Argonne NATIONAL LABORATORY

... for a brighter future

U.S. Department of Energy

UChicago ▶ Argonne LLC

Office of Science U.S. DEPARTMENT OF ENERGY

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Introduction to APS MAC Review

Nov 15th 2006

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Director, Advanced Photon Source

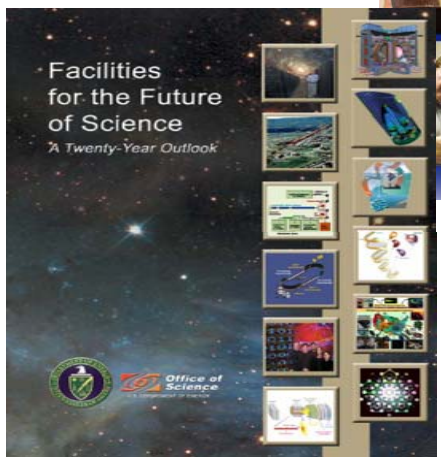
Associate Laboratory Director for Scientific User Facilities

Argonne National Laboratory

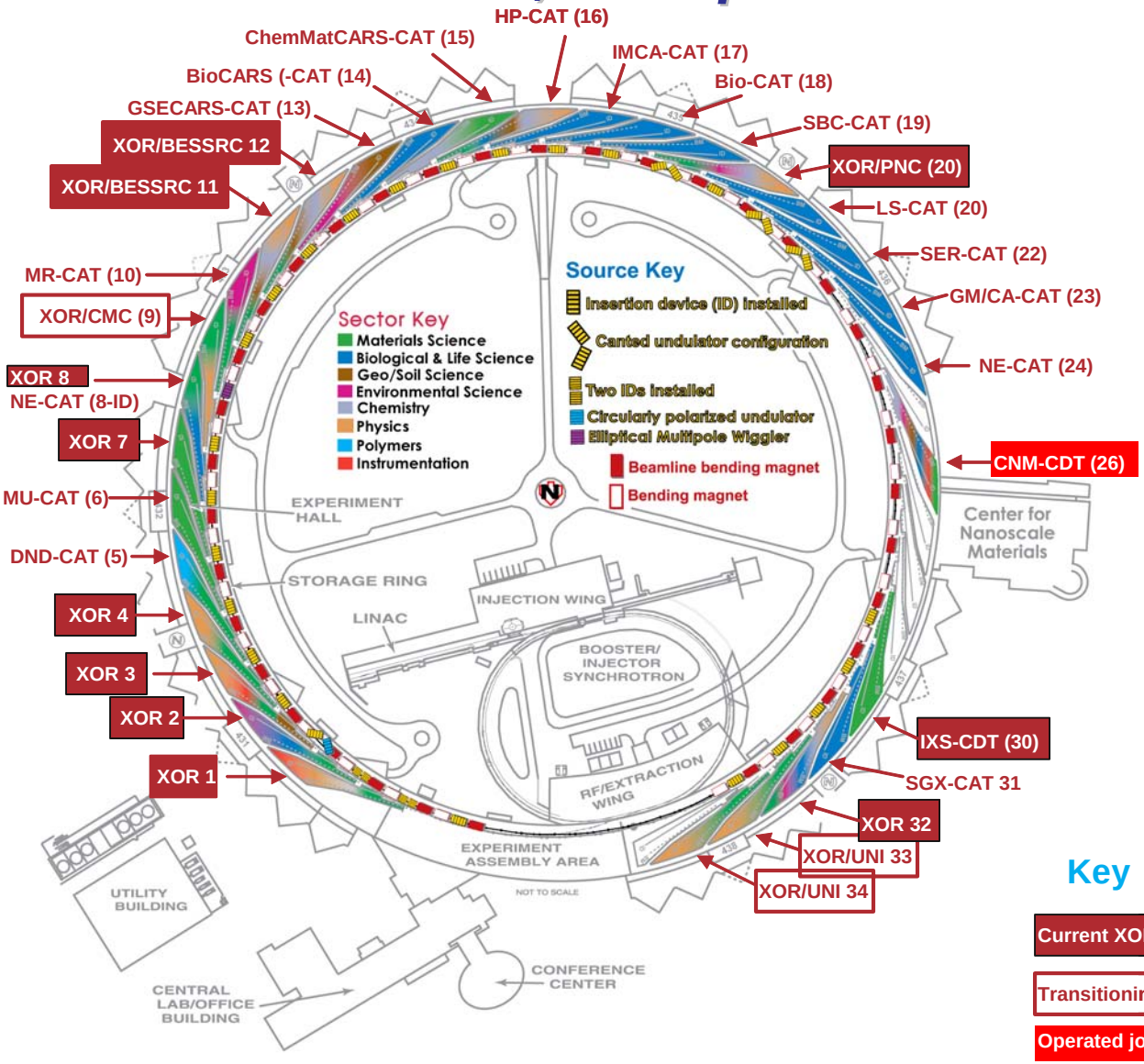
Thank you!

Outline

- APS today
- User demand for x-ray imaging and ultra-fast science drives revolutionary reductions in emittance and pulse width
- Context of APS upgrade planning
- Charge to committee (and next steps)



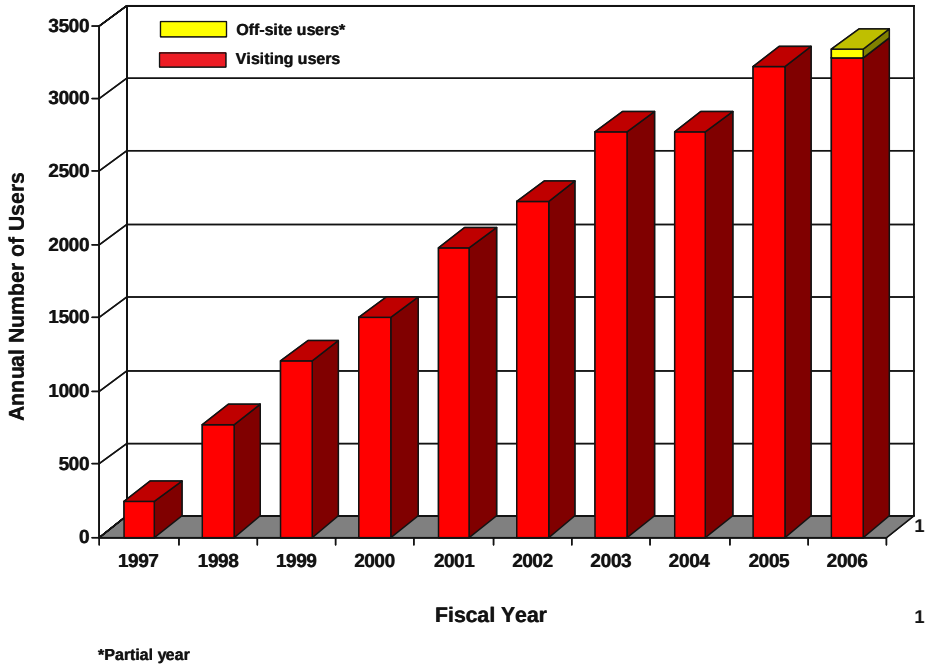
APS has 46 operating beamlines, 12 under construction, ~19 open



Key

- Current XOR sectors
- Transitioning to XOR
- Operated jointly (APS, CNM)

APS User History

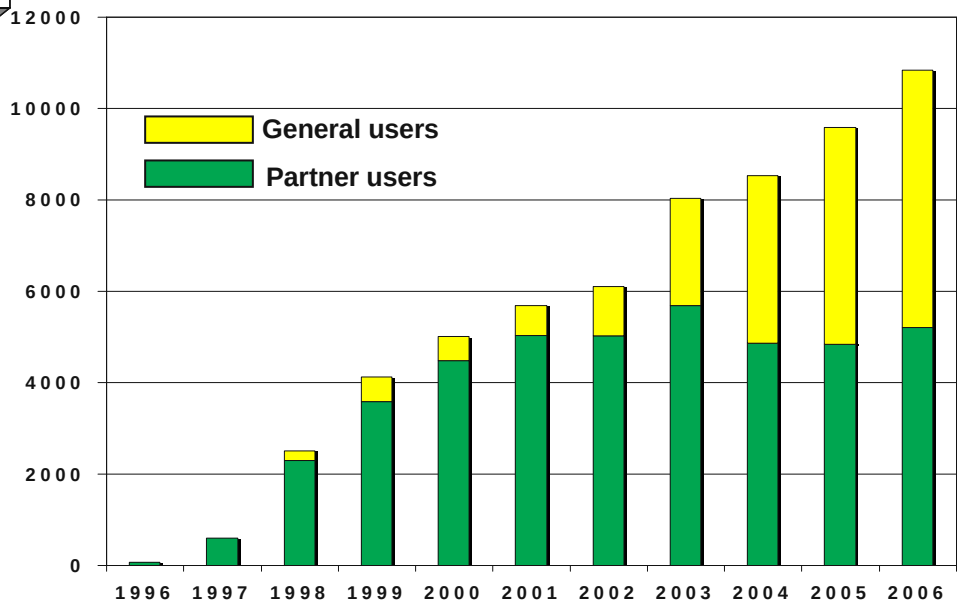


*Partial year

3274
visiting users
FY 2006

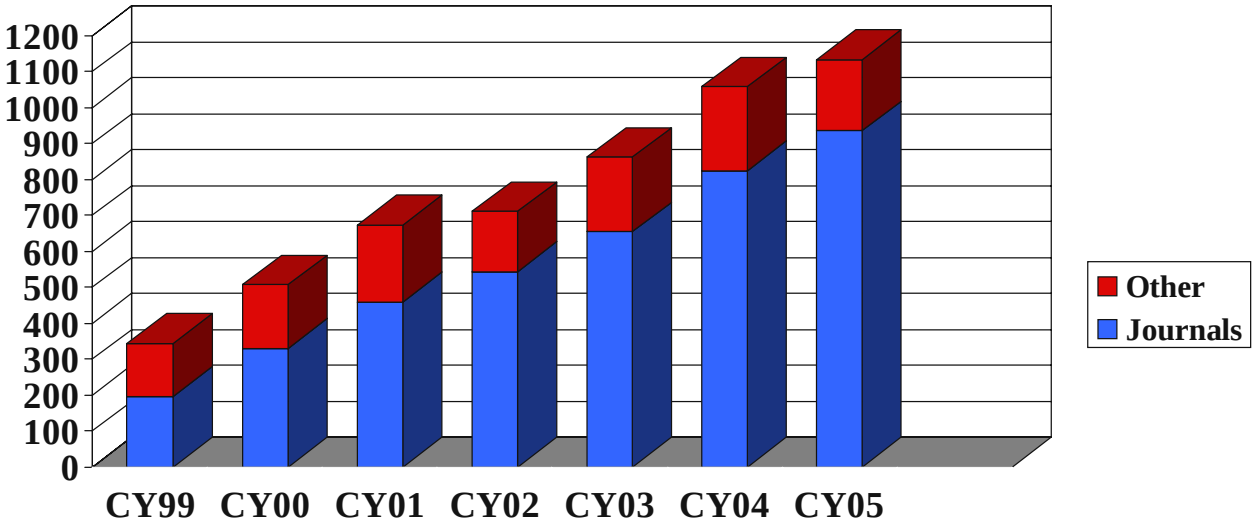
Unique annual users

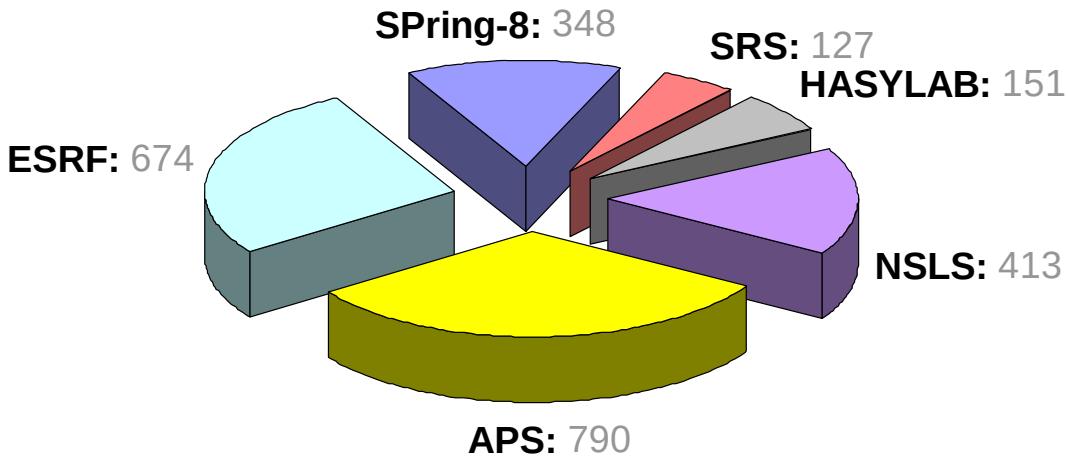
User visits by type



APS Publication Output

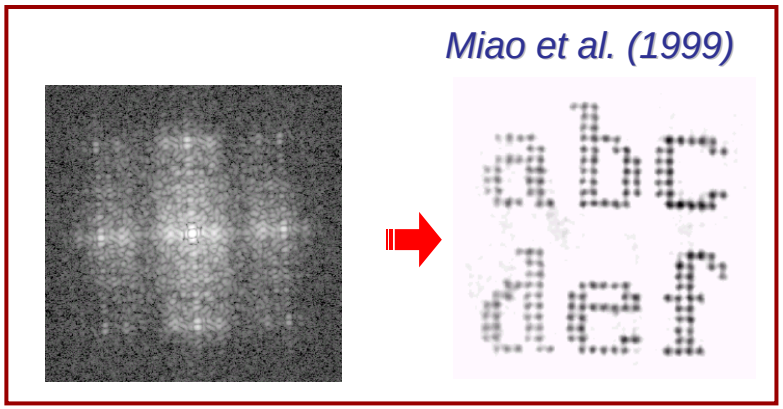
Refereed publications

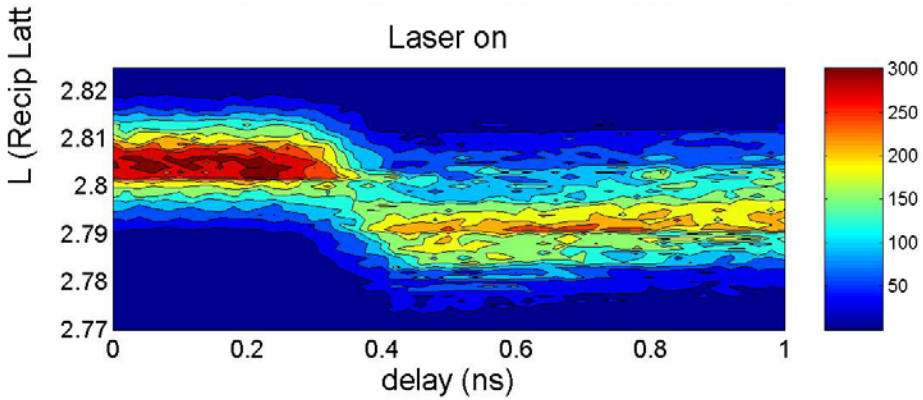




Protein Databank Deposits (2005)

User demand for x-ray imaging and ultra-fast science drives revolutionary reductions in emittance and pulse width





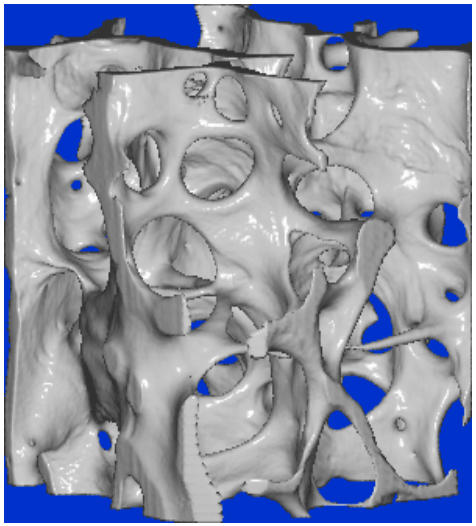
We seek much more than a factor of two improvement ….

Microtomography

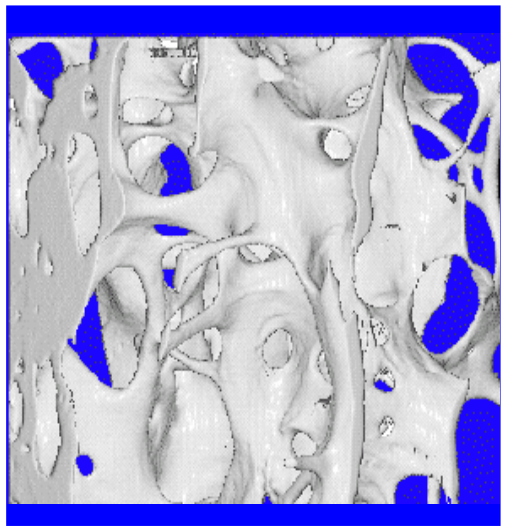
Osteoporosis disease

Human Vertebra Samples

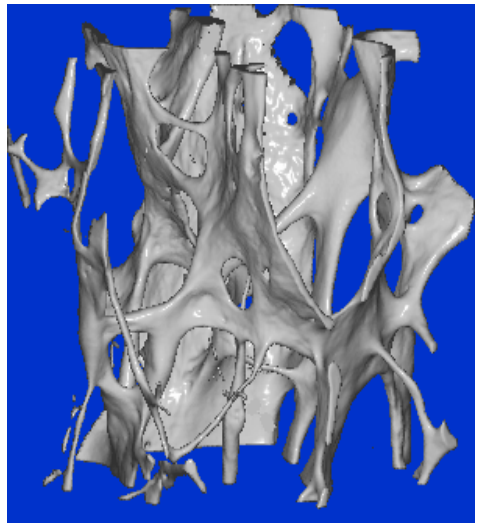
1mm



33 years



55 years



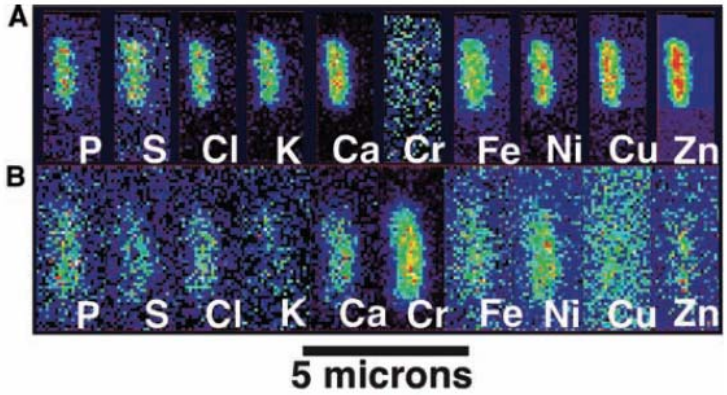
63 years

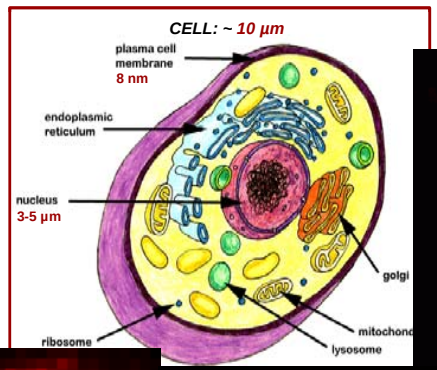
Images $(512)^3$, voxel size = 6.7 µm

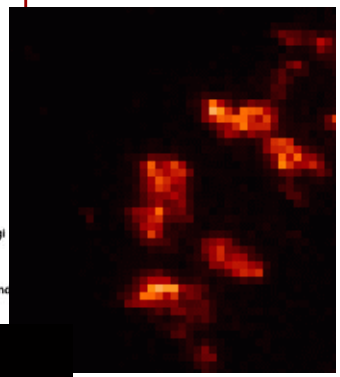
M. Salomé, F. Peyrin et al., Medical Physics 26 (1999) 2194-2204

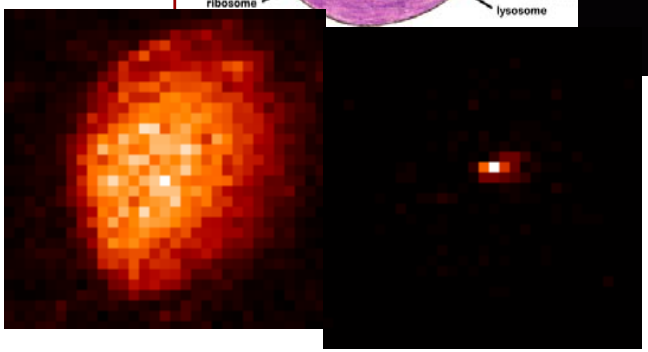
Nanoscale detection of metals

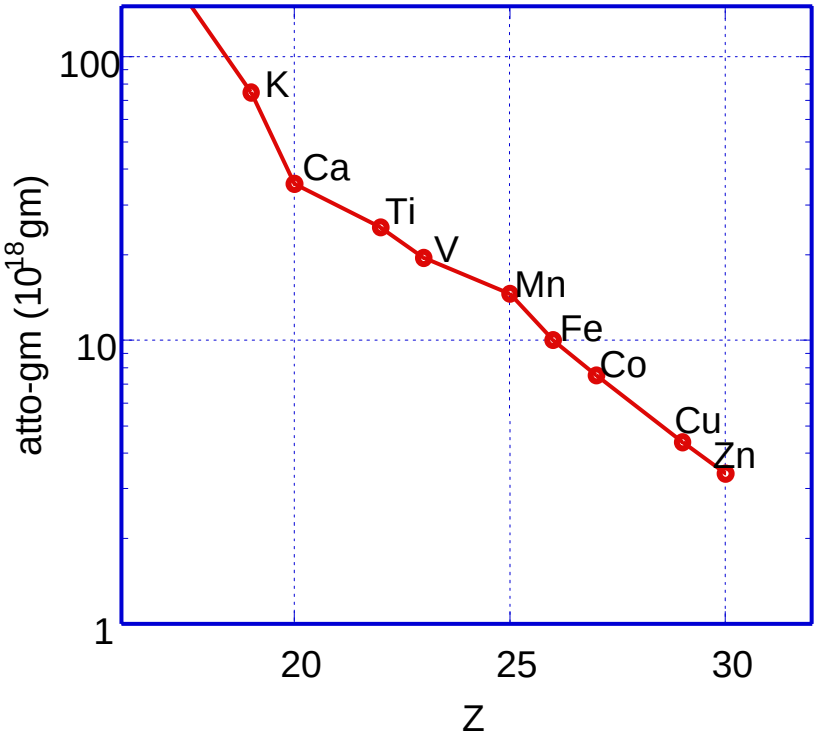
Cr contamination in cells (Kemner)

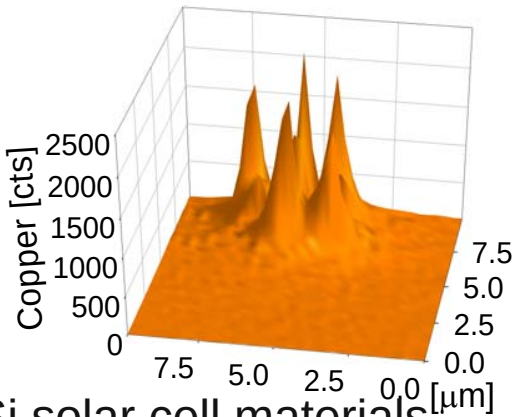










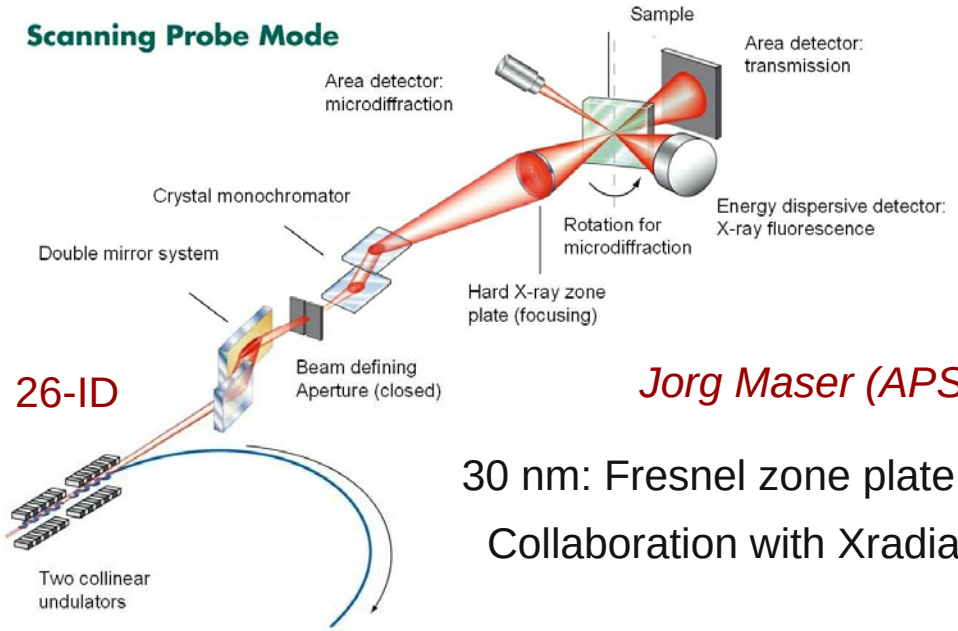


TiO2 labels at
the sub-cellular level
- Woloshak et. al.

Cu in Si solar cell materials

APS pushing the limits of nanobeam optics reduced beam emittance will help

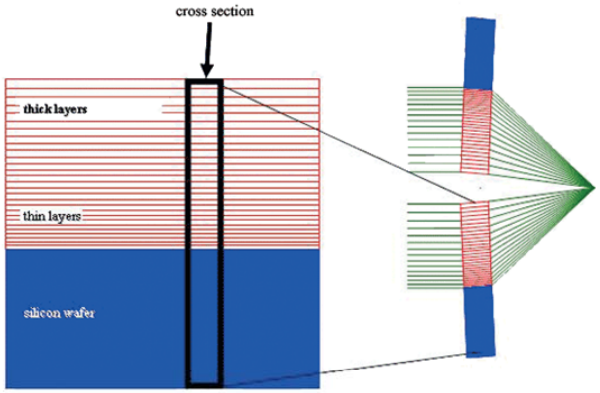
Nanoprobe: joint effort CNM and APS

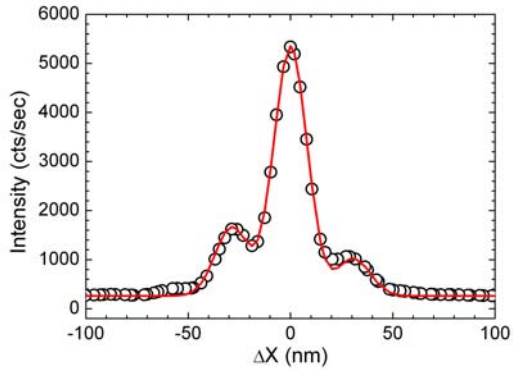


Jorg Maser (APS)

30 nm: Fresnel zone plate

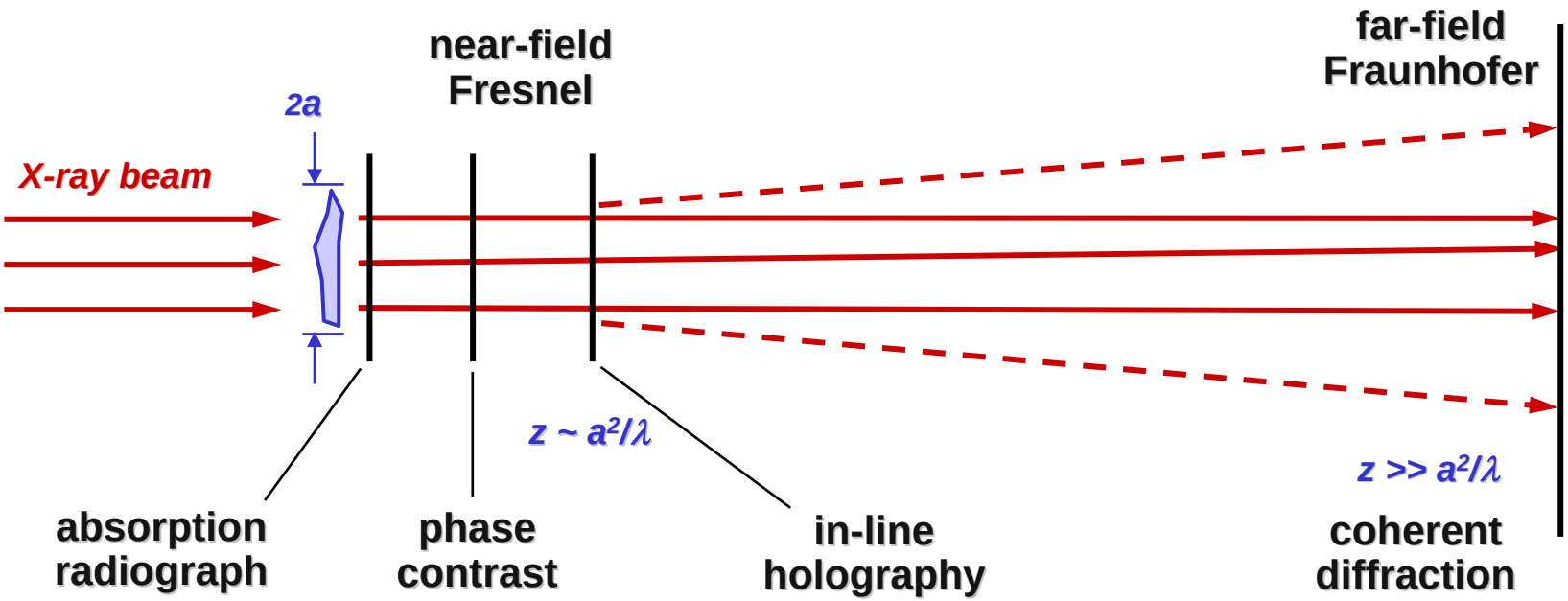
Collaboration with Xradia



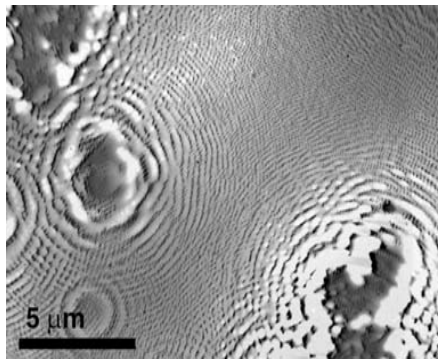


Multi-layer Laue lenses: approach to 1nm resolution

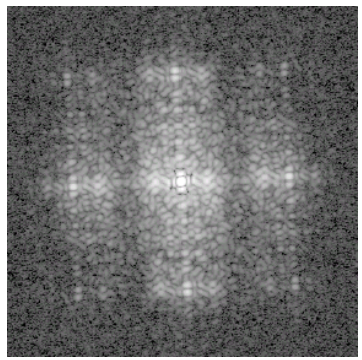
Full-field x-ray imaging demands improved coherence



Kagoshima et al.
JJAP (1999).



Jacobsen (2003).

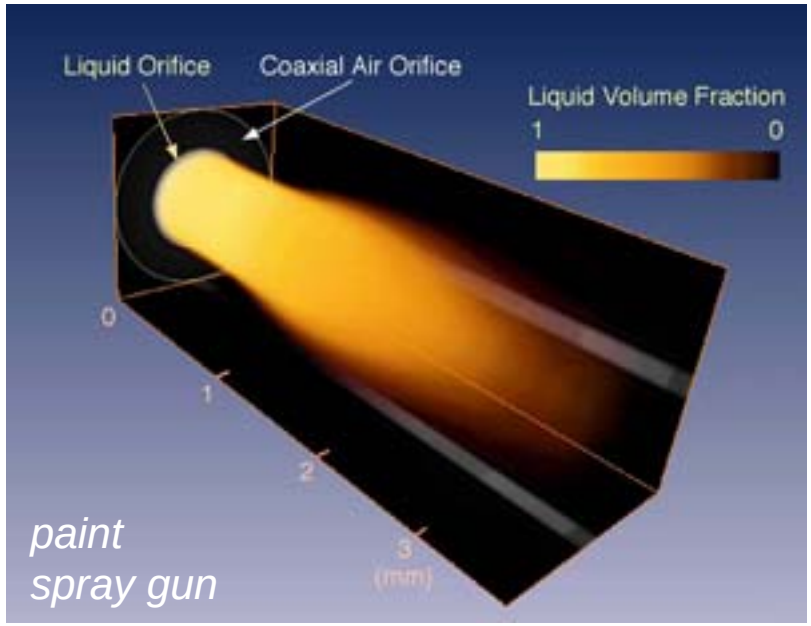


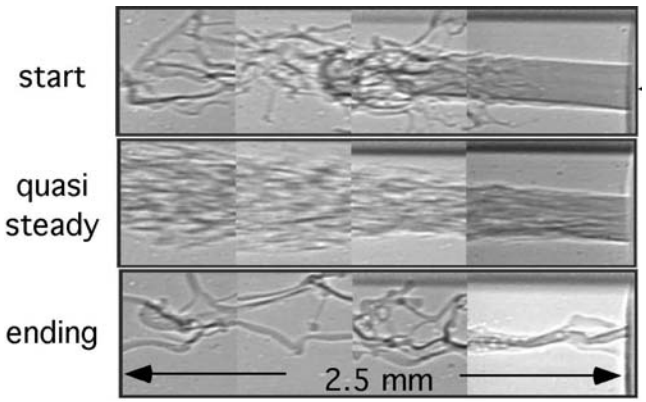
Miao et al.
Nature (1999).

High-speed Imaging of Fuel and Liquid Sprays

Y. J. Wang, Kyoung-Su Im, K. Fezzaa, W. K. Lee, J. Wang, P. Micheli, and C. Laub, "Quantitative x-ray phase-contrast imaging of air-assisted water sprays with high Weber numbers," Appl. Phys. Lett. **89**, 151913 (9 October 2006).

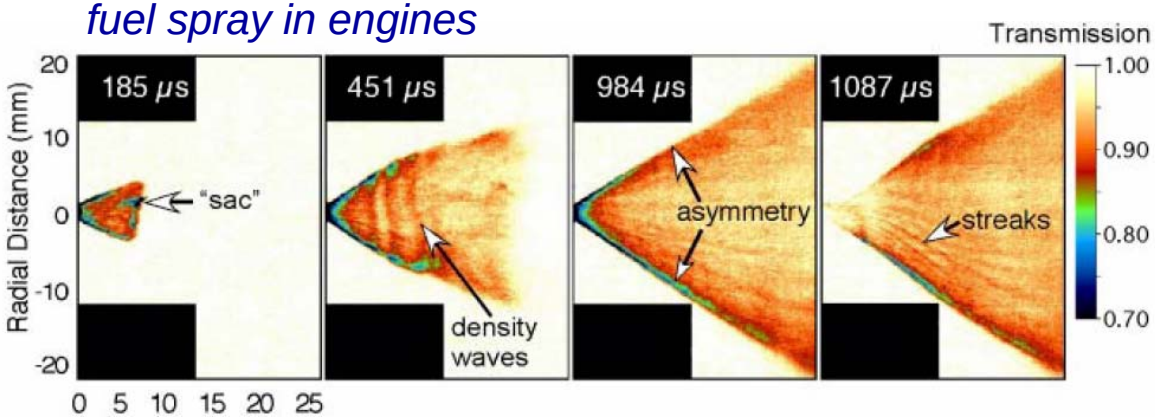
Right: Three-dimensional rendering of the air-assisted coaxial spray in the near-nozzle region of an industrial paint spray gun (Illinois Tool Works, Inc.) with an air pressure of 137kPa. The false color intensity represents the liquid volume fraction, which was quantified for the first time with the x-ray phase-contrast imaging. (Courtesy of Francesco De Carlo of the APS.)





X-ray flash imaging at 300ns !!

fuel spray in engines

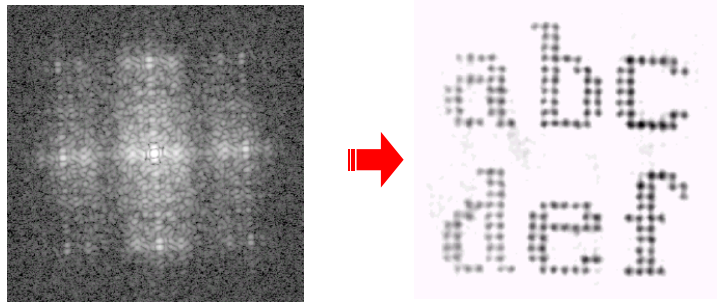


Phase Sensitive Imaging

Well suited to hard x-rays due to lower absorption

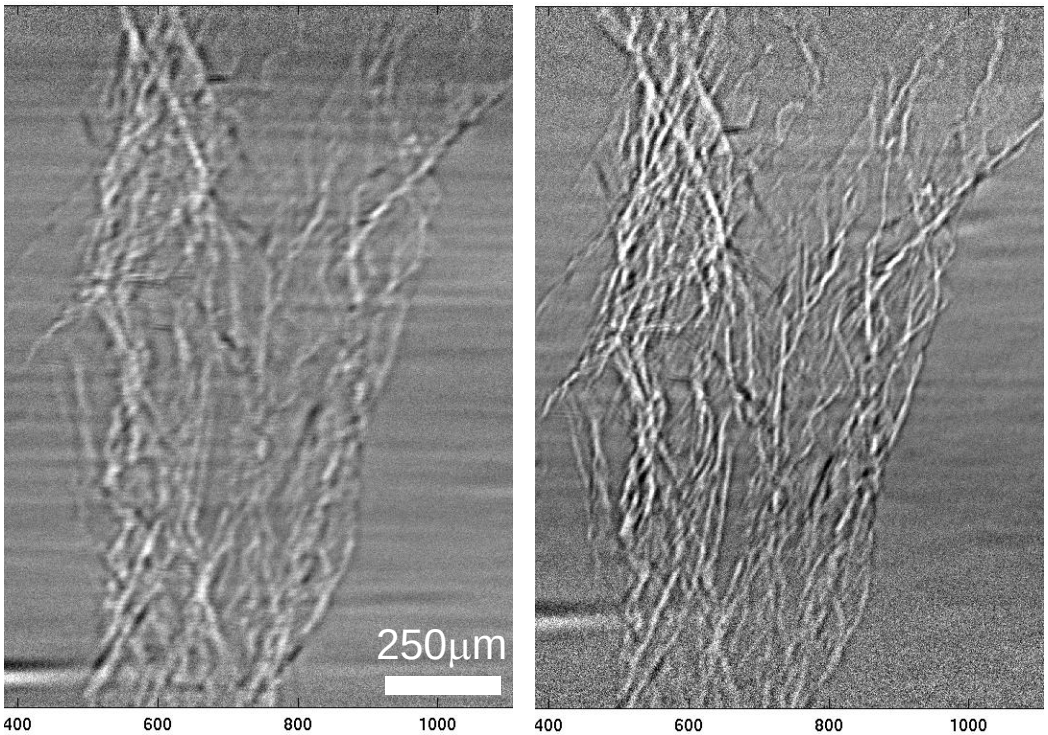
Higher coherence improves signal to noise

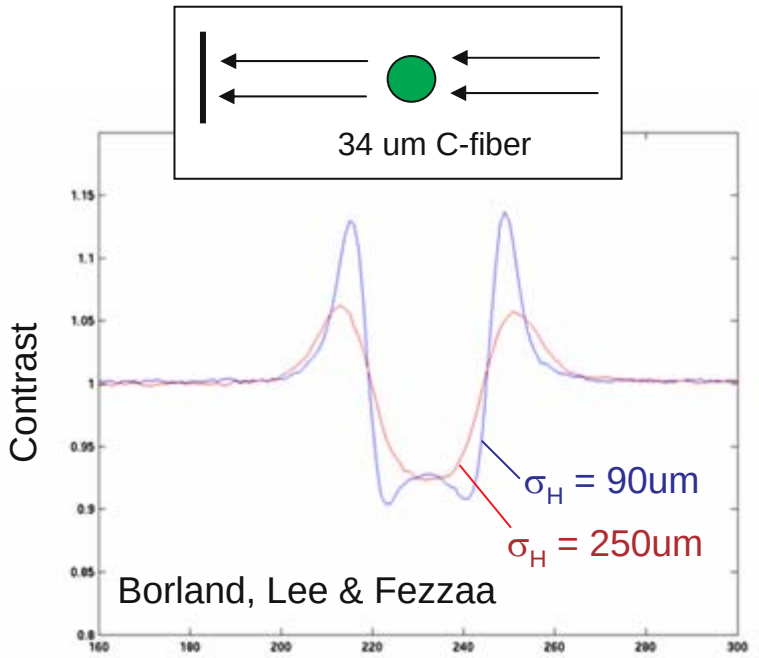
Miao et al. (1999)



Phase-contrast imaging improved with reduced horizontal beam size

- ***Small round source size of the APS/ERL would greatly enhance observable phase contrasts for weak density differences***



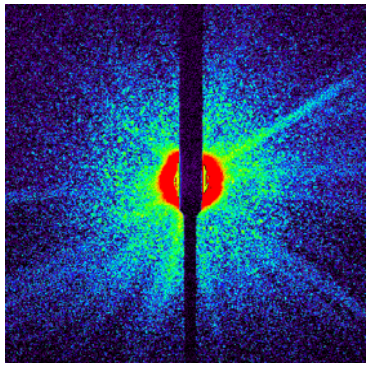


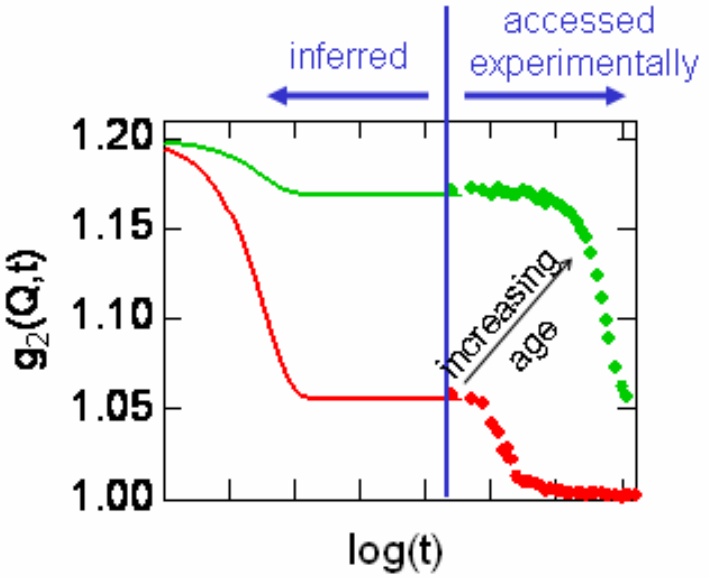
Effect of reduced beta function at APS sector 32

← Stress cracks in Aluminum t = 3 mm, 30 keV, D = 1m

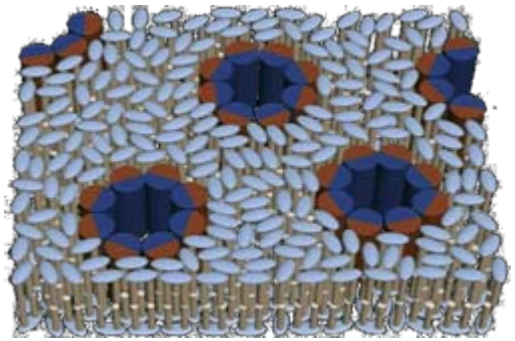
X-Ray Photon Correlation Spectroscopy feeds from coherence

- measures dynamics on short length scales – demands coherent flux
  - XPCS accessible time scales increase with the square of increases in the source brilliance
  - Could reach 1 microsecond with ERL

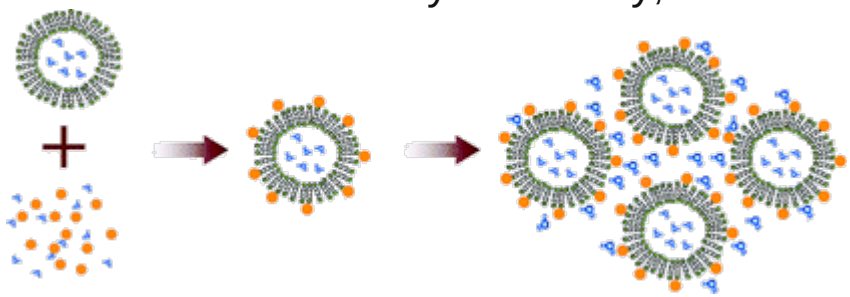




Materials ageing:
Courtesy B. Leheny, JHU



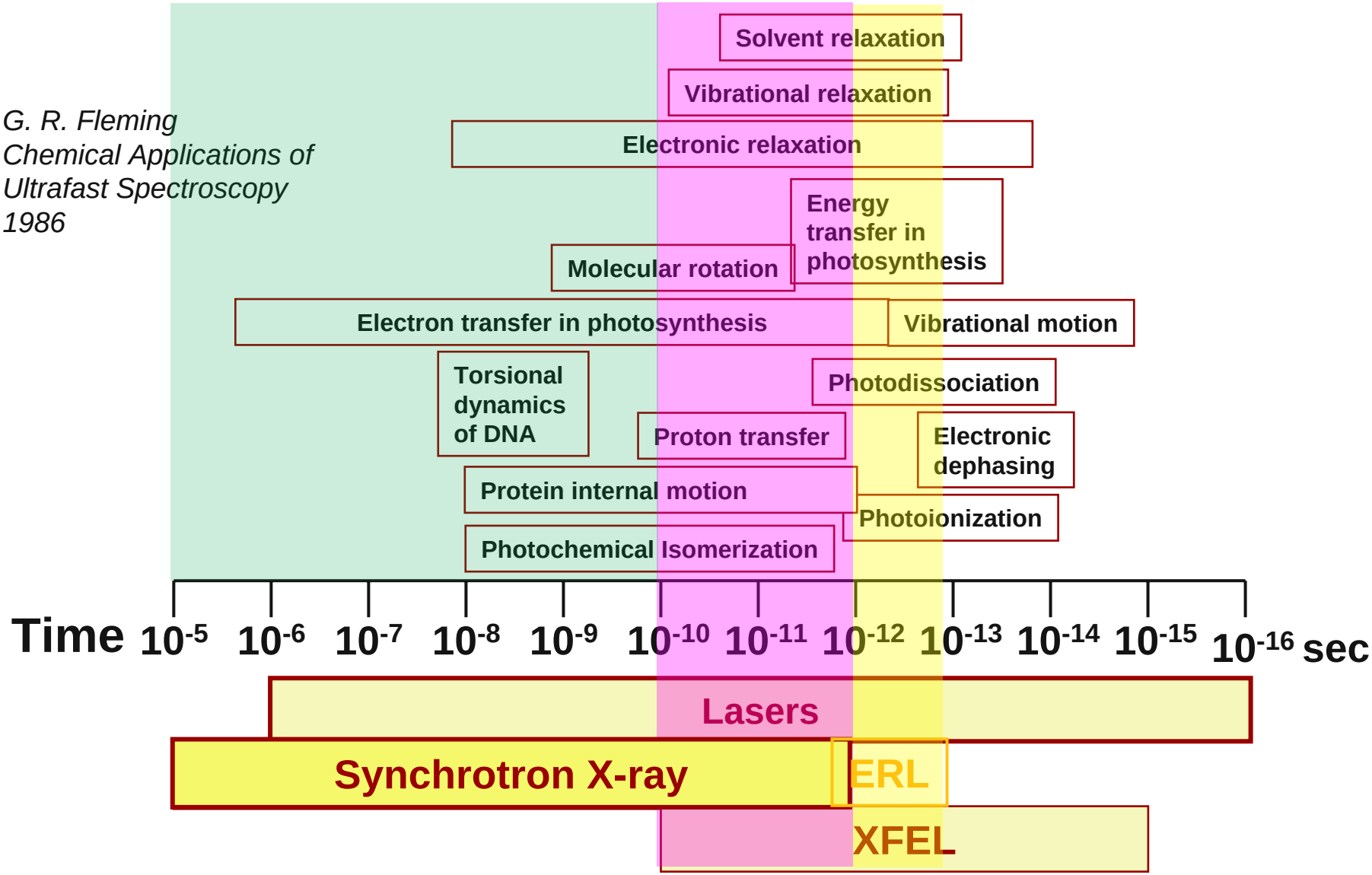
Membrane dynamics



Nanoparticles at interfaces
[L. Zhang and S. Granick, Nano Lett. **6**, 694 (2006)]

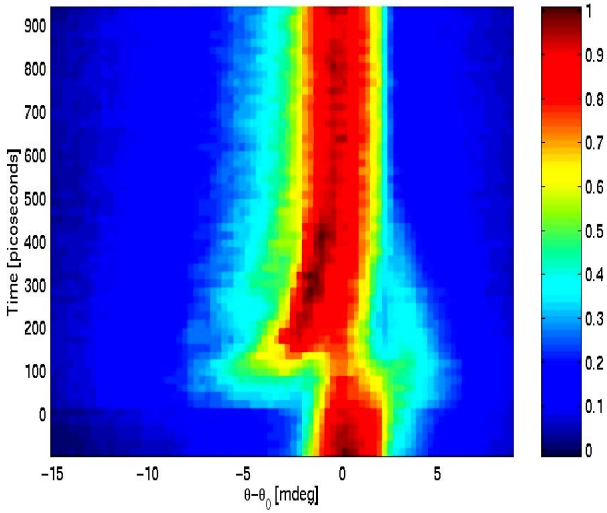
Ultrafast science - chemical processes

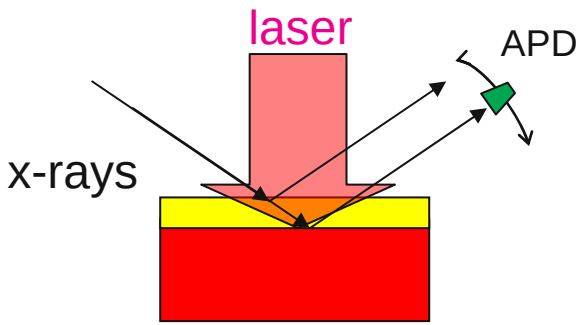
G. R. Fleming
Chemical Applications of
Ultrafast Spectroscopy
1986

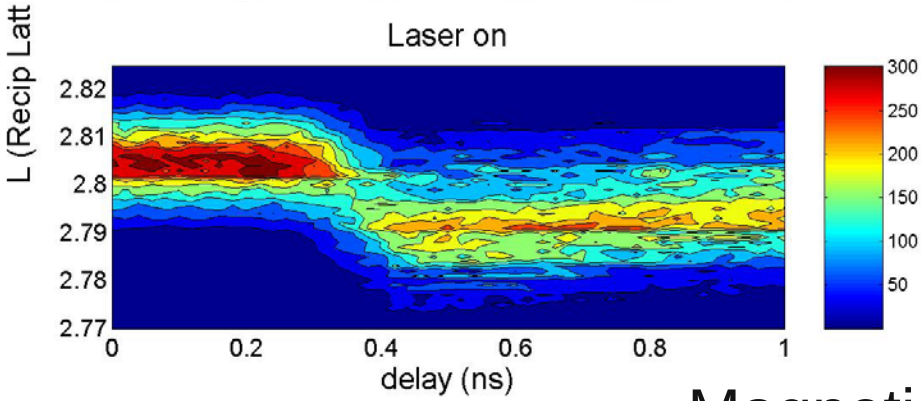


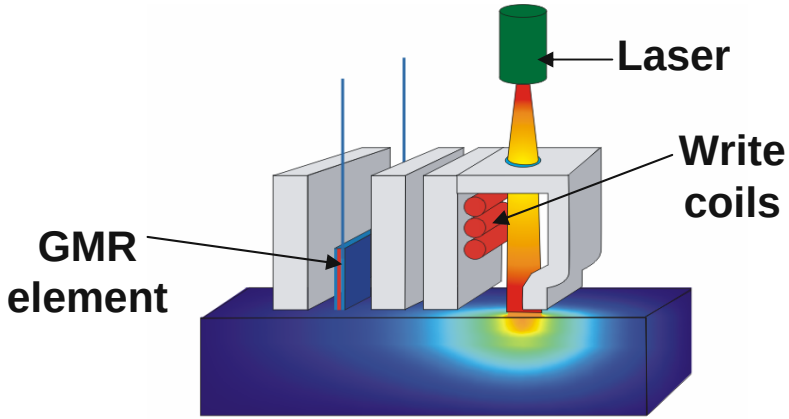
Condensed Matter – 100 ps and above

Shock wave in In Sb

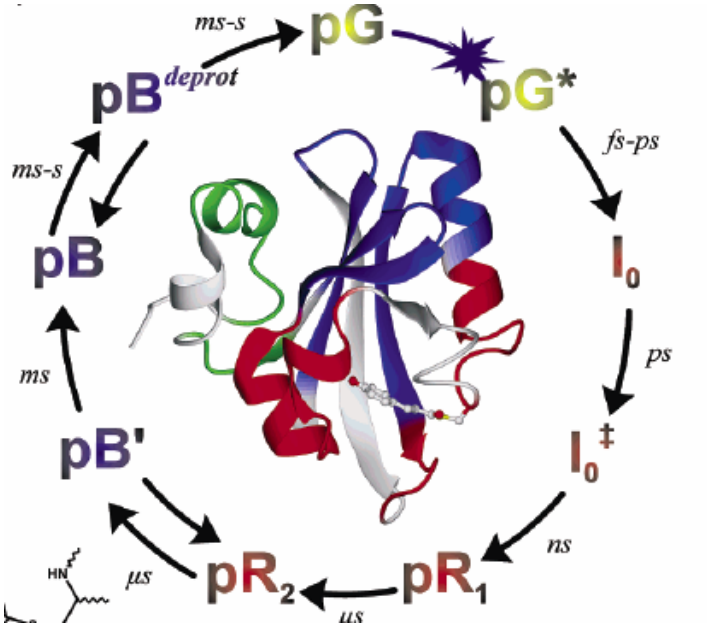






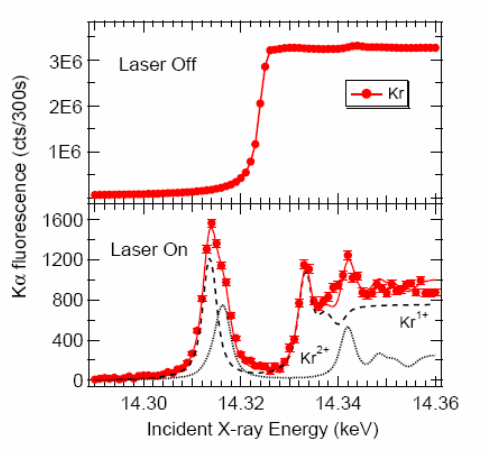


Magnetic Phase transition in FeRh

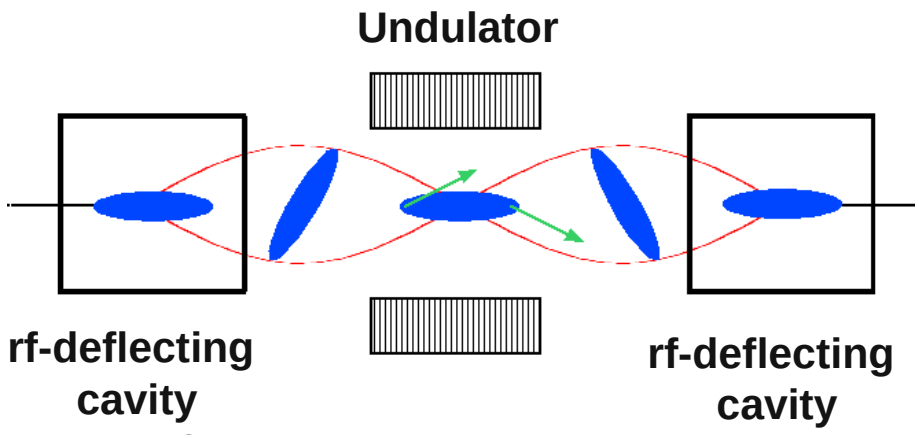


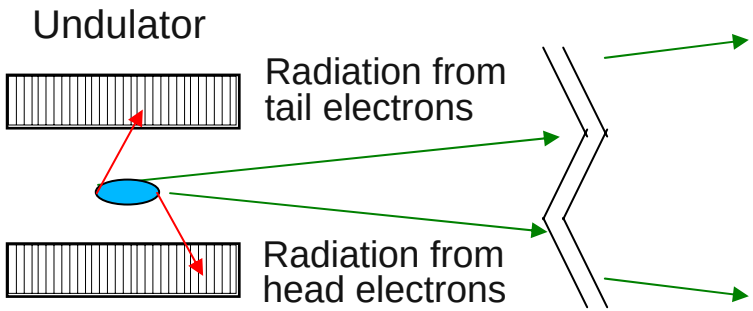
Biology - Structural study of *Photoactive Yellow Protein* on sub-ns timescale (Moffat et al.)

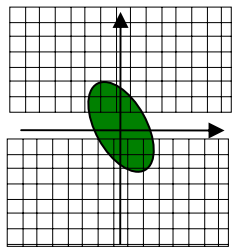
Ionized atoms in ultra-high laser fields – x-ray spectroscopy in atomic physics seeks shorter timescales, higher fields (Young et. al.)



Synchrotron-based rf-deflection source: 1-ps, 10^6/pulse







Slits can be used to clip out a short pulse. Can also use asymmetric cut crystal to compress the pulse.

Concept: A. Zholents, P. Heimann, M. Zolotorev, J. Byrd, NIM **A425** (1999).

Simulation for APS: M. Borland, Physical review special topics - accelerators and beams **8**, 074001 (2005)

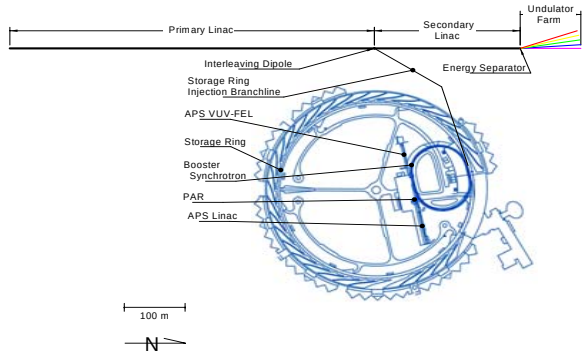
APS Upgrade is on the DOE Office of Science roadmap

U.S. Department of Energy

	Priority	Program	Facility
Near-Term	1	FES	ITER
	2	ASCR	UltraScale Scientific Computing Capability
	Tie for 3	HEP	Joint Dark Energy Mission
		BES	Linac Coherent Light Source
		BER	Protein Production and Tags
		NP	Rare Isotope Accelerator
	Tie for 7	BER	Characterization and Imaging
		NP	CEBAF Upgrade
		ASCR	ESnet Upgrade
		ASCR	NERSC Upgrade
		BES	Transmission Electron Achromatic Microscope
Mid-Term	12	HEP	BTeV
	13	HEP	Linear Collider
	Tie for 14	BER	Analysis and Modeling of Cellular Systems
		BES	SNS 2-4 MW Upgrade
		BES	SNS Second Target Station
		BER	Whole Proteome Analysis
	Tie for 18	NP/HEP	Double Beta Decay Underground Detector
		FES	Next-Step Spherical Torus
		NP	RHIC II
Far-Term	Tie for 21	BES	National Synchrotron Light Source Upgrade
		HEP	Super Neutrino Beam
	Tie for 23	BES	Advanced Light Source Upgrade
		BES	Advanced Photon Source Upgrade
		NP	eRHIC
		FES	Fusion Energy Contingency
		BES	HFIR Second Cold Source and Guide Hall
		FES	Integrated Beam Experiment

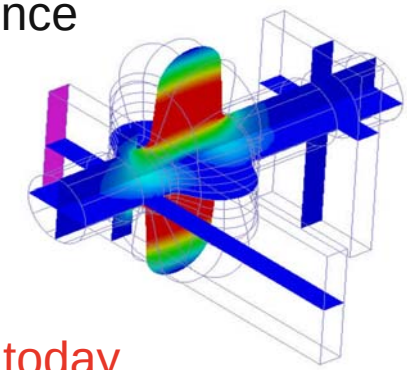
Facilities for the Future of Science available from http://www.science.doe.gov/Sub/Facilities_for_future/20-Year-Outlook-screen.pdf

Proposed several phases including a "LINAC-augmented light-source"

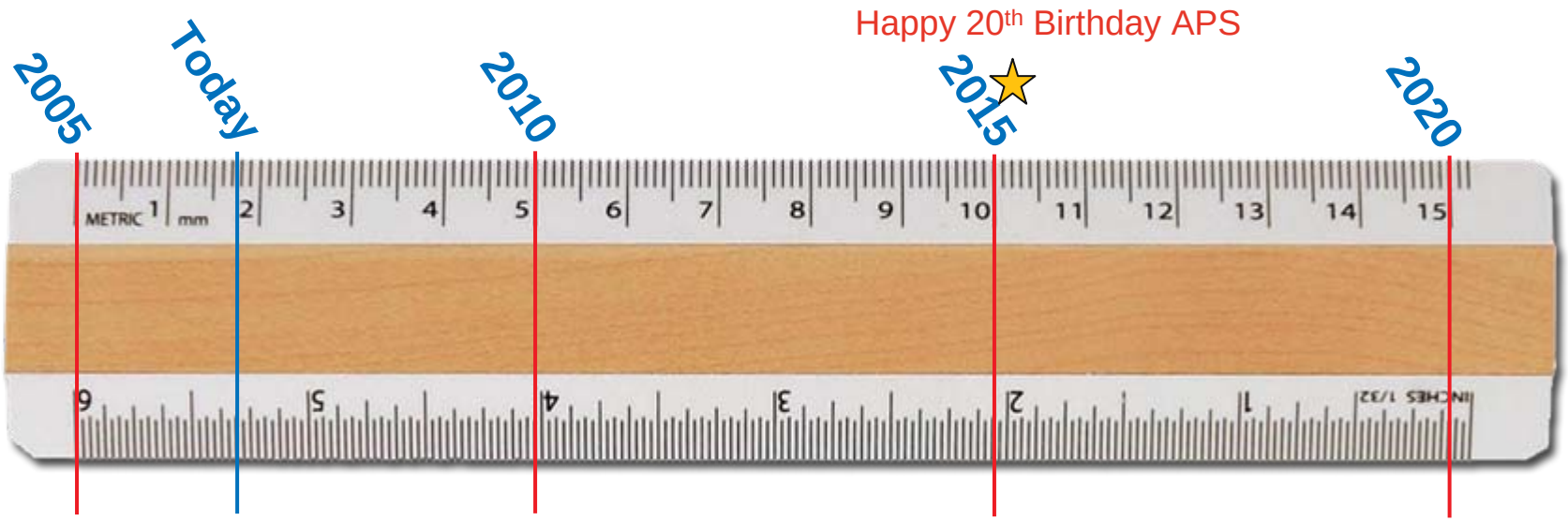


APS scientific strategy

- Develop beamlines, reconstructing old and building new, driven by user science needs
  - Improve detectors, optics and software
- Develop and optimize insertion devices for science impact
- Provide innovative short term machine imporvements for science
  - Picosecond pulse compression
  - Long straight sections….
- Seek revolutionary new capabilities through a major upgrade
  - Which will **revolutionize** the science
  - Which will **minimally disrupt** the users who rely on APS today
- Encouraged by DOE we are examining options
  - User input through strategic planning and workshops
  - Need to validate and narrow machine options
  - Will couple machine choice with instrument and software/theory developments
  - Aiming to submit a proposal in 2007



When an upgrade?



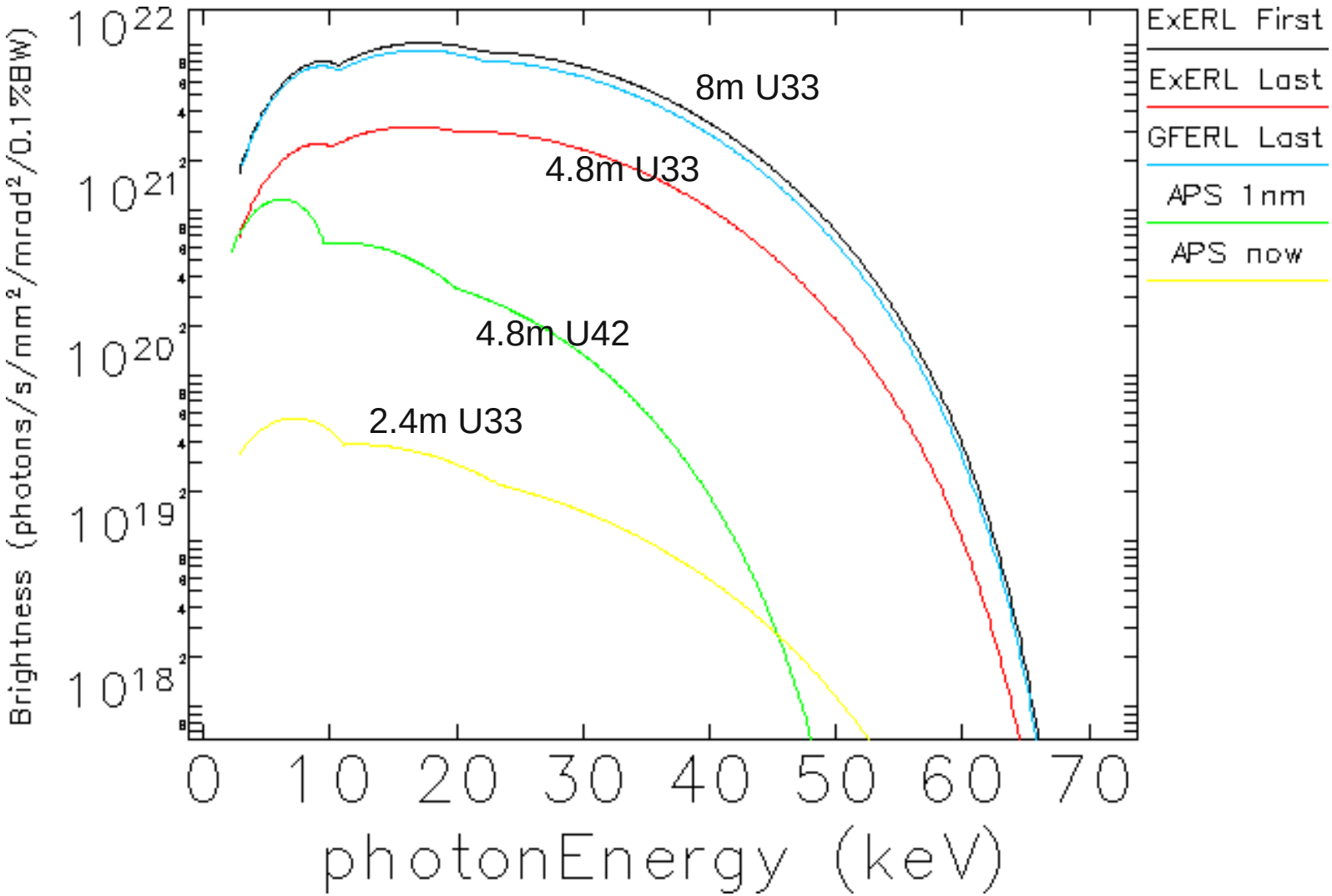
5-6 Year Construction Project

- For construction funding in FY09, need CD-1 in Summer 2008; CD-0 ("mission need") by Fall 2007
  - Scientific and technical proposals to be reviewed Summer 2007
    - *"white paper" on technical design to be submitted February 2007*

We have identified two machine approaches to reduce the emittance and shorten the pulse

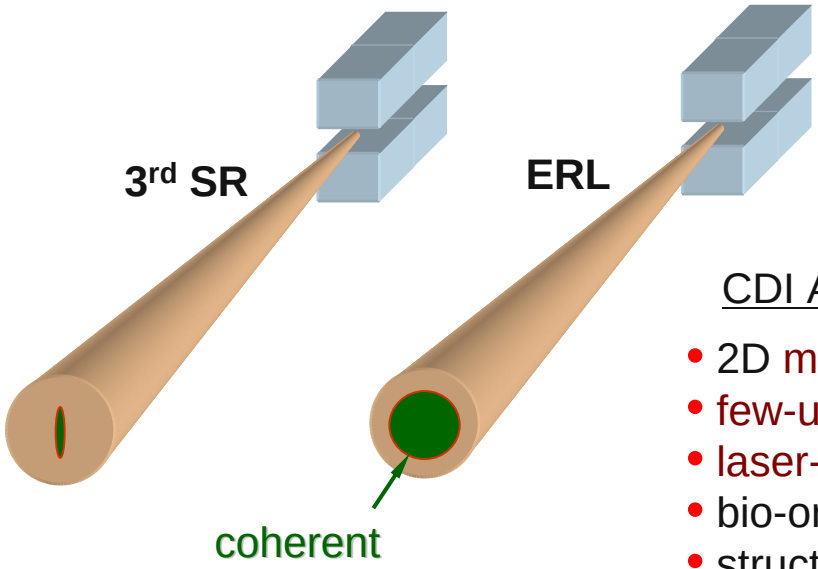
- Energy-recovery LINAC
  - 2-3 orders of magnitude reduction in emittance, almost fully coherent flux, intrinsically short pulses
- Storage ring lattice upgrade
  - Lower emittance
  - Higher Current
  - Longer straights
    - *Together can increase brightness*

ERL@APS is as good as a "Greenfield" ERL (GFERL), at least for the first beamlines!



Device choices and plot after R. Dejus.

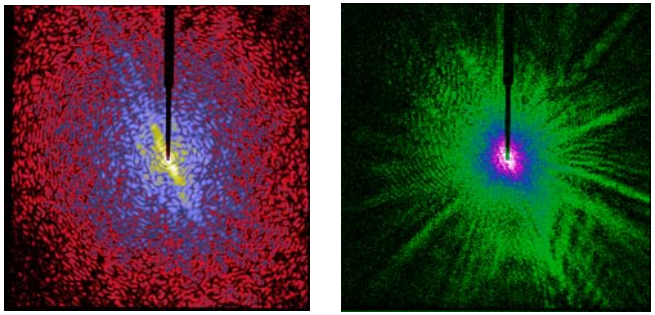
ERL: Ideal Source for Coherent Diffraction Imaging !



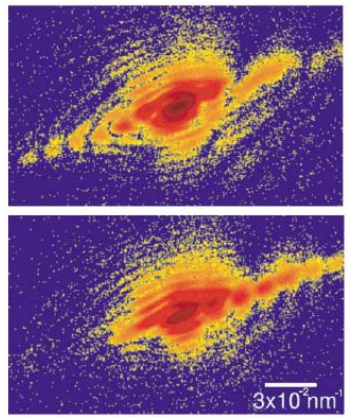
Shen, Hao, Gruner,
Physics Today
(March 2006)

CDI Applications:

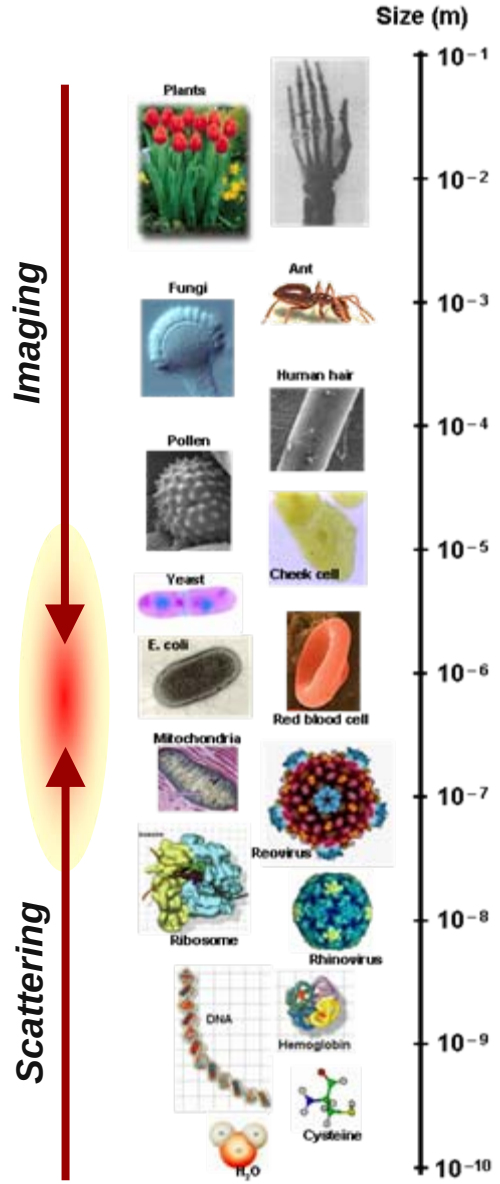
- 2D membrane protein crystals
- few-unit-cell crystals
- laser-oriented macromolecules
- bio-organic-inorganic hybrids
- structure & strain in nanoparticles
- biological cells



Miao – actin filaments, 2-ID-B



Robinson –
Au particles
34-ID-C



My take on the upgrade options

- The APS 1nm lattice is attractive, but not revolutionary and has a ~ 1 year dark time
- The ERL option offers revolutionary capabilities
  - Performance of ERL@APS is quite good compared to Greenfield option
  - Capabilities of ERL beams in terms of imaging, micro-focussing and short pulses are desired by a large number of users
    - *Flux remains at the current level*
  - There is much R&D involved, but commissioning time can be long
  - Disruption for users is much less than for storage ring upgrade option

But your are here to provide your own expert opinion once you have heard all the details….

Partnerships and the ANL Accelerator Institute

- We will seek collaboration on the APS upgrade
- Accelerator technology is critical to other current and future facilities at Argonne, e.g. ATLAS and RIA
- Argonne and Fermi will team to secure the International Linear Collider project in Illinois
- Argonne has set up an Accelerator Institute to fertilize accelerator research with external partners
  - Director, **Rod Gerig**
  - Chief Scientist, **Kwang-Je Kim**
- This includes a component on *detectors*, critically important to many of Argonne's facilities

Charge to Committee and Next Steps

- We seek your input on our proposed options, from a machine viewpoint
  - Have we realistically described the performance of each?
  - Have we recognized the challenges, including R&D and user disruption
  - Which options, if any, offer sufficiently revolutionary performance without major disruption to the existing user base?
  - Have we missed other reasonable upgrade options?

- Following your advice, we hope to narrow down the choices, work with the user community and develop a scientifically-driven proposal for submission next summer
  - Will include accelerator upgrade with relevant x-ray instrumentation developments

- We hope to seek your advice in future as we develop a firmer proposal, with schedule and resource estimates (likely in 2008)