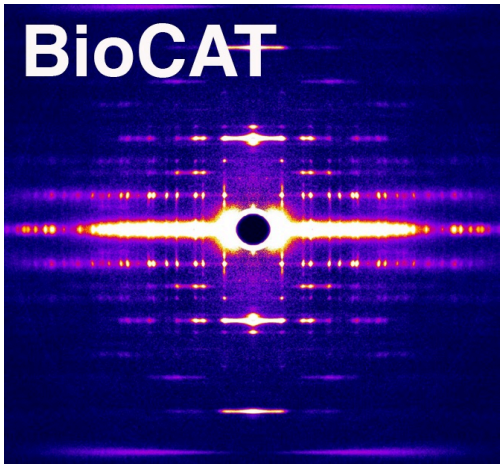
The BioCAT Facility and APS-U



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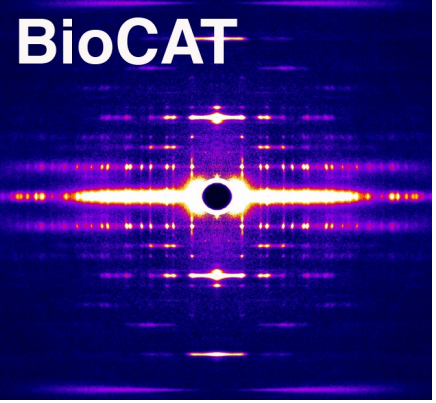
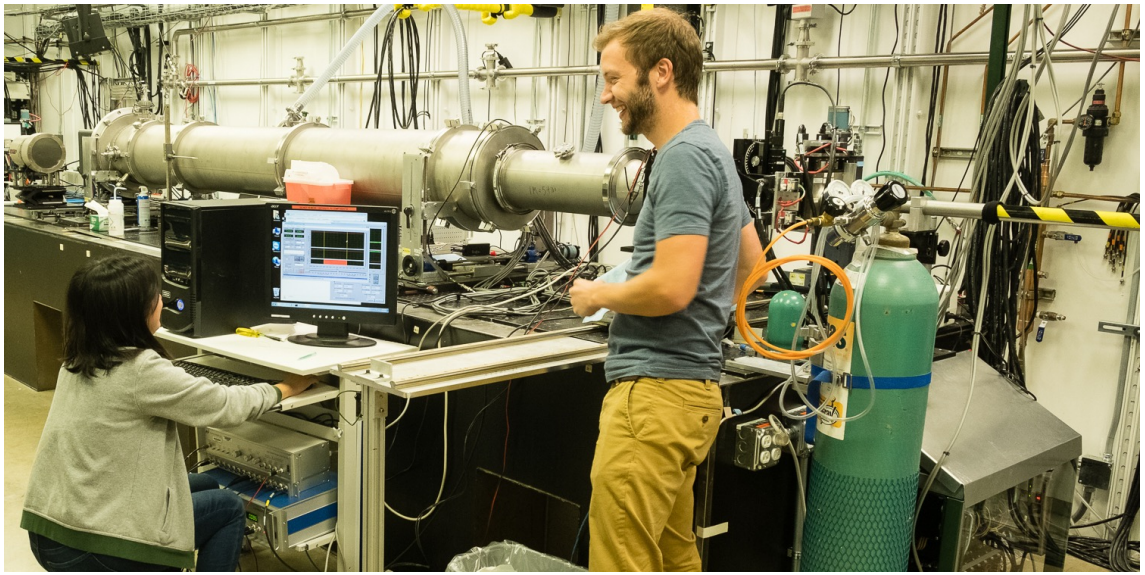
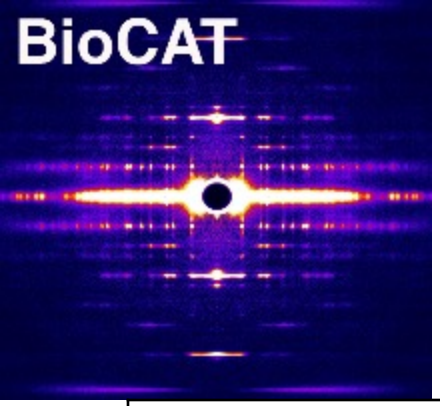
The Advanced Photon Source



What is BioCAT?

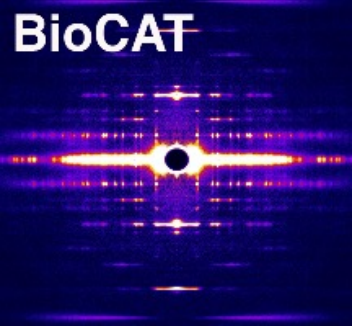


- BioCAT operates beamline 18-ID at the APS providing scientific staff support, wet laboratory and computational facilities
- Operating budget ~ $1.1M/year, 3 scientific staff, 1 software engineer, 2 technical staff, 1 administrative
- Facility owned and operated by the Illinois Institute of Technology under a P41 Biotechnology Research Resource grant from NIH since 1995, (P30 mechanism since 2021)
- No formal affiliation with ANL
- Part of the CSRRI and Pritzker Institute at IIT



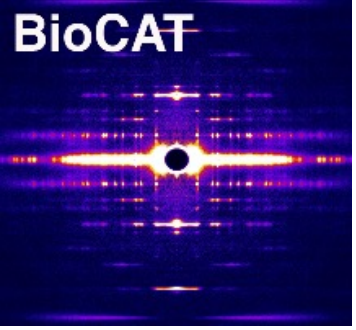
Scientific Mission of BioCAT

Modality		Sample Applications
Fiber diffraction	Muscle Diffraction	Muscle regulation, heart disease, muscular dystrophy, other skeletal muscle diseases
	Fiber Crystallography	Neurodegenerative disease, arthritis, connective tissue
	Fiber Diffraction Imaging	Neurodegenerative disease, arthritis, cancer metastasis, traumatic brain injury, connective tissue diseases
SAXS	Equilibrium SAXS	Structure of Macromolecules: complexes, protein-ligand interactions, flexible and intrinsically disordered proteins
	Time Resolved SAXS	Kinetics, protein and RNA folding, enzymatic reactions



BioCAT's Unique Role

- The only muscle diffraction program in the US
  - Only 2 other beamlines world-wide
- The most advanced facility for equilibrium SAXS in the US
- Strongest and most evolved time-resolved (micro-seconds – seconds) SAXS program worldwide



APS-U

- The APS is now nearly 30 years old and badly needs a refit
- Plan is to build an entirely new accelerator and storage ring ("APS-U") - $815 million upgrade
- New accelerator design (multi-bend acromat) will reduce electron beam emittance (source size x divergence) by a factor of 70 (primarily in the horizontal direction) from its present value
- Will double stored beam current (100-200 mA)
- ~ double flux

APS-U will have much smaller beam sizes than the APS

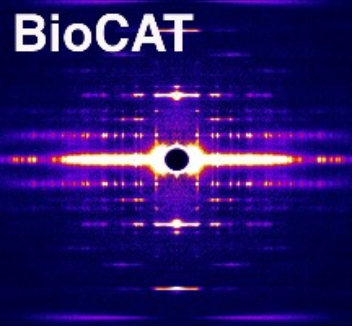
Table 1.1. APS Upgrade Performance Parameters

	APS-U Timing Mode	APS-U Brightness Mode	APS Now	Units
Electron Beam Energy	6	6	7	GeV
Electron Beam Current	200	200	100	mA
Number of Bunches	48	324	24	
Effective Emittance	32	42	3113	pm
Emittance Ratio	1.0	0.1	0.013	
Horizontal Beam Size (rms)	12.9	14.7	280	μm
Horizontal Divergence (rms)	2.5	2.8	11.6	μrad
Vertical Beam Size (rms)	8.8	3.2	10.0	μm
Vertical Divergence (rms)	3.7	1.3	3.4	μrad
Stability of Beam Position/Angle	<10%	<10%	<10%	
Brightness - 20 keV(**)	154	325	0.6	10^{20} [a]
Pinhole Flux - 20 keV(**)	186	217	20.1	10^{13} [b]
Coherent Flux - 20 keV(**)	148	312	0.6	10^{11} ph/s
Single Bunch brightness – 20 keV	321	100	2.6	10^{18} [a]

[a] photons/sec/0.1%BW/mm^2 /mrad^2

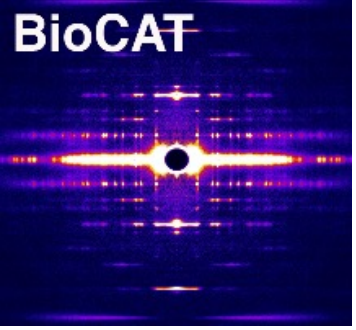
[b] photons/sec/0.1%BW in 0.5mm *times* 0.5mm pinhole @ 30 m

** Nominal energy based on choice of insertion device. Maximum value for an ID optimized for 20keV



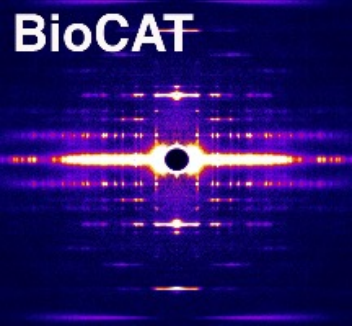
What this means for BioCAT 18ID

- Main benefit for us is the much smaller source size.
- Vertical size and divergence 1/3 of what it is now (brightness mode) about the same in timing mode
- Horizontal size ~ ~ 1/20 what it is now. Divergence about ¼ of what it is now.
- Current beamline focal spots ~ 30 x 140 μm => ~ 10 x 10 μm (theoretically)



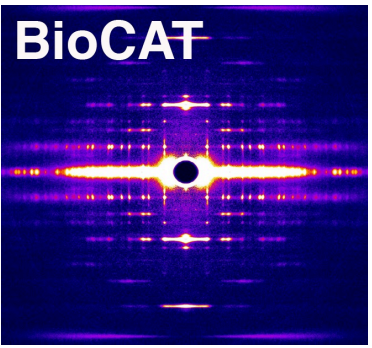
What this means for BioCAT 18ID

- 100 x increase in flux densities
- => Improved signal to noise in all experiments
- More intensity for better time resolved experiments
- Symmetrical beams will give higher quality X-ray fiber diffraction patterns
- Ability to do time-resolved micro-fluidic SAXS with main beamline optics – experiments easier to do

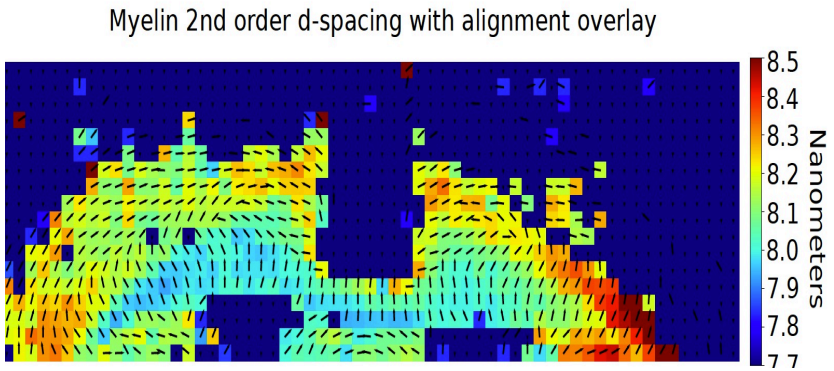


Much smaller beams for micro-beam diffraction and scattering

- Collect all available beam with compound refractive lenses
- With 1.8 m CRL
- 4 x 24 μm => < 2 x 2 μm for time resolved SAXS and micro-diffraction
- With 50 cm CRL
- < 0.5 x 0.5 μm for micro-diffraction

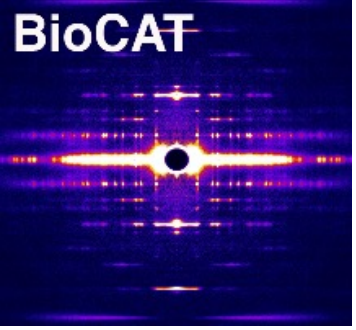


Diffraction Imaging



Angle and intensity map of myelin in rat brain. Allows visualization of local orientation and amount of diffracting material

- A micron-sized beam can be scanned across a tissue sample to see how fibrous molecules are arranged



Impact of APS-U on BioCAT user program

- The APS plans to shut down on April 17, 2023 and restart operations at the beginning of April, 2024.
- No user access to the APS for this “Dark Period”
- BioCAT staff will use this period to do refurbishments and improvements to Beamline 18ID
- Rest of today’s meeting:
  - Benefits of APS-U and planned improvements for muscle/fiber diffraction experiments- Weikang Ma
  - Benefits APS-U and planned improvements for SAXS experiments - Jesse Hopkins
  - How we plan to continue to serve the BioCAT user community during the dark period – Tom Irving