOR (0%)	Improve focusing optics, would become part of short pulse project (25%)	Nanoprobe/Time-Resolved materials science, chemistry	100 nm 1-2 psec UNIQUE
26-ID CNM/XOR (50%)	Nanoprobe Heating/cooling stage, MLM optics, (50%)	Nanoprobe nanoscience, materials science	30 nm
34-ID XOR (100%)	Canted ID to expand capacity and optimize each program (200%)	Nanoprobe materials science	20 nm
	Bionanoprobe LOI (5-30 keV) (100%)	Nanoprobe - life sciences	20 nm UNIQUE
<b>3</b> (equivalent)	<b>6.75</b> (equivalent)	<b>Canted IDs and new sector/ID line</b>	

### Full Field Imaging Beamlines (Micron Resolution)

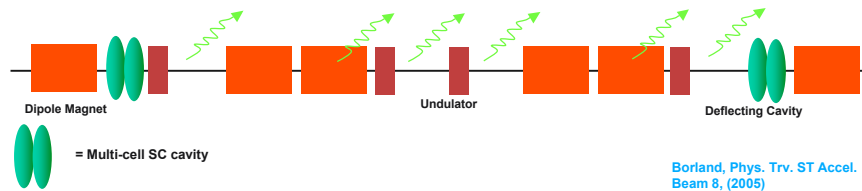
Existing BL Operator (% current)	Upgrade Proposal or LOI/New Proposal (% future)	Techniques and Disciplines	Expected Beam Properties/ Unique?
1-ID XOR (0%)	Improved optics and detectors (50%)	High energy diffract microscopy Materials science, engineering	~ μm spatial resol. 40-90 keV
2-BM XOR (50%)	Improve optics and dedicate BL (100%)	Microtomography Life sciences, materials science	~ μm spatial resol.
5-BM-C DND CAT (25%)	Improved optics and detectors (25%)	Microtomography Materials science	~ μm spatial resol.
7-ID-B XOR (25%)	Optimized ID. Counted as part of short pulse project (0)	Pump-probe; phase-contrast imaging Materials science, chemistry	~ μm spatial resol. psec pulse UNIQUE
13-BM GSE CARS (25%)	Improved optics and detectors (25%)	Microtomography Geosciences, environmental sciences	~ μm spatial resol
32-ID XOR: (50%)	Canted ID (100%)	Phase contrast & ultrafast imaging Materials science, life sciences	~ μm spatial resol.
	Proposal for new Bend Magnet Beamline with several programs (25%)	High energy microtomography Materials science	~ μm spatial resol. white/pink beam
<b>1.75</b> (equivalent)	<b>2.75</b> (equivalent)	<b>Canted and Optimized IDs and one new BM BL</b>	

### Full Field Imaging Beamlines (Nanometer Resolution)

Existing BL Operator (% current)	Upgrade Proposal or LOI/New Proposal (% future)	Techniques and Disciplines	Expected Beam Properties/ Unique?
26-ID CNM/XOR (50%)	Improved optics and positioners (50%)	Hard x-ray nanoprobe Materials science, nanoscience	30 nm spatial resol. UNIQUE
32-ID XOR: (15%)	Canted ID (25%)	Transmission X-ray Microscope Materials science, life sciences	30 nm spatial resol.
33-ID XOR (10%)	Canted ID (25%)	X-ray reflection interface microscopy Surface/interface science	30 nm spatial resol. UNIQUE
34-ID-C XOR (50%)	Dedicated Bragg CDI facility (100%)	Coherent Diffraction Imaging Materials science	5-50 nm spatial resol.
	Advanced X-ray Imaging CDT: (long straight, long beamline) (150%)	Phase contrast imaging Coherent Diffraction Imaging Life sciences, materials science	5-50 nm spatial resol., but could be reduced for larger objects
<b>1.25</b> (equivalent)	<b>3.5</b> (equivalent)	<b>Canted IDs and one new ID BL</b>	

## Time-resolved Tools

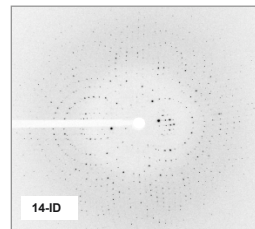
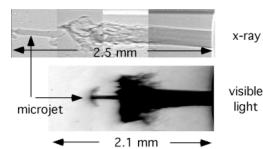
- Comments
  - Time-resolved experiments will be an important direction for future growth
  - It is an integral part of *both* central themes of the Science Cases
- Short Pulse X-rays (SPX) Project
  - CW (superconducting) RF transverse deflecting cavities for the production of (a few) **picosecond pulses at megahertz rep rates** will be included in our renewal proposal
  - It is a large project (both in effort and cost) and hence, I believe it warrants (at least) two ID lines to realize a good return on the investment (Sectors 6 and 7 likely candidates)



## Time-resolved Beamlines

### ■ Summary of Beamline Renewal Proposals and Sector LOIs/Proposals

- Presently have the equivalent of about **4.5 beamlines** dedicated to time-resolved experiments:
  - Short pulse (0)
  - Single shot imaging (0.5)
  - General time-resolved experiments (2)
  - XPCS (1)
  - Laue diffraction (1)
- With beamline renewals and new LOIs/Proposals that number would more than double to about **9.5 beamlines**:
  - Short pulse (2)
  - Single shot imaging (2)
  - General time-resolved experiments (3.5)
  - XPCS (1)
  - Laue diffraction (1)



## Beamline Renewals and New Sector LOIs/Proposals

- Most of the growth of time-resolve beamlines is due to requests for canted IDs
  - Increases capacity
  - Allows better performance of *each* beamline through
    - *Optimized insertion devices*
    - *Technique-specific optics*
  
- We also have in hand Sector LOIs/Proposals for imaging beamlines
  - *Dynamic Compression (DC) CDT* is a new proposal
  - *AXI CDT will have time-resolved capabilities*
  
- Pump/probe Experiments
  - Many time-resolved experiments require fairly substantial high-power/short pulse laser systems for sample excitation.
  - Should they be part of the proposal? (we already have several laser systems but they have all been procured by users, current and ex-CATs, etc.)

## Short Pulse X-ray Beamlines

Existing BL Operator (% current)	Upgrade Proposal or LOI/New Proposal (% future)	Techniques and Disciplines	Expected Beam Properties/ Unique?
7-ID XOR (0%)	Hard x-rays (4-35 keV) (100%)	Time-resolved Materials science, chemistry, AMO	1-2 psec
6-ID XOR (0%)	Soft x-rays (100%)	Time-resolved Materials science, chemistry, AMO	1-2 psec
<b>0</b> (equivalent)	<b>2</b> (equivalent)	<b>Requires re-programming of activities of Sector 6 but no new BLs</b>	

## Single-shot Imaging

Existing BL Operator (% current)	Upgrade Proposal or LOI/New Proposal (% future)	Techniques and Disciplines	Expected Beam Properties/ Unique?
7-BM XOR Under construction (0%)	(100%)	Phase-contrast imaging Engineering/fuel spray	White/pink beam UNIQUE
32-ID XOR (50%)	Second (tandem) ID (50%)	Phase-contrast imaging Engineering	Long beamline? Long straight section?
	Advanced X-ray Imaging CDT: already accounted for as a new sector (50%)	Phase contrast imaging Life sciences, materials science	5-50 nm spatial resol., but could be reduced for larger objects
<b>0.5</b> (equivalent)	<b>2</b> (equivalent)	<b>Requires re-programming but no new BLs</b>	

## General Time-resolved Techniques

Existing BL Operator (% current)	Upgrade Proposal or LOI/New Proposal (% future)	Techniques and Disciplines	Expected Beam Properties/ Unique?
1-ID XOR (25%)	High Energy Diffraction Microscope (50%)	Time-resolved Diffraction mechanical behavior of materials, metallurgy	High energy
4-ID-C XOR (0%)	Time-resolved cryo-PEEM (25%)	Microtomography Life and materials science	10-50 nm spatial resol.
7-ID (25%)	Will be dedicated to the SPX program (0%)		1-2 psec pulses
11-ID-D XOR (25%)	Probably should be moved to a XAS-dedicated beamline (20-ID?) (0%)	XAS Laser-initiated pump/probe Chemistry,	High energy
12-ID XOR (25%)	Construction ongoing to install canted IDs (50%)	SAXS/WAXS chemistry, life sciences, materials science	Basic SAXS properties
16-ID HP (0%)	Canted IDs (25%)	Diffraction HP studies	

### General Time-resolved Techniques (cont)

Existing BL Operator (% current)	Upgrade Proposal or LOI/New Proposal (% future)	Techniques and Disciplines	Expected Beam Properties/ Unique?
18-ID BioCAT (50%)	2nd (tandem) undulator for increased flux (no capacity increase)	Fiber diffraction (SAXS/WAXS) and XRF life sciences	1 $\mu\text{m}$
20-ID XOR (25%)	(50%) Canted ID and dedicate beamline to XAFS (need to move some programs) (50%)	Micro-XAFS environmental science, geoscience, materials science	0.5 - 10 $\mu\text{m}$
33-ID XOR (25%)	Canted IDs (50%)	Diffraction/laser ablation Materials science	??
	Dynamic Compression CDT (100%)	Diffraction Materials, physics, HP studies	Special drivers UNIQUE
<b>2</b> (equivalent)	<b>3.5</b> (equivalent)	<b>Requires reprogramming, canted IDs &amp; 1 new ID/sector</b>	

### XPCS

Existing BL Operator (% current)	Upgrade Proposal or LOI/New Proposal (% future)	Techniques and Disciplines	Expected Beam Properties/ Unique?
8-ID XOR (50%)	Long experiment station (50%)	Correlation spectroscopy Soft matter, polymers	Long straight section Beam-deflecting optics for liquid-like samples
<b>1</b>	<b>1</b>	<b>No increase in capacity</b>	

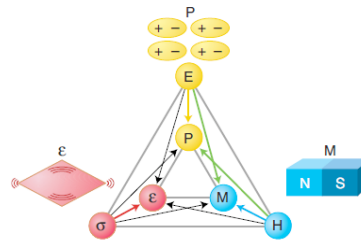
### Time-resolved Laue Diffraction

Existing BL Operator (% current)	Upgrade Proposal or LOI/New Proposal (% future)	Techniques and Disciplines	Expected Beam Properties/ Unique?
14-ID BioCARS (100%)	Additional hutch and improved focusing (100%)	Time-resolved diffraction Life sciences, chemistry	6-16 keV pink beam
<b>1</b>	<b>1</b>	<b>No increase in capacity</b>	



## Sample Environments - a Coherent Approach

- Centralized support for specialized sample environments within APS (expanding the HPSync concept?)
- Coherent development of sample environments that support multiple fields (pressure, temp, magnetic, etc.)
- Key focus would be *portable* systems; a single beamline does not have all the tools and can't keep up with all the cutting edge developments.
- Shift base level responsibilities away from instrument scientists.
- Areas to consider
  - High magnetic fields
  - Levitation
  - *In situ* catalysis cells
  - Extreme chemical environments



Spaldin & Fiebig, Science (2005)

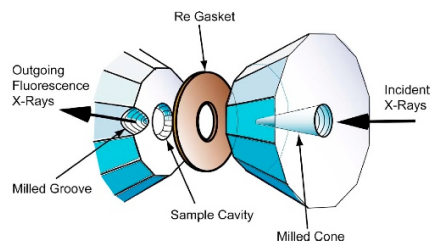
Multiple tiers of support –

**e.g. Cryostats**

1. Base level technical: Installation on beamline, maintaining cryogenics, minor repairs
2. High Level technical: Managing finite resources, complex technical Troubleshooting/Repairs,
3. Scientific/Engineering level: Science driven development of next-gen cryostats

## An Example of “Local Expertise” in High Pressure DACs

- Next Generation High Pressure anvils and micro sample preparation – a laser ablation facility at the APS for precision cutting of diamonds.
  - Next Generation Anvils
    - Optimize highest stable pressures
    - Maximize sample volumes
    - Minimize path lengths thru anvils
  - Micro-sample Preparation
    - As samples tend towards 1 micron and smaller, “by hand” sample prep is increasingly difficult if not impossible.

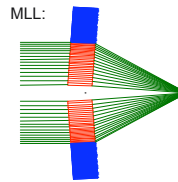


[Mayanovic et al Rev Sci Inst. 78, 053904 (2007) ]

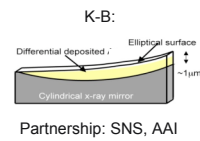
## Technical Support - Optics

### ■ Upgrade deposition system

- New sputtering chamber
  - Multilayer Laue lens
  - Differential deposition



Partnerships: NSLS-II, XRadia



Partnership: SNS, AAI

### ■ Metrology needs to be upgraded

- Hard to make it when you can't measure it
  - New Fizeau interferometer with sample stage capable of measuring large mirrors
  - New Atomic Force Microscope

### ■ Metrology and Detector BM Beamline

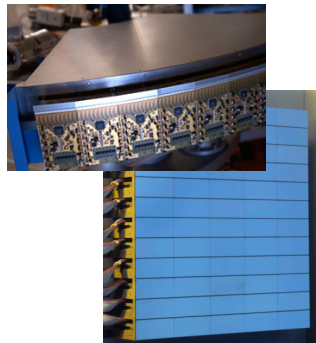
- At-wavelength metrology of mirrors
- Stable set-up for tests of nanofocusing optics
- Detector testing and calibration
- Could also be used to beta-test new software

## Technical Support - Detectors

### ■ Not unexpected, there was a strong demand for better detectors

### ■ A large part of this could be coordinating large procurement packages for existing commercial detectors

- Based on the submitted beamline renewal proposals, existing commercial detectors could meet many of the current needs ( \$15M -\$17M)



### ■ Still demands for detectors that are not commercially available

- Collaborate with groups that develop novel sensors/ASICs
- Contract with companies
- SBIR/STTR process
- Work at the sensor/ASIC level

### ■ Operations

- There was also the suggestion that the APS increase the staffing that can support these state-of-the-art detectors

## Technical Support - Software

- **Common theme throughout all - WE NEED BETTER AND MORE USER-FRIENDLY DATA COLLECTION AND DATA ANALYSIS PACKAGES!**
  - *“Data handling and analysis are increasingly a bottleneck for producing science from synchrotron experiments”*
  - *“Develop user-friendly “expert” software for all engineering stations...”*
  - Reduce the learning effort to using the facility
  - Improve visualization
  - Portable controls (move between beam lines)
  
- **Need to prepare for more remote access in the future.**
  - Hardware/robotics
  - Safety issues
  
- **This is primarily a people issue, but I think the important question is “How do we organize the effort and package it in the renewal proposal?”**

## Technical Support - Computing and Networks

- **Beamline proposals and the march of technology**
  - Detector technology increases in resolution and acquisition rates every year.
  - This creates a huge challenge for APS IT Support to keep the APS technological infrastructure up to date and able to meet the ever-changing needs of beamline users
  
- **Specific requests in the submitted renewal proposals**
  - High Availability (HA) Computing
  - Real Time High Performance Computing (HPC)
  - HA,HPC, and Beamline Storage Backups
  - High Performance and High Availability Networking

## Technical Support - Conventional Facilities/Infrastructure

### ■ Additional Conventional Facilities/Infrastructure

- Build-out of final Lab/Office Module (LOM) - Bldg 437 interior
- Existing LOM expansions - more space for beamline staff
- Out-Buildings - extended beamlines (?)
- Storage Facility – act as staging and assembly area during project construction and later used as APS storage building
- Computer Room Expansion – current server room is full. Additional space is required for support of new renewal project requirements
- Utility System Expansion – Evaluate cumulative utility system requirements generated from all renewal projects
- Temperature control in storage ring tunnel for improved beam stability

## Techniques with Substantial Changes in Beamlines

Technique/Beamlines	Now	Proposed	Delta
Surface Scattering (2.8X)	3.60	10.20	6.60
High Energy Beamlines (2.4X)	3.00	7.25	4.25
Imaging (2.12X)	8.25	17.50	9.25
Laue Diff Microscope (counted in imaging)			
Nano/Micro XAS (counted in imaging)			
Time-resolved (2.11X)	4.50	9.50	5.00
SAXS/GISAXS (1.86X)	3.50	6.50	3.00
Magnetic Scattering/XMCD (1.67X)	3.00	5.00	2.00
MX (1.2X)	15.00	18.00	3.00

An increase of 33 beamlines (a 50% increase over the number of beamlines expected by end of FY09)  
 3 new MX beamlines require no additional ports/canting  
 5 new BLs are included in the Interface CDT which will take up one new Sector  
 3 new BLs are BM sources (HE, 7-BM and 8-BM)

That leaves an increase of 22 ID beamlines  
 2 open sectors (could support 4-5 BLs total, depending on the final configurations)  
 Still have many straights that could be canted.....

### *Discussion Points*

- If there is something in my talk that I did not make clear, please ask and I will try to clarify and expand on the point.
- **Thanks for your attention and we look forward to your advice on moving forward!**