APS Upgrade Project Overview and Status

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APSUO and PUC Joint Meeting
September 18, 2013

Agenda

- Update on Current Activities
  - Accelerator area
- Update on October Workshop Preparation
  - Preliminary meetings
  - Educational activities

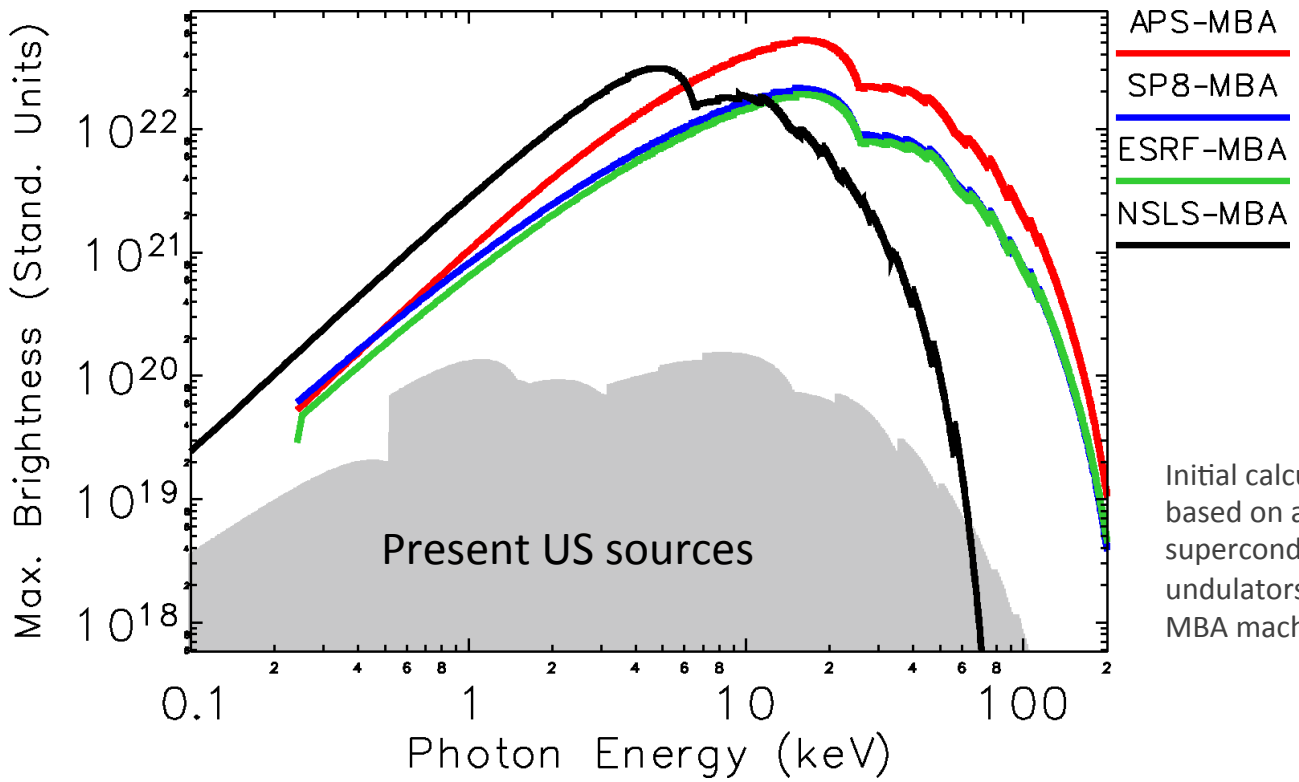
Planning at APS in Light of the BESAC Review

Recommendation:

"It is essential that the facilities this science community relies on remain internationally competitive in the face of the innovative developments of storage rings in other countries. Such developments include diffraction-limited storage rings with beamlines, optics, and detectors compatible with the 10^2-10^3 increase in brightness afforded by upgraded storage rings."

APS is working with DOE to evaluate the incorporation of MBA technology into the ongoing APS Upgrade project

Goal: World-Leading Brightness



Initial calculations based on advanced superconducting undulators for all MBA machines.

Approach:

- 6 GeV multi-bend achromat (MBA) storage ring
- Emittance of 60-100 pm with 200 mA current
- Small-gap superconducting and conventional undulators
- Enhanced beam stability

Preliminary APS MBA Parameters

- Based on an LDRD-funded study, we've developed a set of preliminary parameters for a possible APS MBA lattice

Quantity	Symbol	Range	Units
Beam energy	E	6	GeV
Natural emittance	ϵ_0	60 - 80	pm
Rms energy spread	σ_δ	0.09 - 0.12	%
Emittance ratio	$\kappa = \epsilon_y/\epsilon_x$	0.1 - 1.0	
Emittance increase due to IBS	-	< 25	%
Horizontal emittance	ϵ_x	30 - 91	pm
Vertical emittance	ϵ_y	40 - 5	pm

- Note that horizontal emittance is very similar to our present vertical emittance of 35 pm

Preliminary APS MBA Fill Patterns

- Total beam current would be 200 mA
- Fill patterns with 48 to 432 bunches would be possible
- Various timing patterns should be possible with up to 4 mA/bunch

Quantity	Symbol	Range	Units
Total current	I	200	mA
Number of bunches	N_b	48-432	
Bunch rate	f_b	13-117	MHz
Rms bunch duration	σ_t	67-12	ps

Preliminary APS MBA ID Parameters

- ID gaps would be much smaller than in the present machine
  - More than compensates for decrease of beam energy
- Also, MBA would permit
  - Vertically polarized undulators (small horizontal gap)
  - Helical devices at a few locations

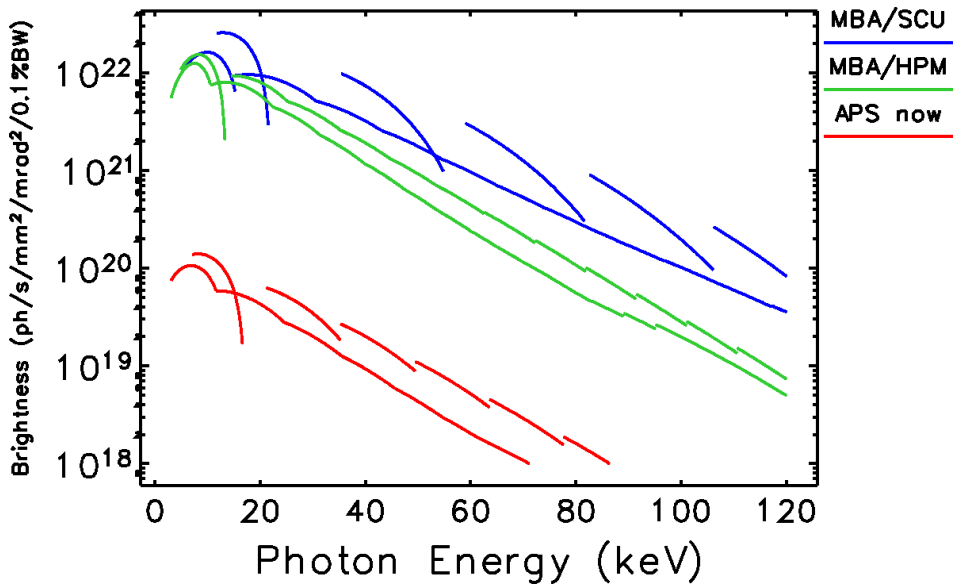
Quantity	Symbol	Range	Units
Maximum length	L_u	4.8	m
Vertical chamber inside gap	g_v	$\geq$6	mm
Horizontal chamber inside gap	g_h	$\geq$6	mm
Vertical magnet gap	m_v	$\geq$8.5	mm
Horizontal magnet gap	m_h	$\geq$8.5	mm

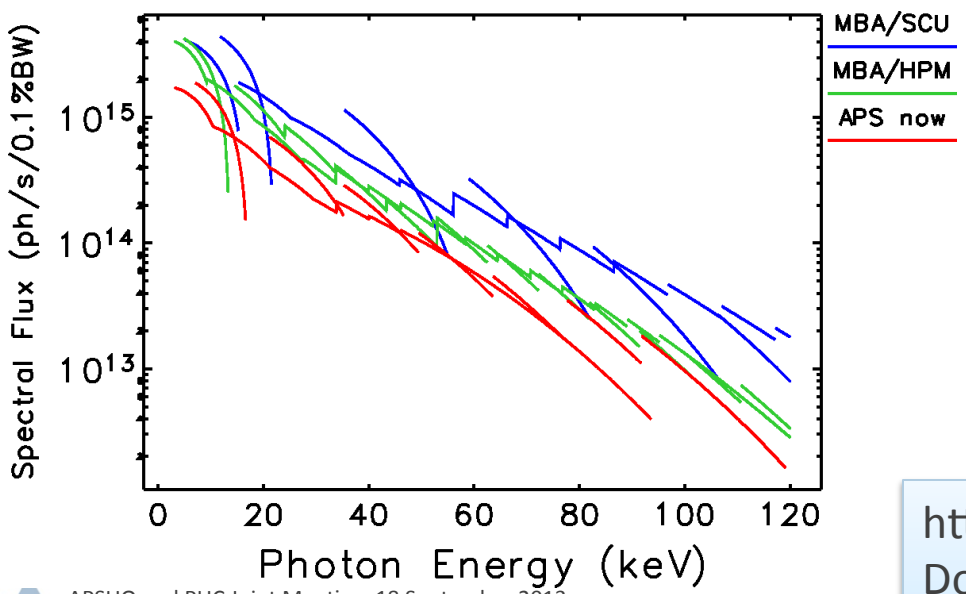
Preliminary APS MBA Dipole Source Parameters

- Emphasis is high brightness for ID beamlines
- Goal would be to retain all dipole beamlines with comparable performance to present day

Quantity	Symbol	Range	Units
Critical energy	e_c	15-20	keV
Radiation fan width	θ_B	>1	mrad

Examples of Preliminary Expected Performance





Smaller gaps, optimized periods, higher current, and lower emittance more than compensate for lower beam energy

Brightness increases of 100x or more compare to brightest devices in APS today

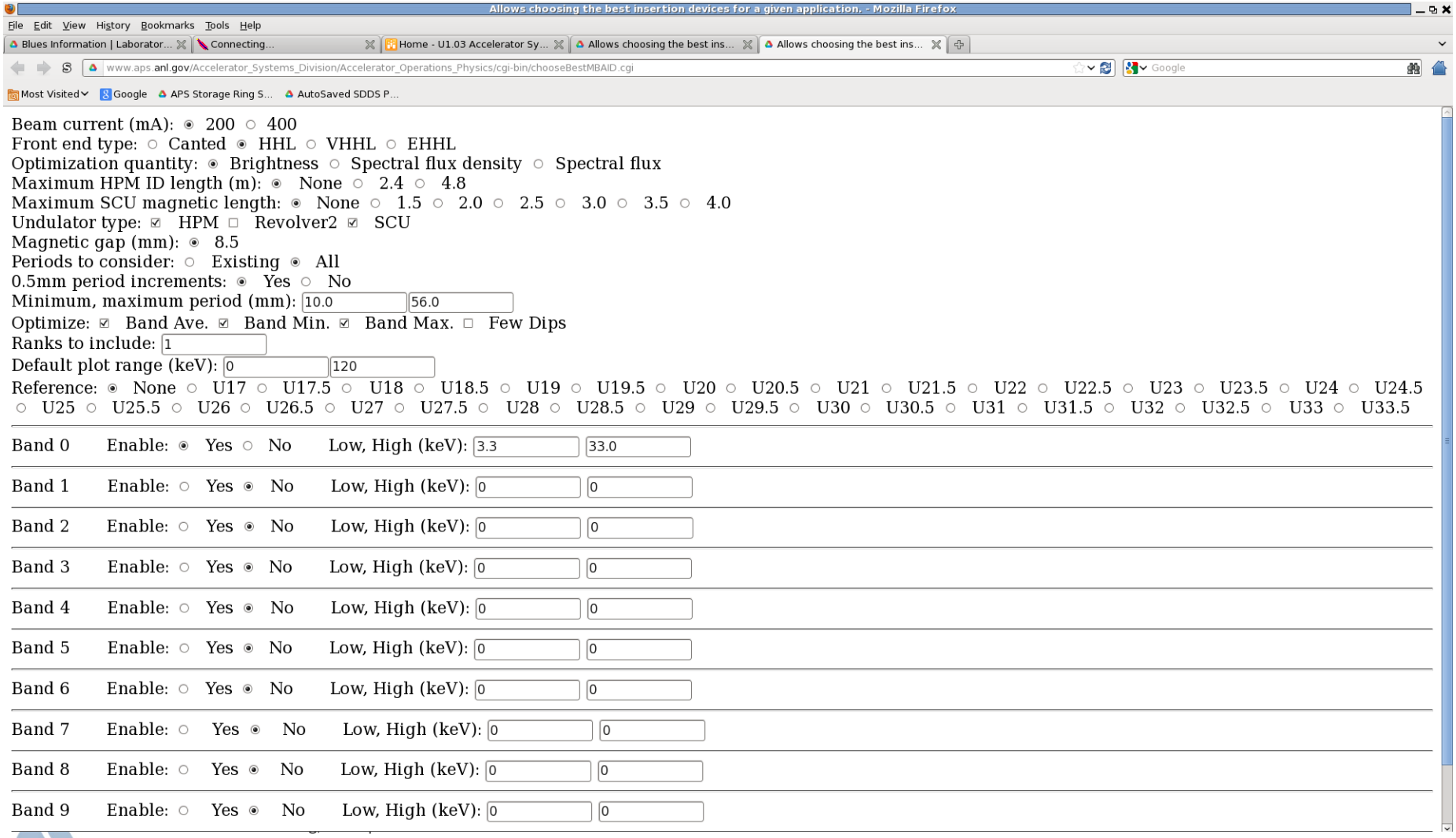
Flux increases a factor of two or more

Curves based on the reference 80 -pm lattice, present-day undulators

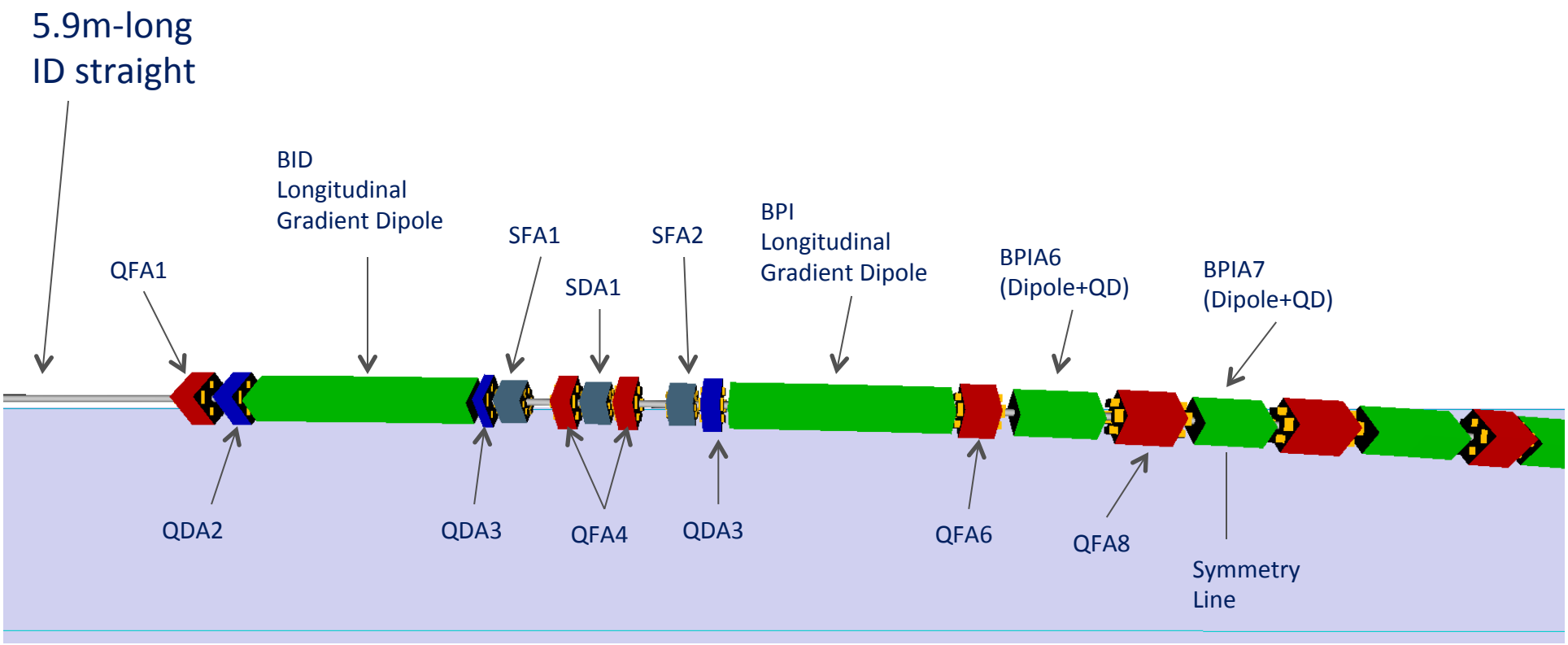
http://www.aps.anl.gov/Upgrade/Documents/MBA_prelim_expected_perf%20v2.pdf

Web App for Brightness/Flux Optimization

Explore optimized performance for your application using
www.aps.anl.gov/asd/oag/cgi-bin/chooseBestMBAID.cgi



APS MBA Preliminary Lattice Layout



- Feedback from magnet designers being incorporated into next iteration of lattice

APS MBA Magnets – First Pass

Element Name	Length m	Angle deg	B T	B_1 T/m	Count
Multi-segment longitudinal-gradient dipole nearest ID					
BID5LU	0.47	0.57	0.43	0.00	80
BID4L	0.47	0.31	0.23	0.00	80
BID3L	0.47	0.24	0.18	0.00	80
BID2L	0.47	0.19	0.14	0.00	80
BID1LD	0.47	0.15	0.11	0.00	80
Multi-segment longitudinal-gradient dipole furthest from ID					
BPI1U	0.47	0.15	0.11	0.00	80
BPI2	0.47	0.18	0.14	0.00	80
BPI3	0.47	0.22	0.16	0.00	80
BPI4	0.47	0.27	0.21	0.00	80
BPI5D	0.47	0.39	0.29	0.00	80
Gradient Dipole Type 1					
BPIA6	0.86	1.56	0.63	-39.43	80
Gradient Dipole Type 2					
BPIA7	0.70	0.54	0.27	-49.23	40

Element Name	Length m	K_1 $1/m^2$	G_1 T/m	Count
QFA1	0.24	4.38	87.75	80
QDA2	0.20	-3.90	-78.14	80
QDA3	0.11	-4.97	-99.37	80
QFA4	0.20	2.80	56.00	160
QDA5	0.20	-2.92	-58.51	80
QFA6	0.37	4.13	82.68	80
QFA8	0.59	4.01	80.23	80

Element Name	Length m	K_2 $1/m^3$	G_2 T/m^2	Count
SDA1	0.28	-115.58	-2313.18	80
SFA1	0.28	144.24	2886.76	80
SDA2	0.28	-82.98	-1660.72	80

- 14 magnet types
- 1800 individual magnets
- Quadrupole designs underway at ANL, dipoles at FNAL

MBA Accelerator Scope

- Replacement of accelerator magnets, adaptation/replacement of power supplies and controls
- Replacement of vacuum chambers, adaptation of controls
- Replacement of supports
- Implementation of swap-out injection scheme using fast stripline kickers and existing injector
- Adaptation of high-level accelerator applications
- Removal of one sector's worth of rf cavities (4 of 16 cavities)
- Implementation of beam stabilization component of existing APS upgrade project, perhaps with additional channels
- Implementation of bunch-lengthening cavities
- Replacement of insertion devices to restore tuning range and maximize brightness

High-Priority Technical Task List

- Complete optimization and evaluation of lattice
  - Magnet strength and field quality specification
  - Placement of correctors, BPMs, skew quads
  - Effects of canting magnets and IDs, including vertical and polarizing devices
  - Magnet strength and alignment tolerances
- Design magnets
- Design vacuum system, including synchrotron radiation management
- Injection system
  - Complete physics analysis and design for on-axis injection
  - Purchase and assess high-voltage pulse, design stripline
- Analyze impedance and instabilities, including bunch-lengthening cavities

Technical Working Groups

- Groups are being organized to assess high-priority tasks:
  - Magnets
  - Vacuum
  - Girder/System Integration (Magnets, Vacuum, Supports)
  - Decommissioning
  - Installation
  - Supply Chain Planning
  - Space Planning and Infrastructure
  - Electrical System Integration
  - Tolerances/Vibrations

- The APS Upgrade accelerator team has done a great in a short time to define the scope of the work

Science Opportunities

- **Transformational Brightness Improvement with MBA – "4th Generation Storage Ring"**
  - High coherent flux, high intensity focusable to smallest (e.g. nanometer) spots
  - Maintains advantages of rings: high flux (~10^{14}-10^{15} photons/sec), stability, capacity, and nearly cw operation for minimal damage
- **What are the New Capabilities?**
  - Spectroscopic nanoprobes using all the powerful x-ray contrast modes: XRF, XRD, XAS/XES, ARPES, RIXS, XMCD, …
  - Coherent diffractive imaging with wavelength-limited spatial resolution
  - Photon correlation spectroscopy of dynamics
  - Improvement of 100X or more in brightness gives corresponding transformational improvements in sensitivity, spatial resolution, signal
- **Scientific Opportunities**
  - Real materials in real time under real conditions
  - Mastering hierarchical structures through imaging
  - Understanding and control of ***nanometer-scale heterogeneity and fluctuation dynamics*** in matter

Adapted from P. Evans presentation to BESAC subcommittee

Community Engagement Plan

- August:

  - Initial evaluation of impact on the Upgrade and draft White Paper on incorporating MBA lattice into APS Upgrade http://www.aps.anl.gov/Upgrade/Documents

- September:

  - Engage user community, APS staff and other Labs in evaluating opportunities and organizing October workshop

- October 21-22:

  - Workshop to optimize incorporation of MBA into APS-U, including science opportunities for all communities

- November 6-7:

  - APS Scientific Advisory Committee review of Workshop report

Workshop on Science Opportunities with MBA Lattice

Monday, October 21

9:00-11:30 Plenary Session

MBA sources overview: scientific opportunities and global perspective

Source properties of a potential MBA lattice at the APS

Optics, detector, and instrumentation developments for high brightness x-ray sources

1:00-5:00 Breakout Sessions

Scanning Probe Imaging

Coherent Diffraction and Phase Contrast Imaging, XPCS

Timing and Dynamics

Interface and Single Crystal Diffraction

Structural and High Energy Scattering, SAXS

Spectroscopy and Inelastic Scattering

Macromolecular Crystallography

Tuesday, October 22

9:00-11:00 Breakout Discussion and Report Preparation

11:00-12:00 Workshop Reports and Plenary Discussion

1:30-4:30 Workshop Reports and Plenary Discussion continued

Goals for the Workshop

- *Inform the APS community* concerning the properties of an MBA low-emittance lattice being considered in the APS Upgrade.
- *Gather input on the new science opportunities* offered by such a source.
- Address how our current suite of beamlines map onto these envisioned science opportunities, and *what new capabilities are needed.*
- *Explore the technical advances in optics, detectors, and undulators* that are required to realize these science opportunities.
- *Identify areas that require R&D efforts* to achieve the ultimate performance from an MBA x-ray source.

Input from the user community and APS staff essential

Workshop Breakout Areas

Breakout Session	Internal Chair	External Chair
Scanning Probe Imaging	Stefan Vogt	Tonio Buonassisi
Coherent Diffraction and Phase Contrast Imaging, XPCS	Jin Wang	Ian Robinson
Timing and Dynamics	David Keavney	Paul Evans
Interface and Single Crystal Diffraction	Jon Tischler	Paul Fuoss
Structural and High Energy Scattering, SAXS	Ian Ilavsky	Lyle Levine
Spectroscopy and Inelastic Scattering	Steve Heald	Clem Burns
Macromolecular Crystallography	Robert Fischetti	TBD

Workshop Organizing Committee

- *Dean Haeffner (chair)*
- *George Srajer*
- *Jonathan Lang*
- *Dennis Mills*
- *Mark Beno*
- *Connie Vanni*
- *Diane Wilkinson*
- *Denis Keane*

Preliminary Meetings Schedule

Preliminary Meeting	Location	Breakout Title	Internal Lead
Thurs (9/12) 2:30 pm	438/C010	Coherent Diffraction and Phase Contrast Imaging, XPC	Jin Wang
Fri (9/13) 11:00 am	A1100	Timing and Dynamics	David Keavney
Mon (9/16) 11:00 am	E1100	Macromolecular Crystallography	Robert Fischetti
Mon (9/16) 1:30 pm	E1100	Interface and Single Crystal Diffraction	Jon Tischler
Tues (9/17) 11:00 am	A1100	Scanning Probe Imaging	Stefan Vogt
Wed. (9/18) 1:30 pm	A1100	Spectroscopy & Inelastic Scattering	Steve Heald
Fri (9/20) 11:00 am	E1100	Powder/Pair Distribution Functions/Small Angle X-ray Scattering/High Energy/Nano Diffraction/High Pressure	Jan Ilavsky

Pre-workshop Activities

- Two meetings with subject area local communities
  - Preliminary meetings (on-going)
  - Schedule at http://www.aps.anl.gov/Upgrade/Workshops/2013/MBA-Technology/pre-workshop-activities.html)
  - Inform/kickoff thinking about beamlines, science with high brightness, coherence, nanometer beams,…
  - Follow up (Early October)
    - Gather information, discussion on ideas
    - Begin putting together workshop report draft
- Optics tool tutorial session by Rueben Reininger
  - Three sessions scheduled
  - Limited number of slots; 10 per session (Contact Dean)
- Optics talk by Lahsen Assoufid and the Optics group
  - Schedule will be released soon

Ruben Reininger's X-ray Optics Tools Tutorials

September 19th, 9-11 AM, room E1100
Brief introduction to SHADOW
Sources
Mirror types and their aberrations
Meridional and sagittal focusing
Screens and slits
KB system
Double crystal monochromator

2nd set of sessions will be scheduled as needed

September 26th, 9-11 AM, room E1100
Complete beamline
Figure errors
Heat bump
Diffraction
Transfocator
Exercise for next meeting: Ray trace your own beamline

October 3rd, 9-11 AM B1209
Discussion of exercises

Summary

- We have begun working with DOE Office of Science and the scientific community to study incorporating an MBA lattice into the APS Upgrade
  - Development of MBA lattice
  - Accelerator scope
- Community Engagement: Workshop on Science Opportunities scheduled for October 21-22
- Workshop report will be reviewed by SAC on November 6-7 and subsequently incorporated in a proposal to the DOE Office of Science
- Incorporation of the MBA lattice in the APS Upgrade offers transformational scientific opportunities