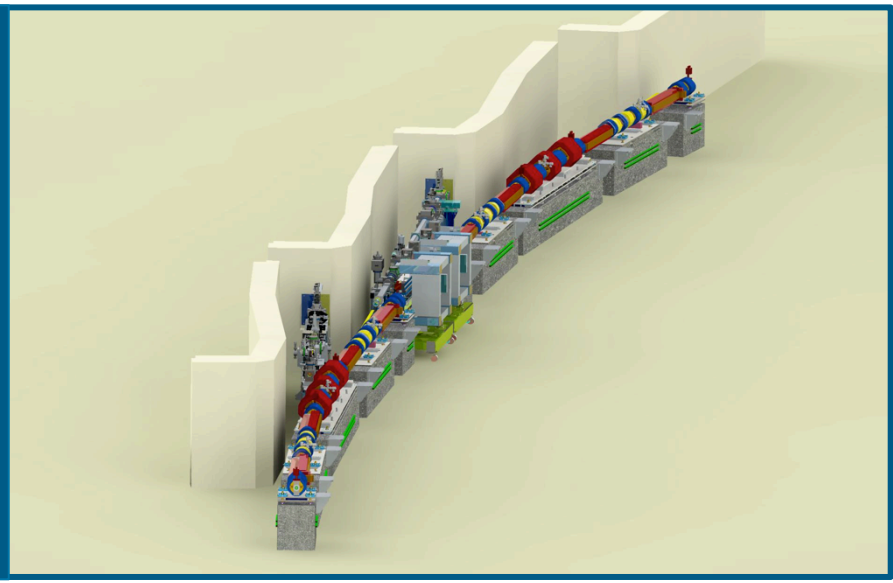
APS-U Beamlines and Other Experimental Systems

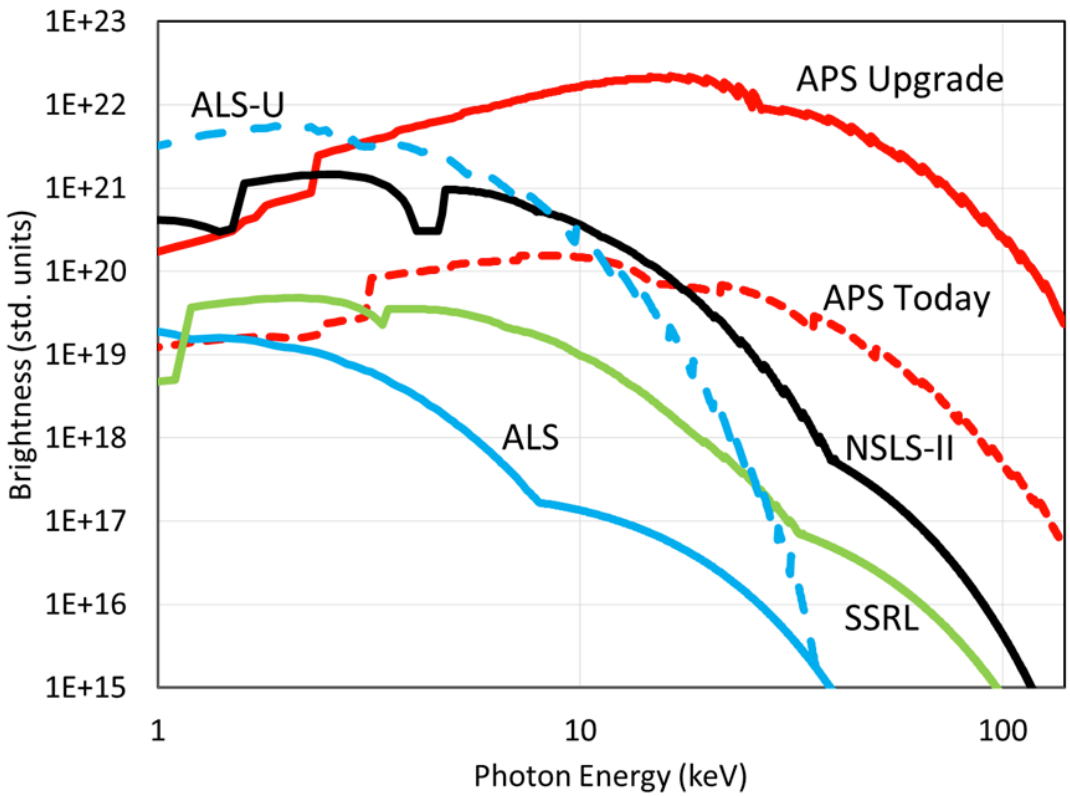


Dean R. Haeffner
Associate Project Manager
Argonne National Laboratory

Three-way Meeting
DESY
September 15, 2016

APS-U Beamline Basics

- Beamlines are a big part of the APS-U
  - 29% of budget
  - Another 14% is front ends and insertion devices
- Reuse of much existing beamline infrastructure
- Key aspects:
  - High brilliance
  - High flux
  - High photon energy



APS-U Beamline Basics (cont.)

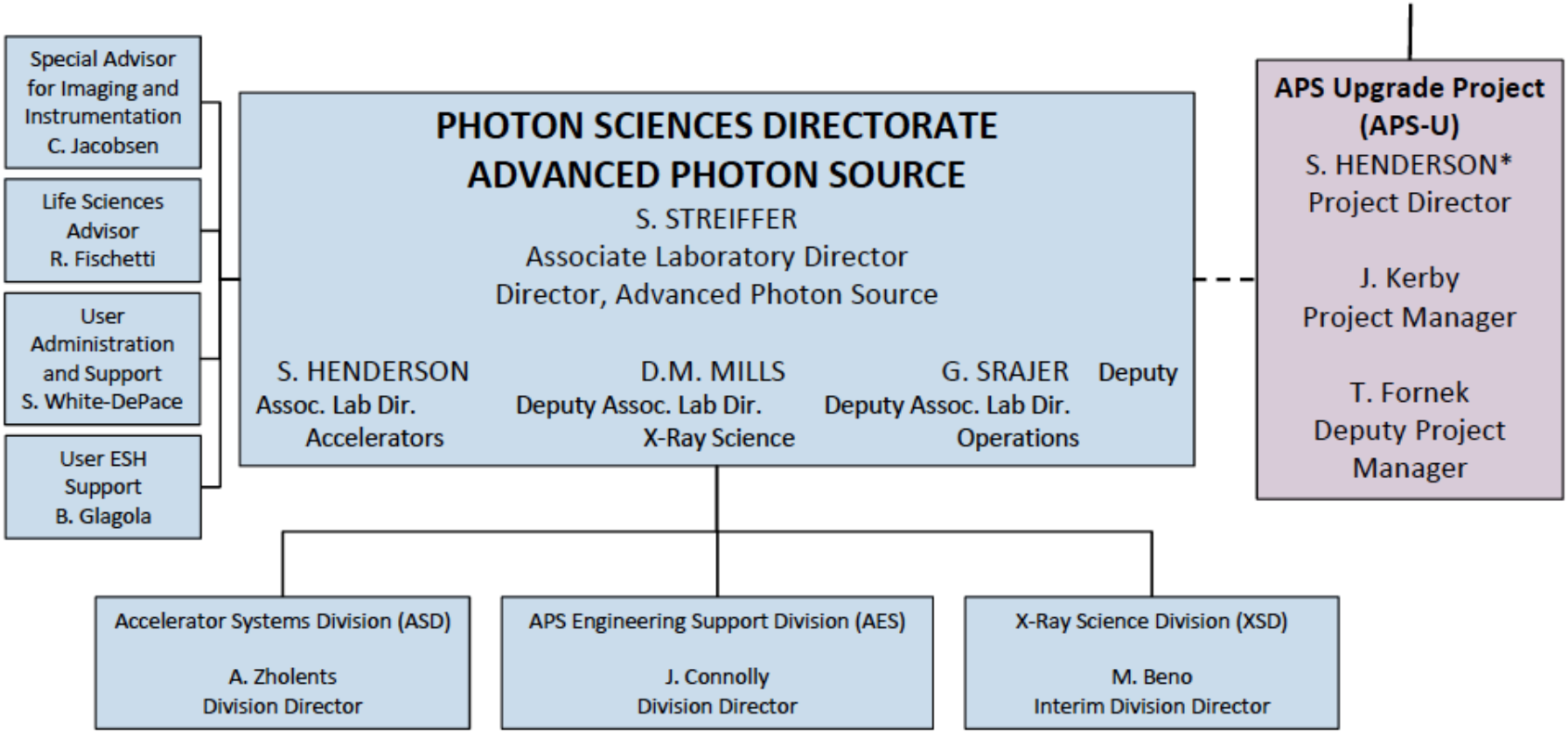
- Current APS
  - 33 of 35 ID ports are in use
  - 19 of 35 Bending Magnets
    - Several ID and BM ports split into multiple beamlines
    - Approximately ½ of beamlines run by the APS, ½ by CATS

- Guiding principles for the APS-U
  - New beamlines and major upgrades will result in world-leading capability that utilize the key aspects of the APS-U storage-ring improvements
  - Other Beamlines Enhancements
    - Minor upgrades that are essential in order to be able to utilize beam from the APS-U – “Do no harm”
    - Further upgrades that are desirable to be able to make the most out of the APS-U

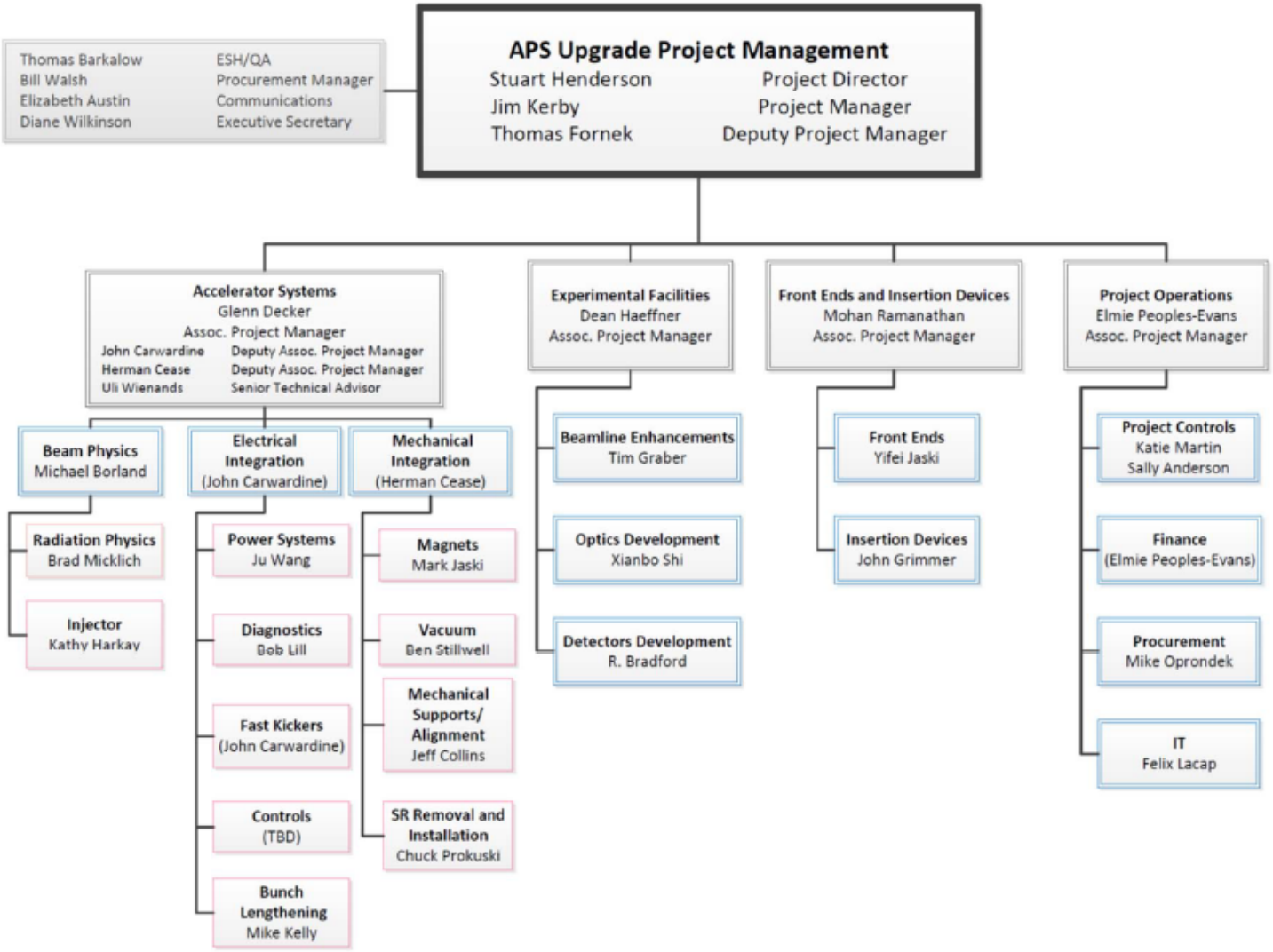
Major Challenges

- Organizational/Political
  - Separate organizations for APS Ops, APS-U
    - Matrixed personnel
    - Complicated communications
  - Selection of new beamlines, major upgrades
- Project
  - Budget usage
  - Minimize the dark period
  - Scope pile up
  - Managing partners (Other labs, CATs)
- Technical
  - Optics
  - Nanopositioning
  - Vibrations/Stability
  - Detectors
  - Bending magnet sources

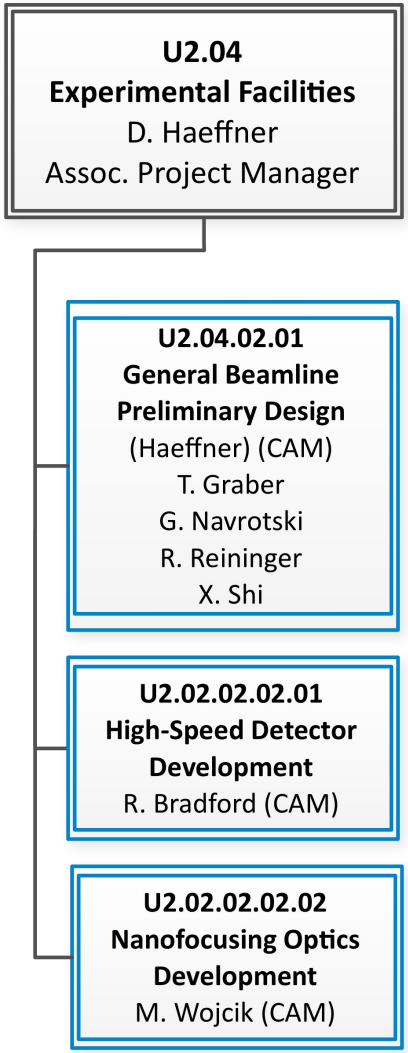
APS Org Chart



APS-U Org Chart



Experimental Facilities Org Chart



- Effort from
  - XSD/AES Engineering
  - XSD Optics
  - XSD Detectors
- Beamline proposal effort from all XSD groups
  - Science Case
  - White Papers
  - Full PDR proposals
- Matrixed XSD staff being added to manage individual beamline effort

Beamline Selection – Basic Principles

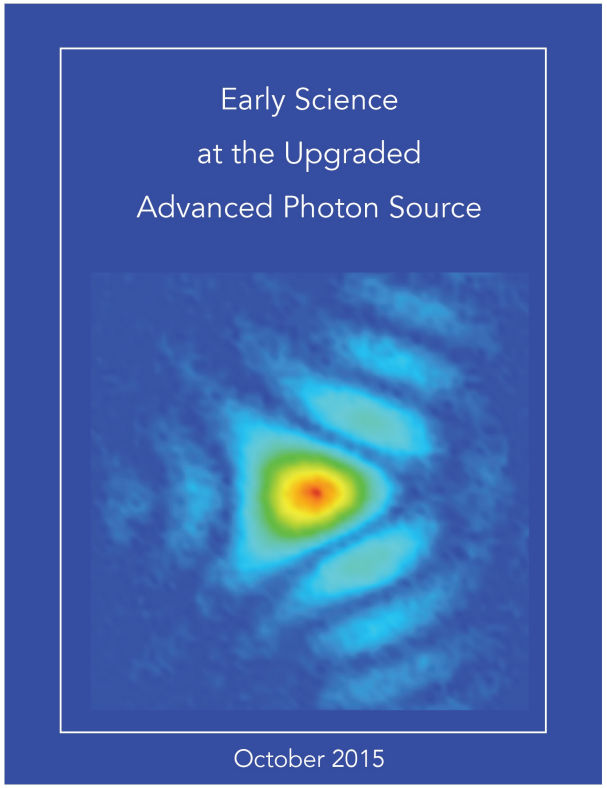
- Budget allows for selection of approximately 6 “new” beamlines and 2 major beamline upgrades
- Guiding Selection Principle
  - New beamlines and major upgrades with resultant world-leading capability that utilize the key aspects of the APS-U storage-ring improvements
- Goals
  - Solicit the best ideas from the community
  - Open and transparent process
  - Meet relevant DOE CD deadlines
  - Effectively use APS & APS-U advisory committees
  - Scope selection that meets the overall strategic needs of the APS
    - “Managed process”

APS-U Beamline Selection

Many workshops, etc. over the last decade

Early science workshops in May 2015

> 200 participants



Guide that underlies beamline development plans

Beamline Selection Process

- **Call** for White Papers for possible beamlines for inclusion in the APS-U Project
  - 10 pages maximum
  - 36 Submitted
- **Review** of White Papers
  - APS-U Beamline Review Committee
  - Followed by APS/APS-U Management Review/Feedback
  - Discussion with APS Scientific Advisory Committee (SAC)
- **Call** for Full APS-U Beamline Proposals from the approved White Papers
  - 30 pages maximum
  - 14 proposals requested
- **Review** of Full APS-U Beamline Proposals
  - APS-U Beamline Review Committee
  - APS/APS-U Management Prioritization/Selection
  - Presentation of Prioritization/Selection to the APS SAC for comment
- **Finalization** of the Prioritization/Selection by APS/APS-U Management

- Roadmap – siting of beamline scope at the APS
- Selected Proposals developed to DOE Preliminary Design level

Selected Beamline Proposals

Name	Title	Technique
CHEX	Coherent High-Energy X-ray Sector for In Situ Science	*In situ*, surface high-energy coherent scattering
Polar	Polarization modulation spectroscopy	Magnetic spectroscopy
HEXM	A High-Energy X-ray Microscope	High-energy microscopies & CDI
SAXPCS	Development of a Small-Angle X-ray Photon Correlation Spectroscopy Beamline for Studying Dynamics in Soft Matter	Small-angle XPCS
WAXPCS	Wide-Angle X-Ray Photon Correlation Spectroscopy and Time-Resolved Coherent X-Ray Scattering Beamline	Wide-angle XPCS
Ptycho	PtychoProbe	Ultimate resolution, forward scattering ptychography/ spectromicroscopy
InSitu	In Situ Nanoprobe Beamline	*In situ*, forward scattering ptychography/spectromicroscopy Long working distances
CSSI	Coherent Surface Scattering Imaging Beamline for Unraveling Mesoscopic Spatial-Temporal Correlations	Coherent GISAXS, XPCS
Atomic/ 3DMicroNano	3D Micro & Nano Diffraction Atomic – A beamline for extremely high resolution coherent imaging of atomistic structures	Diffraction microscopy & CDI Bragg CDI Upgrade of current 34-ID

Beamline 1 for R&D

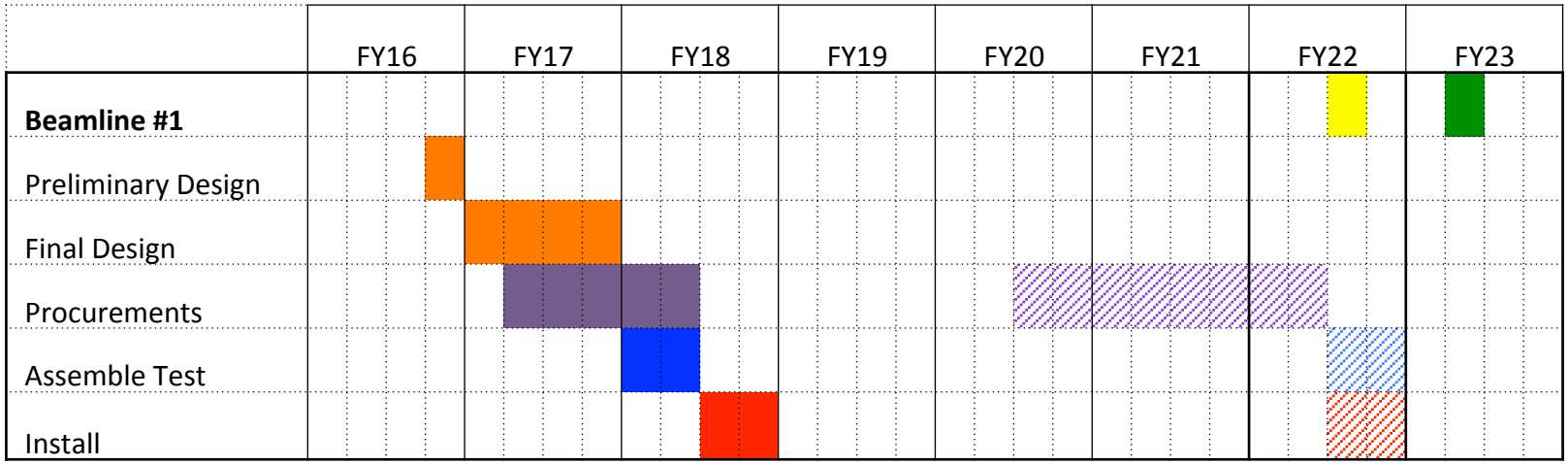
- Need
  - Currently, no APS ID beamline is available for significant APS-U R&D
  - Optics & detector test beamline (1-BM) useful, but does not have ID capabilities for coherence or heat loads
- Use of one of the open APS ID ports for a temporary R&D beamline
  - 25-ID or 28-ID
  - Post Beamline Selection/Roadmap process for final choice
  - Phase I – Build enclosures, infrastructure appropriate for eventual scientific program
  - Goal is to award enclosure(s) contract in 1Q CY17
  - Designed so that FOE and other basic infrastructure would useful for R&D program
  - Turn over to scientific program prior to the start of the storage-ring shutdown for Phase II (completion of beamline)

Beamline 1 for R&D (continued)

- Available for R&D for at least 1.5, possibly 2+ years
- Used for
  - Optics testing
  - BPM testing, calibration
  - Heat-load component testing
  - Undulator testing
- Reduces installation time/risks

Begin Dark Period
End Dark Period

Design
Procurement
Assembly & Test
Installation & Check Out



Phase I

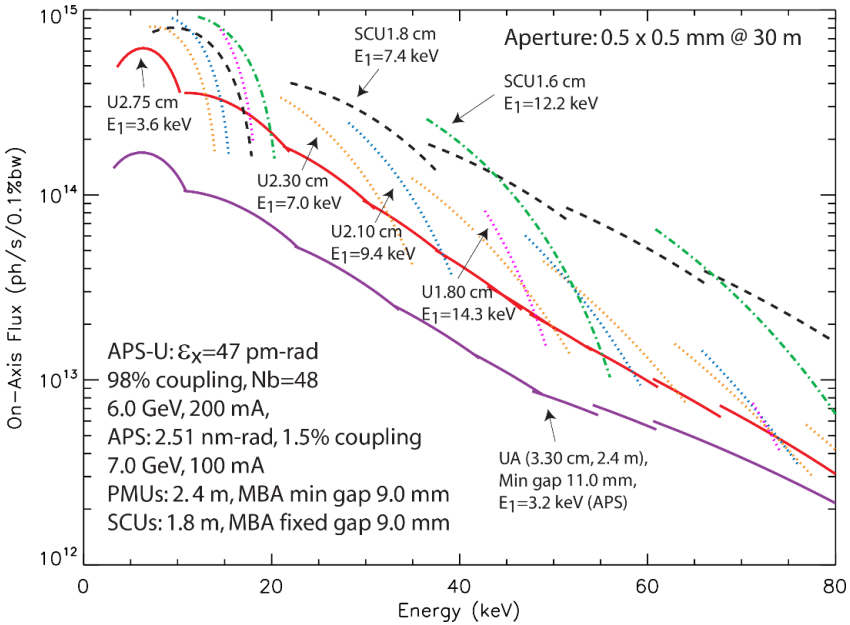
Phase II

Beamline Enhancements

- Improvements to all beamlines not involved in the Beamline Selection process
  - Minor upgrades that are essential in order to be able to utilize beam from the APS-U
    - "Do no harm"
  - Upgrades that are desirable to be able to make the most out of the APS-U
    - "Bang for the buck"
    - Do as much as the budget will allow
- Meetings between APS-U staff and beamline staff for every beamline
  - Data gathering
  - 36 meetings in all
- Top down budget developed
- Detailed scope will be determined in the next year

Possible Thermal Issues with HHL Monochromators and Mirrors

- Due to the reduction in storage ring energy from 7 to 6 GeV, all beamlines will require a new insertion device with shorter period to maintain current tuning range
- The storage ring current will be increased from 100 to 200 mA.
- An APS-U 27.5 mm period is equivalent to the current APS undulator A that has a 33 mm period.

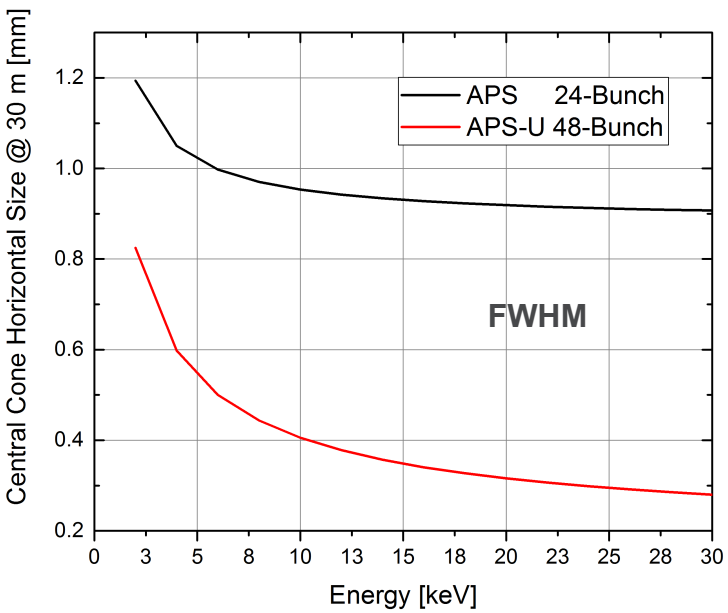


Source	Maximum K	Minimum Energy (keV)	Power (W) 3x2 mm² aperture at 30 m	Power (W) 1x1 mm² aperture at 30 m	Power Density (W/mm²)
APS* 33	2.598	3.2231	897.1	164.4	171.1
APSU 27.5	2.37	3.2642	1306.5	234.5	241.6
APSU 29.5	2.731	2.4505	1326.5	237.3	245.1

All ID are 2.4 m long APS*: 7 GeV 100 mA APSU : 6 GeV 200 mA

Possible Thermal Issues with HHL Monochromators and Mirrors

- The horizontal size of the central cone at a typical monochromator or mirror location (30 m) is smaller
- Allows smaller front-end mask aperture
- Total power incident on the optic is significantly less than with the current source
- The peak power density is higher but is not considered unreasonable for a LN_2 cooled Si monochromator
- Side-cooled mirrors are good up to 700 W total power
- Monochromator crystal-cooling geometries may need updating



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Thermal Distortions in Cryogenically Cooled Monochromators

J. Synchrotron Rad. (2000). **7**, 12–17

Performance limits of direct cryogenically cooled silicon monochromators – experimental results at the APS

Wah-Keat Lee,* Patricia Fernandez and Dennis M. Mills

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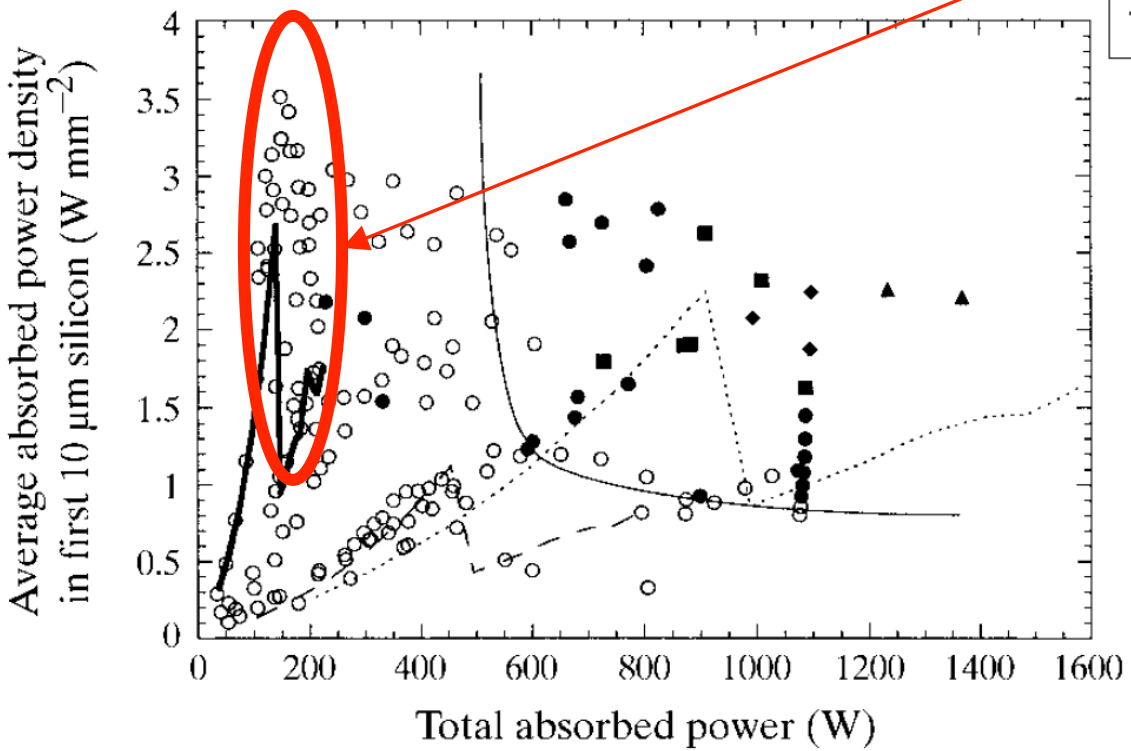


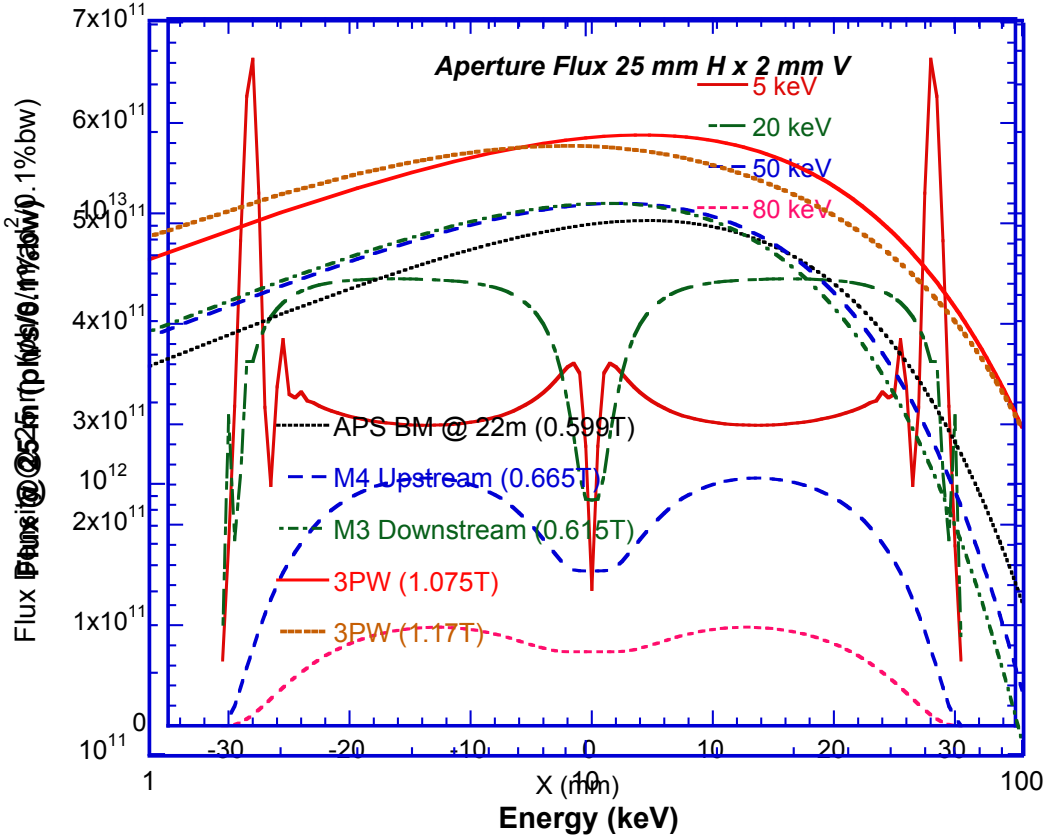
U27.5 Si (111) Darwin width should show < 10 μrad thermal distortion

- Extinction lengths for a Bragg diffracted beam in silicon are on the order of 10 μm
- Calculate the average power from the incident white beam absorbed in the first 10 μm and assume that this causes crystal distortions

Based on this criteria APS-U undulator U2.75 is well within the good region of this plot

Three-pole Wiggler Bending Magnet Beamlines

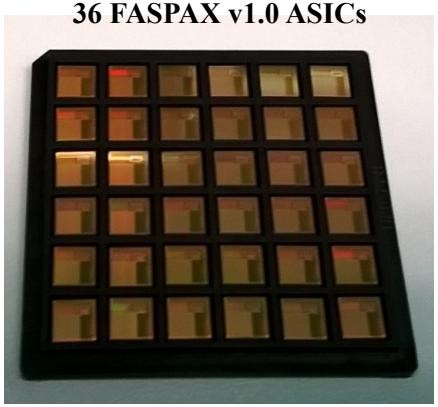
- Higher critical energy
  - Current Source 19.5 keV
  - APS- U 3PW source up to 27.9 keV
  - More Flux
- Thermal considerations
  - Current source 87 W/mrad with a power density of 1.61 W/mm^2 at 22 m
  - APS- U 3PW-1.075T source 279 W/mrad with a power density of 3.96 W/mm^2 at 25 m
  - Probably will require cryogenically cooled monochromator crystals
- Complicated source

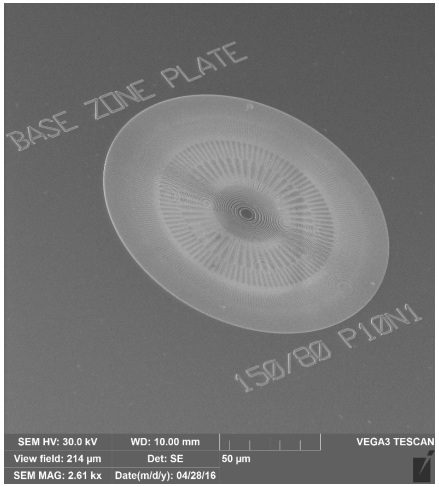


APS-U Experimental Facilities R&D Update

- R&D is coordinated with APS Ops and LDRD
- Currently funded by the APS-U
- U2.02.02.02.02.01 High Speed Detector Development
  - FASPAX v1.0 ASIC chips have arrived and initial tests are promising
  - Carrier boards and DAQ electronics to test full chip in fabrication
  - Silicon sensors (N-in-N) from BNL have arrived
  - CdTe sensors from Acrorad have arrived.
  - ASICs and sensors will be sent for bump bonding soon
- U2.02.02.02.02 Nano-focusing Optics Development
  - 4 zone plates with 40-nm outer zone width were stacked and achieved expected gains in efficiency while retaining focal size
  - 3 zone plates with 20 nm outer zone width were fabricated and prepared for stacking tests scheduled in the next few months
  - Currently developing the atomic layer deposition capability for Pt deposition at CNM. This is the final process for 16 and 20-nm zone-width zone plates to achieve the focal spot size goal.
  - Developed fabrication processes for zone plates with zone width down to 16 nm and greater than a 15 aspect ratio

36 FASPAX v1.0 ASICs





Summary

- The Experimental Facilities scope includes
  - New beamlines,
  - Upgraded beamlines,
  - Global beamline support (Beamline Enhancements/detectors), and
  - R&D associated with beamlines
- The Beamline Selection has selected beamline scope. Roadmap process is underway.
- Many challenges exist, but all appear to be manageable

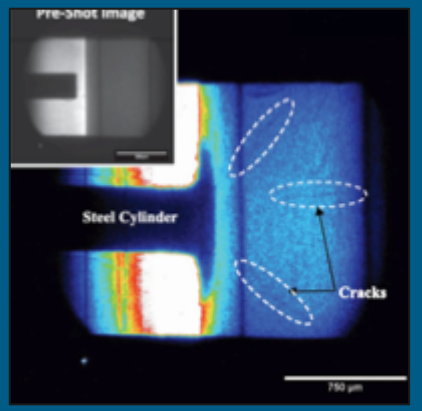
- We need to hire additional good people, so let us know of good students, postdocs, etc. looking for positions
- Anyone interested in a visiting scientist position should contact me
- We are eager to collaborate on R&D. Beamline 1 presents interesting possibilities.

Conclusion: APS-U – The Future Looks Very Bright

High Energy

Penetrating bulk materials and operating systems

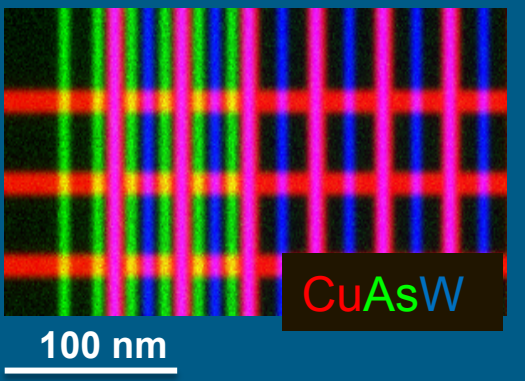
- World's brightest source of hard x-rays
- 3D mapping deep inside samples
- X-ray cinematography in previously inaccessible regimes



Brightness

Providing macroscopic fields of view with nm-scale resolution

- Multi-scale imaging connecting nanometer features across macroscopic dimensions
- Fast sampling with chemical, magnetic, electronic sensitivity



Coherence

Enabling highest spatial resolution even in non-periodic materials

- Extends lens-less imaging to hard x-ray domain, with resolution down to <1 nm, localizing atoms
- Increases phase contrast for fast full-field imaging
- Correlation methods improve by 10,000x-1,000,000x