Welcome to Brookhaven Lab

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Director, NSLS-II
Deputy Associate Lab Director for Energy and Photon Sciences

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Where are we?

300 miles apart (5.5 hrs drive)

Brookhaven Lab

Details

- One of 17 U.S. Department of Energy national laboratories
- The Northeast's only multi-program DOE Office of Science lab
- Fundamental research to commercialization: nuclear and high energy physics, energy S&T, bio and environmental sciences, data science , and national security

Numbers

- Employees: 2,550
- Visitors and Users: 5,000 per year
- Grad/Undergrad students on payroll: 400
- Total funding for FY 2018: $657 million
  - $517 million from the U.S. Department of Energy
  - $65 million from other agencies

Doon Gibbs
BSA President,
Brookhaven Lab
Director

Robert Tribble
Deputy Director
For Science &
Technology

Jack Anderson,
Deputy Director
For Operations

Discovery and Innovation, Serving the Nation

Nobel Prizes in Physics and Chemistry


1957


1976


1980


1988


2002

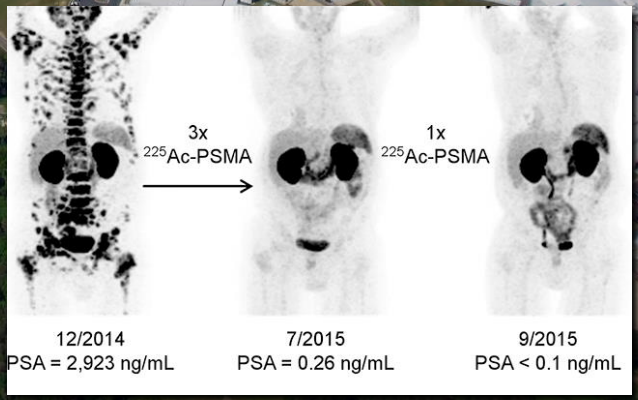

2003


2009

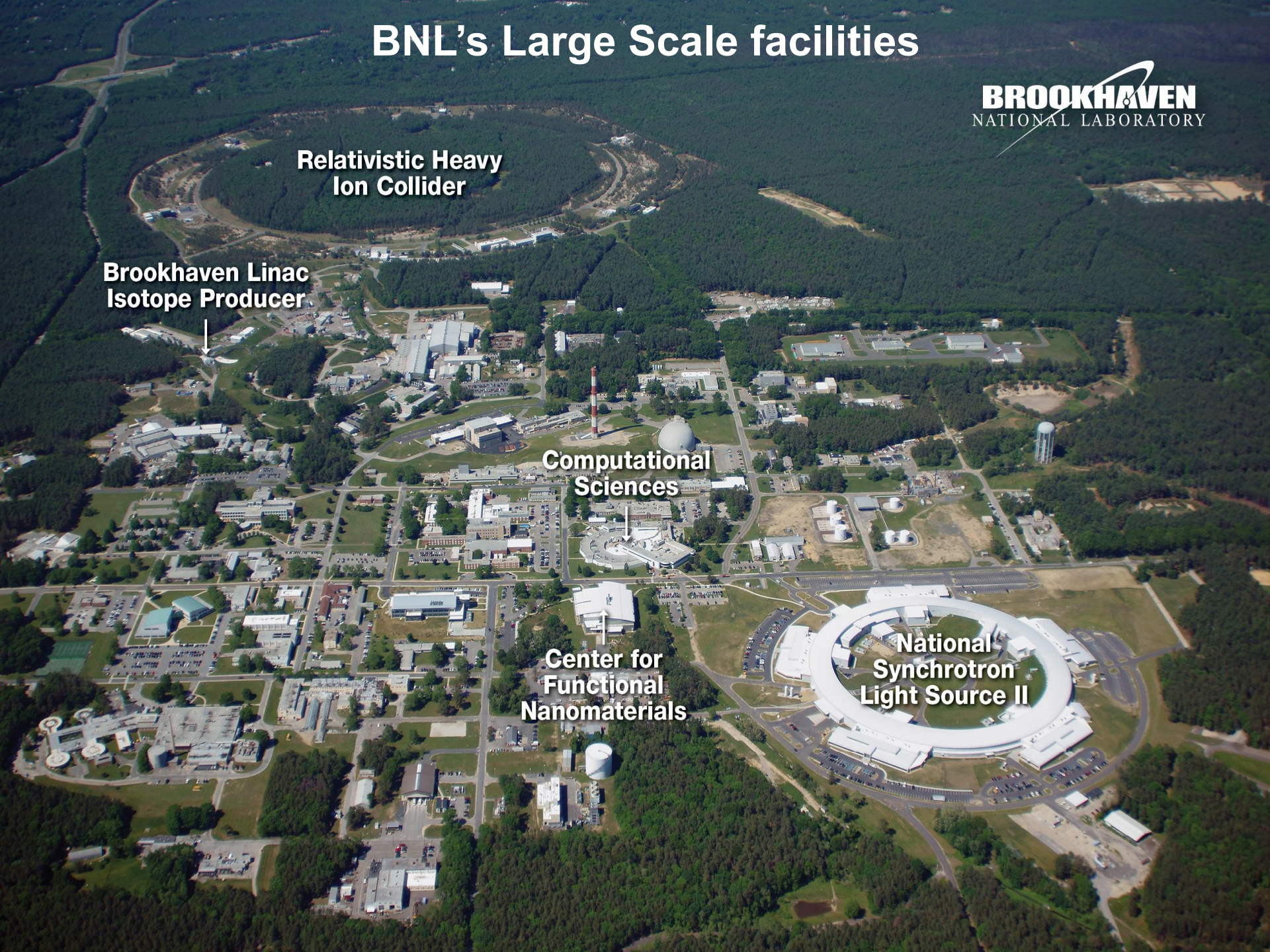
Some billion-dollar impacts at Brookhaven Lab include:

- Tc-99m for imaging and fighting cancer
- Cleaner-combusting oil burners: $25B savings, CO_2 reduction
- PET scan radiotracers used to study the nervous system and image cancer

Actinium-225

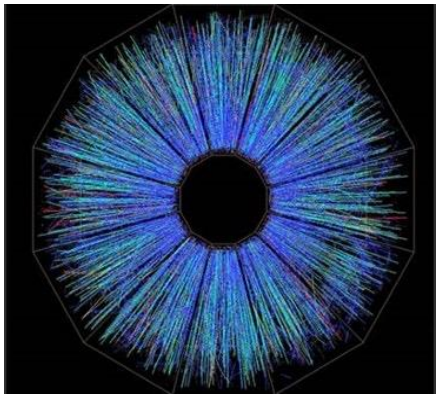


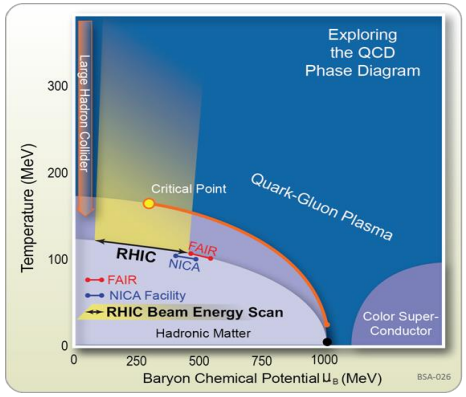
BNL's Large Scale facilities

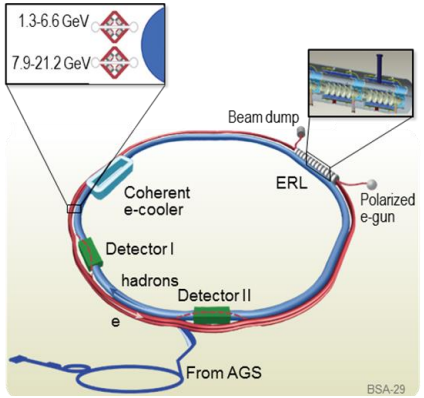


Relativistic Heavy Ion Collider (RHIC)

- The world's highest energy machine for fundamental nuclear physics
  - World-wide collaboration of more than 1,000 scientists, engineers and students
- Unique, most powerful microscope to explore the mysterious world of the Strong Force inside the proton and 0.00001 sec after the birth of the universe
  - 4,000,000,000,000K
  - It is a Quark-Gluon Plasma and a "Perfect Liquid"!
- Strategy for the future
  - Measure the extraordinary properties of the perfect liquid
  - Transition from RHIC to eRHIC to learn what's at the heart of all visible matter
  - Applications of nuclear science

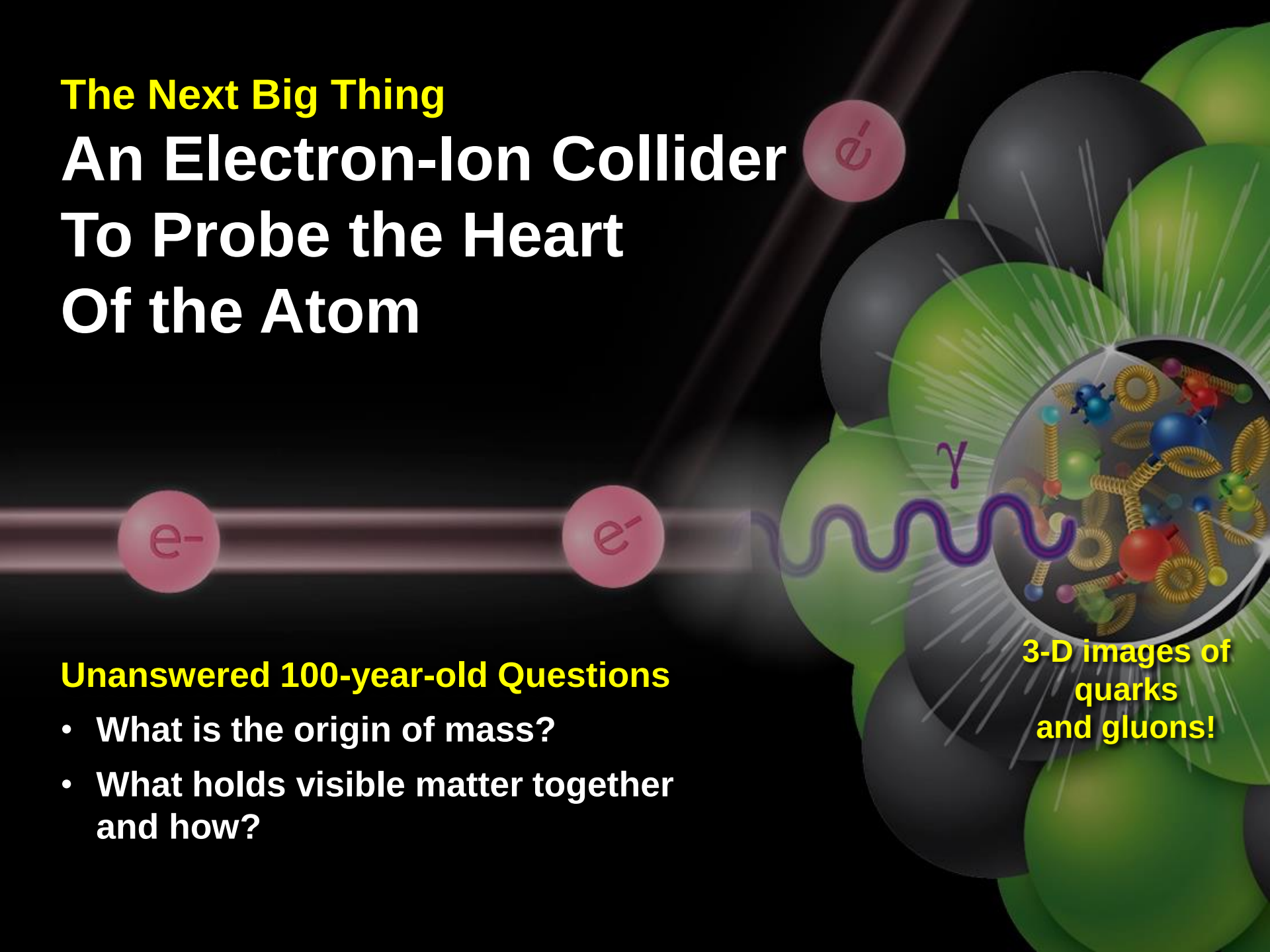






The Next Big Thing

An Electron-Ion Collider To Probe the Heart Of the Atom



Unanswered 100-year-old Questions

- What is the origin of mass?
- What holds visible matter together and how?

3-D images of quarks and gluons!


NSLS-II
BROOKHAVEN
NATIONAL LABORATORY
Relativistic Heavy
Ion Collider
Brookhaven Linac
Isotope Producer
Computational
Sciences
Center for
Functional
Nanomaterials
National
Synchrotron
Light Source II

Inside NSLS-II

The brightest light source of its kind, for unprecedented capabilities

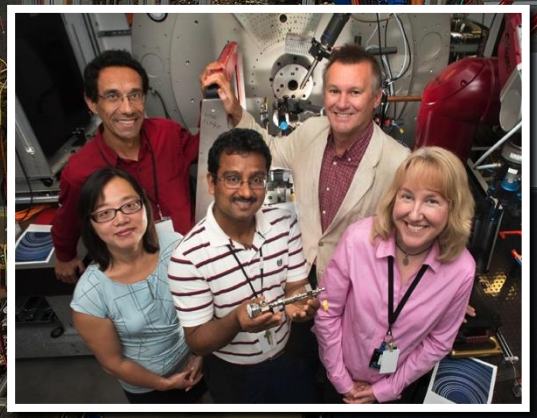
- 10,000 times brighter than its predecessor, NSLS
- 1,700 users per year

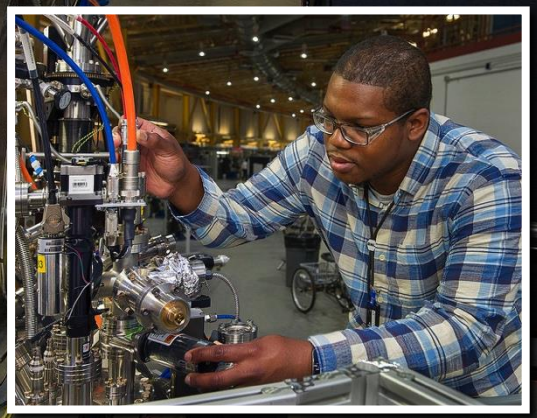
Research for energy challenges

- Advanced electrical storage
- High-temperature superconductors for the electric grid
- Fuel cells based on nanocatalysts
- Plant/environment interactions

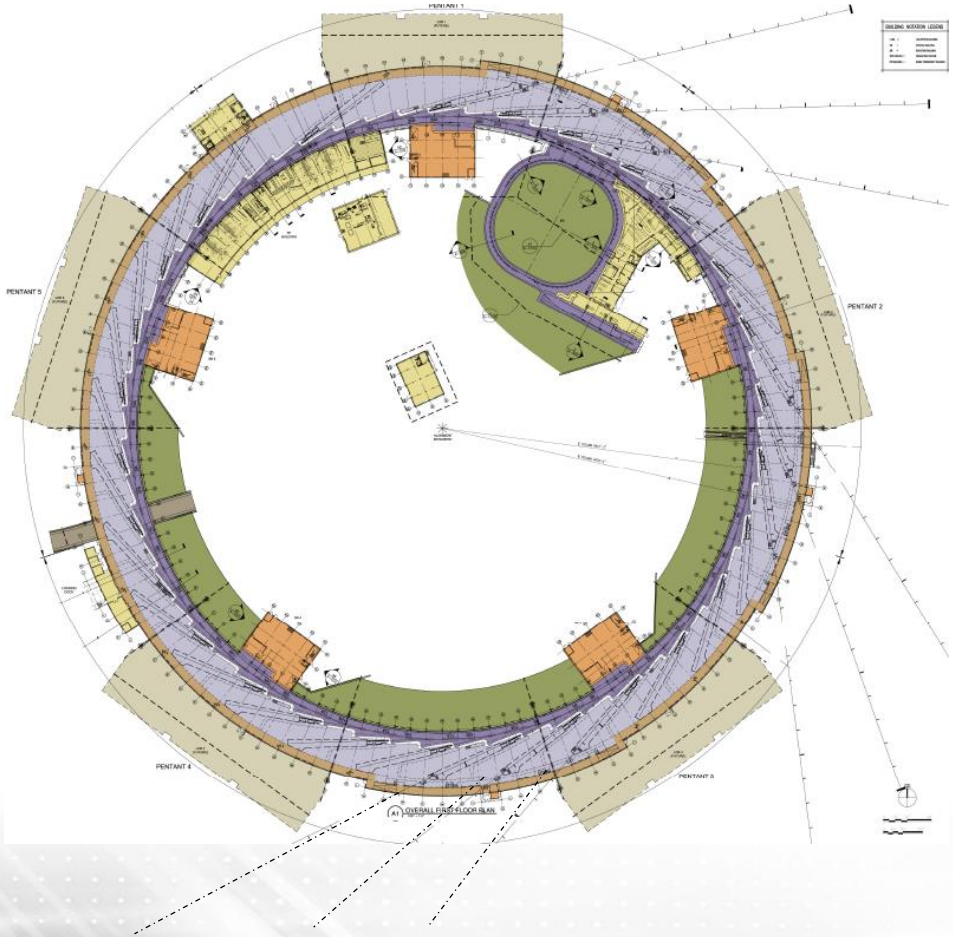
Life sciences: From proteins to cells to organisms

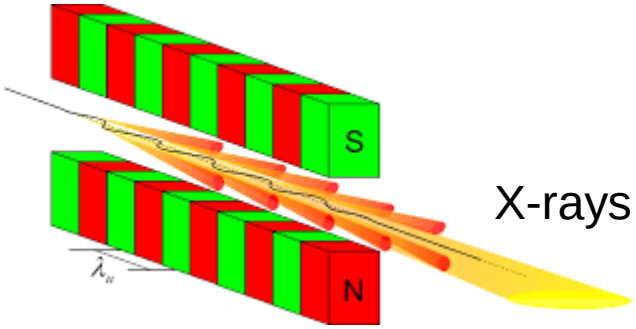
- 3 beamlines funded by the National Institutes of Health
- Cryo-EM: Partnering with Stony Brook, Cold Spring Harbor, and New York State





NSLS-II: Best in class from far-IR to hard x-ray





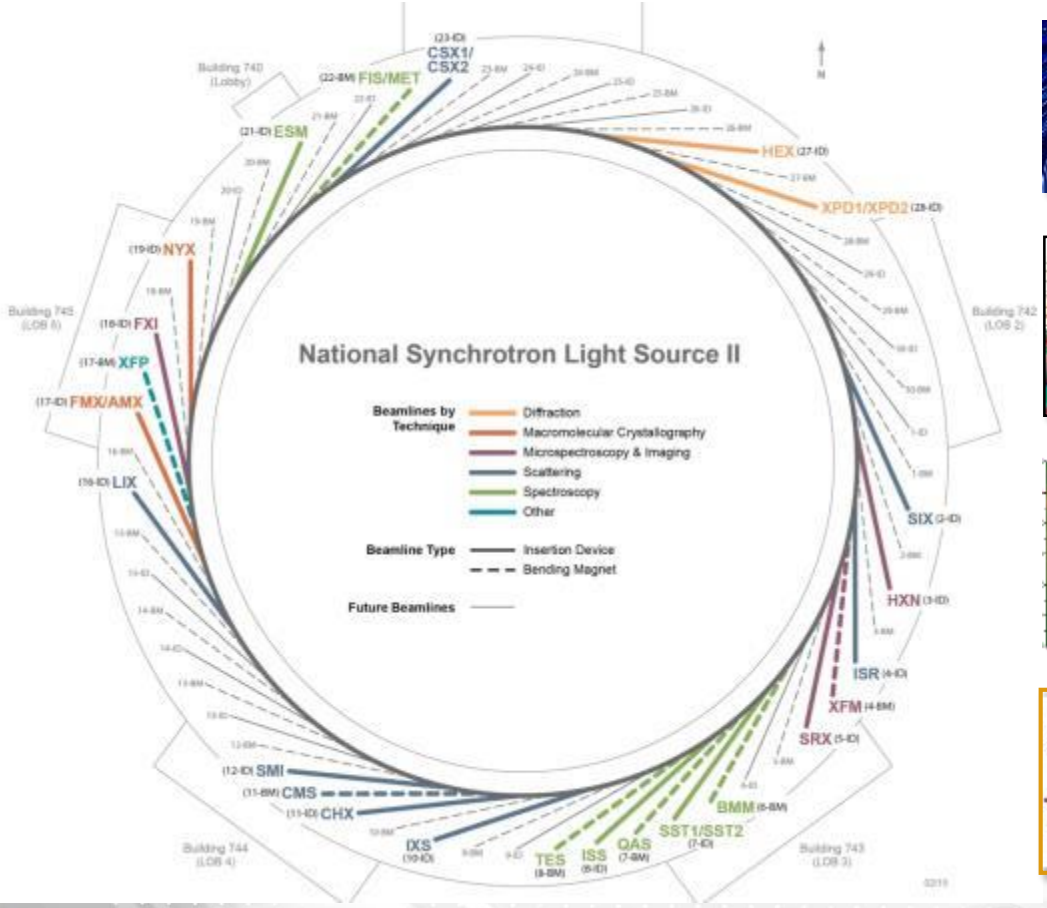
User Facility

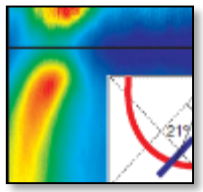
- Capacity for ~ 60 beamlines
- Ultimately will host > 4000 users/yr
- Proposal access. Free if intend to publish.
- Proprietary fee ($421/hr)

NSLS-II Beamlines

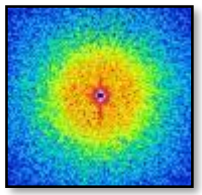
- 28 Operating/Commissioning
- 1 Under Development

http://www.bnl.gov/ps/nsls2/beamlines/map.php



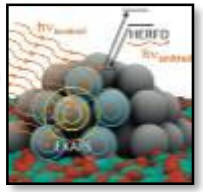


Soft X-Ray Scattering & Spectroscopy
Electronic and magnetic structures and excitations

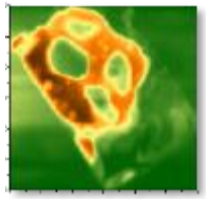


Complex Scattering
Soft materials, structures and dynamics

Diffraction & In Situ Scattering
Hard materials, *in operando* Structure



Hard X-Ray Spectroscopy
Chemical reactions *in operando*

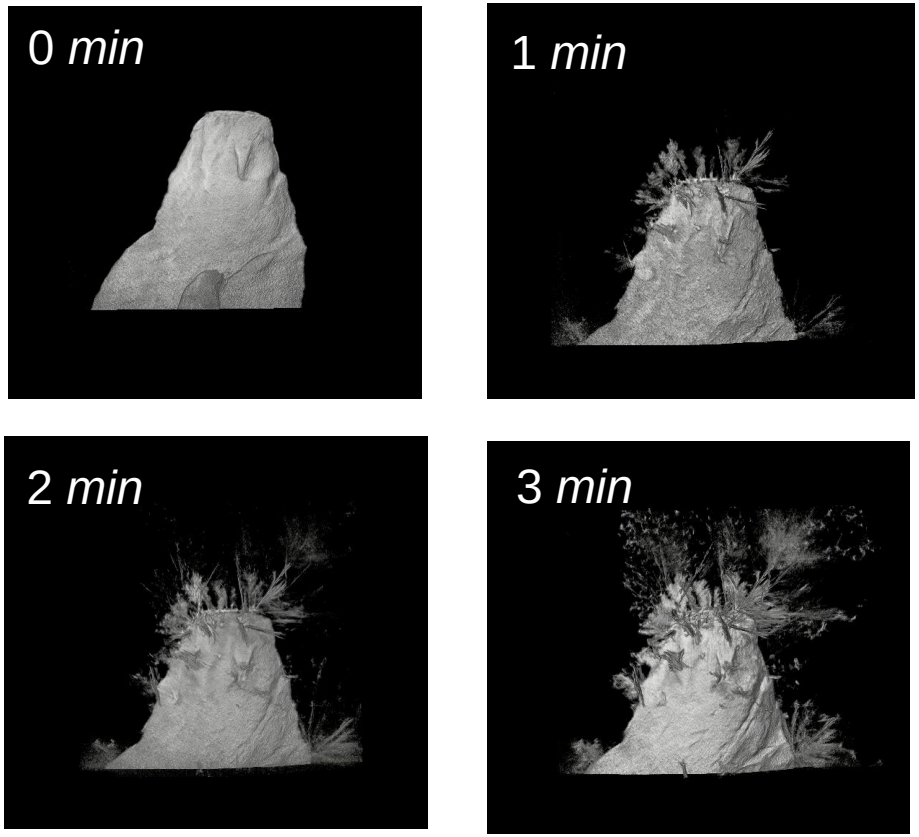


Imaging & Microscopy
Chemical, structural and morphological imaging down to 5nm

Structural Biology
Protein structures to 1 A resolution from ~1 micron crystals

Full field imaging

- 30 nm spatial resolution over 100 micron field of view
- 3D images in seconds
- x10 faster than any similar instrument in the world
- Allows first 3D movies of dynamic processes



Appl. Phys. Lett (2018)

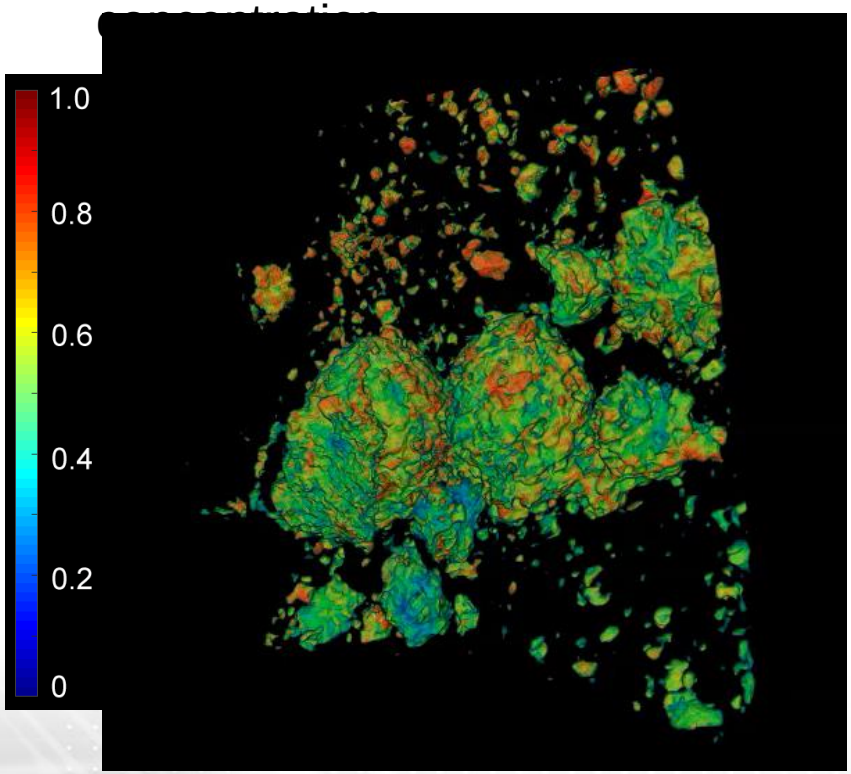
Tracking 3D silver nano-dendritic growth in real time, under *in-situ* chemical reaction conditions: $Cu + AgNO_3 \rightarrow Ag + Cu(NO_3)_2$

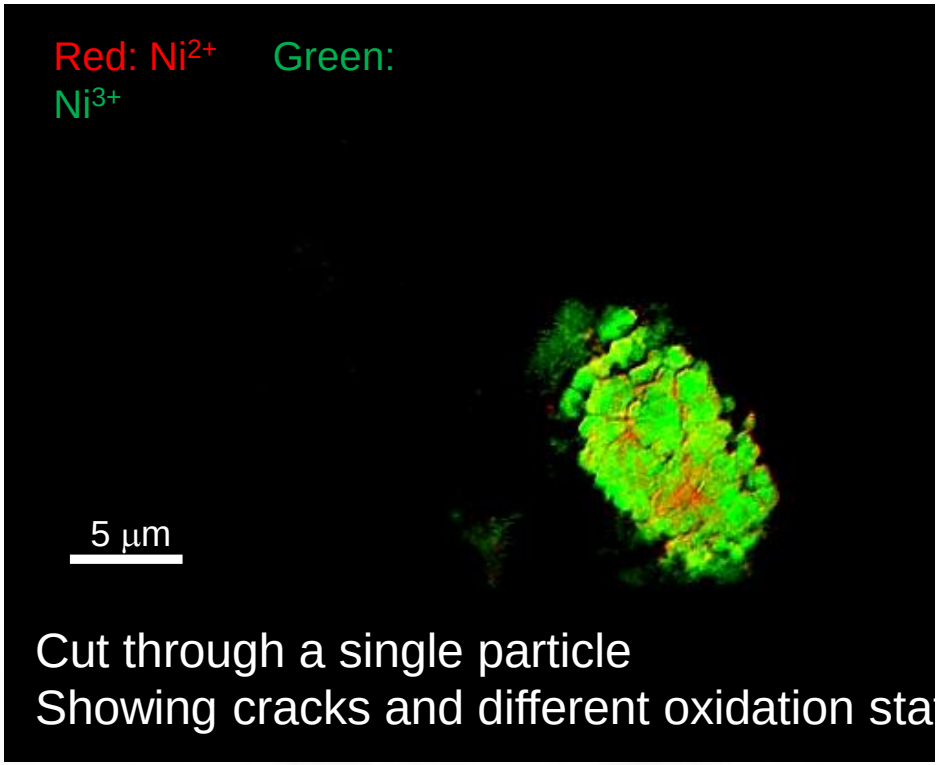
Cathode of a Li ion battery after 100 cycles

- Failure modes of batteries
- Cracks form in particle after cycling
- At crack sites, more Ni^{2+} observed → side reaction

3D rendition of Ni^{3+} concentration

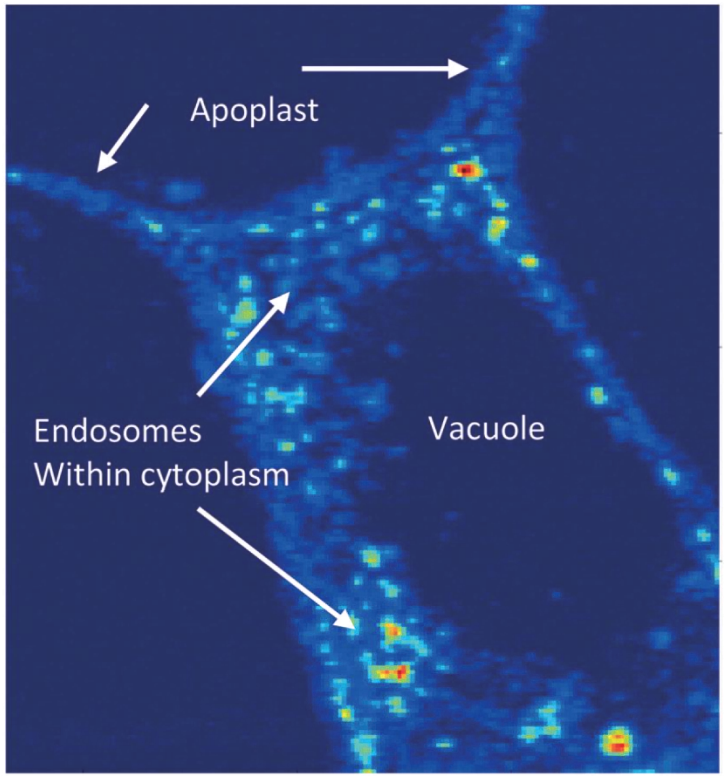
Mingyuan Ge, Xiaoqing Yang





NMC532 ($LiNi_{0.5}Mn_{0.3}Co_{0.2}O_2$)

A Nanomaterial's Journey through a Tomato Plant



This 60 nm resolution x-ray fluorescence image. The brighter areas show the highest concentration of Ce within the apoplast and within endosomes.

Scientific Achievement

Scientists revealed how a manufactured nanomaterial (MNM) based on Ce travels through a tomato plant on a subcellular level.

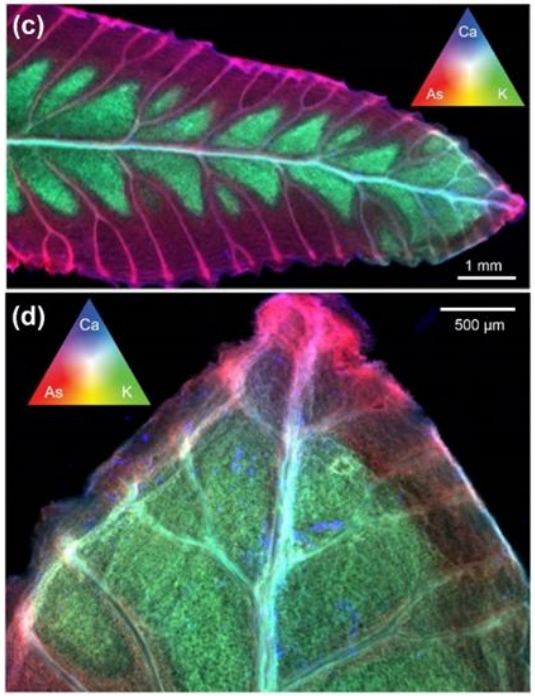
Significance and Impact

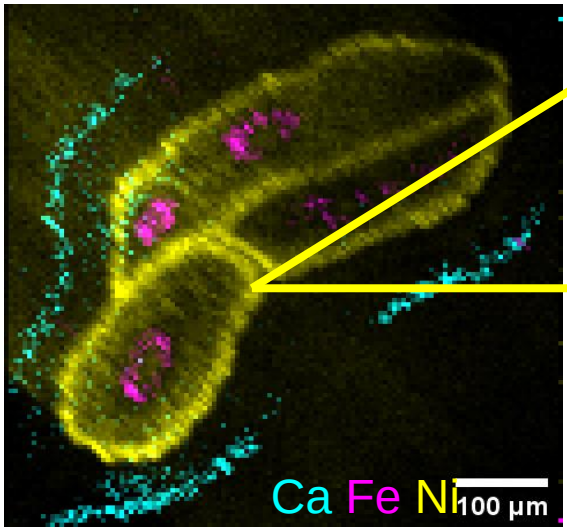
This study will enhance our ability to predict how properties of MNM such as CeO_2 – used in rechargeable batteries – influence the uptake, transformation, and transfer of nanomaterials in terrestrial food webs.

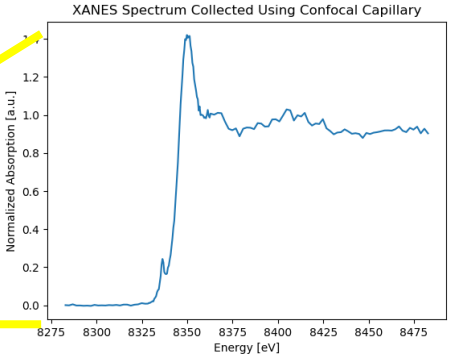
J. Li, R. V. Tappero, A. S. Acerbo, H. Yan, Y. Chu, G. V. Lowry, J. M. Unrine. *Environ. Sci.: Nano* **6**, 273 (2019).

Spectroscopic imaging from nm to mm

Arsenic uptake in leaves



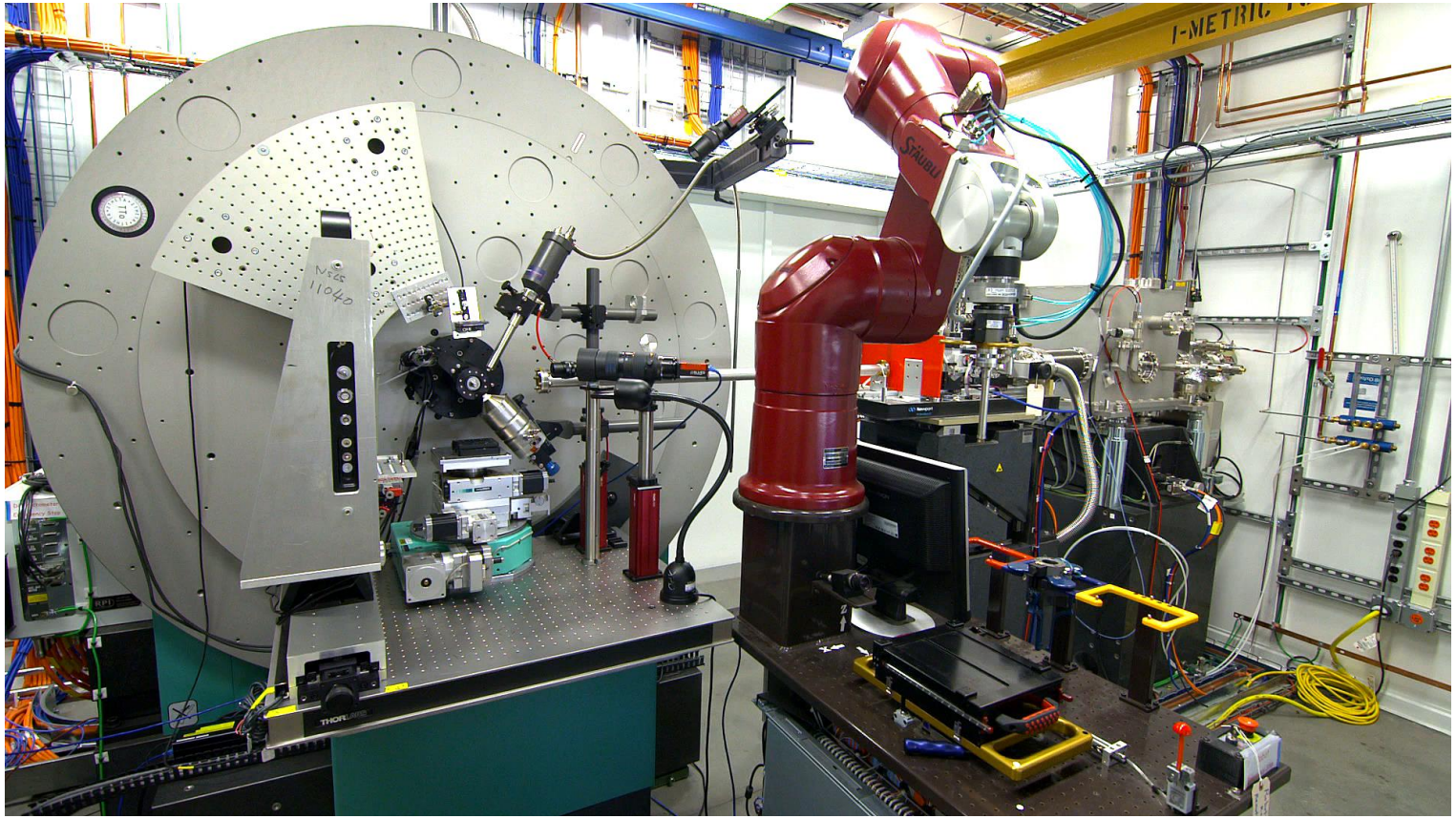




Kopittke *et al.*, 2018. Plant Physiology (DOI: 10.1104/pp.18.00759).

Not just elemental sensitivity, but spectroscopic (chemical) information too with unprecedented resolution and senstivity

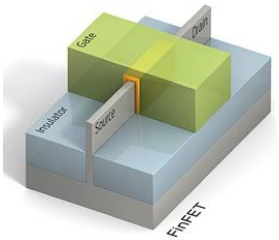
X-ray Powder Diffraction

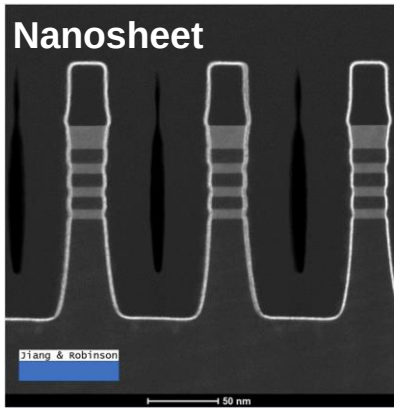


- Precise measurements of atomic structure *in-situ*
- Batteries, catalysts, nanoparticles,…..
- Robot to process large numbers of samples quickly

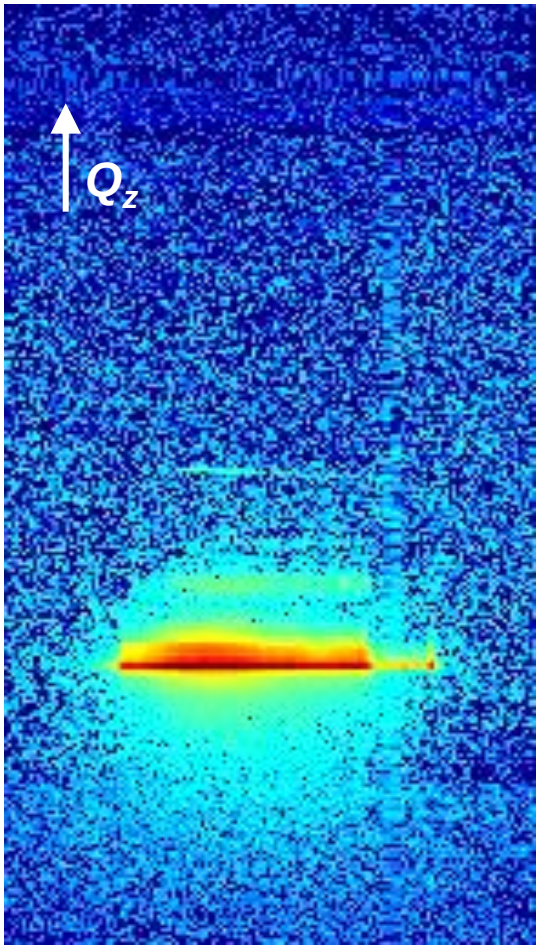
Nano Diffraction from Nanosheet

FinFET





- Strain determines performance of the next-generation microprocessors with complex 3D structure, *e.g.* in IBM's new nanosheet technology
- Scanning-nanoprobe 3D rocking curve measurement provides strain mapping. Studied 7 nm thick and 100 nm wide nanosheet
- Can do such measurements while current is flowing - operando



Nano-diffraction at HXN
(5 sec/frame)

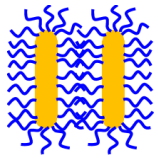
C. Lavoie, C. Murray, J. Jordan-Sweet (IBM);

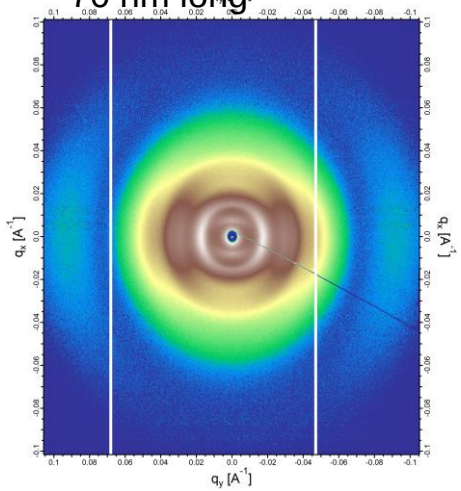
H. Yan, X. Huang, Y. Chu (NSLS-II)

Autonomous exploration of nanoscale ordering in a blade-coated polymer-grafted nanorod film

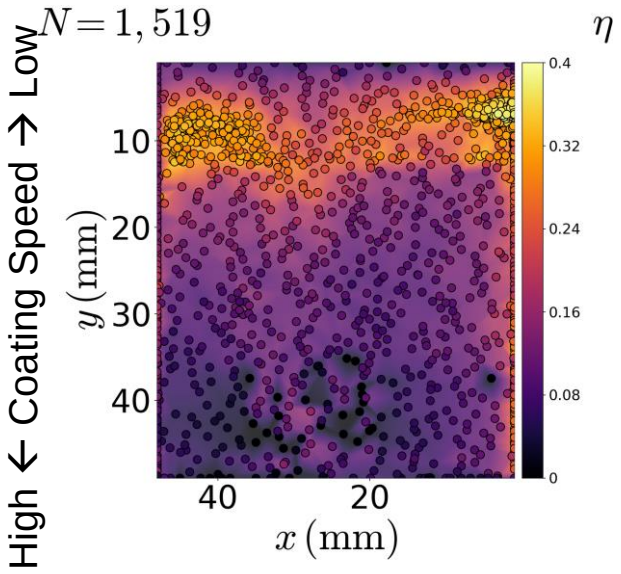
J. Streit, R. Vaia (AFRL), M. Fukuto, R. Li (BNL/NSLS-II), K. Yager (BNL/CFN), M. Noack (LBNL/CAMERA)

Polystyrene-grafted gold nanorod
11 nm dia.
70 nm long

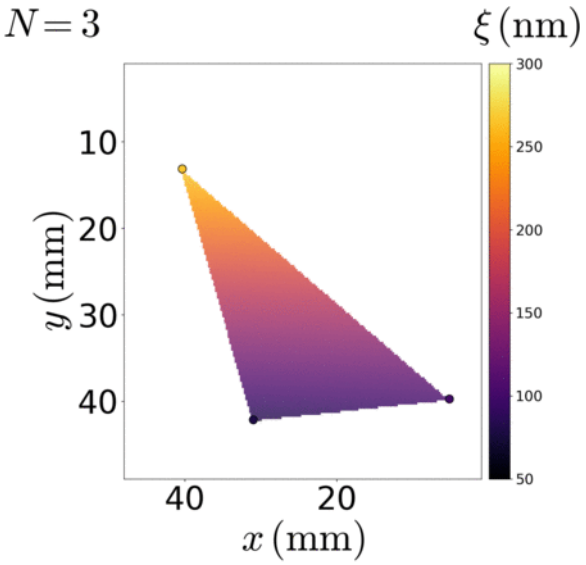




Anisotropy $0 < \eta < 1$



Grain size ξ
(animation)

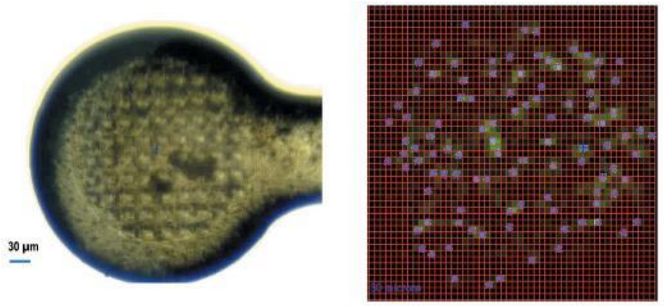


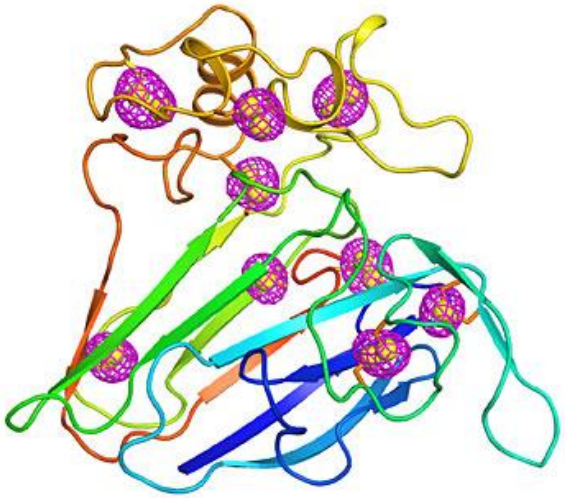
Hydrophilic ← Substrate → Hydrophobic

Protein structure determination from microcrystals

- Protein structure determines protein function. X-ray scattering from protein crystals gives structure to atomic precision
- Growing large enough single crystals is the bottleneck in determining structure
- Automation and intense x-ray beams at NSLS-II allow the study of microcrystals of proteins
- Automated data collection from ~1,400 microcrystals on polyimide wellmounts, leading to a merged dataset for structural solution of Thaumatin at 2.6 A

Guo et al. *IUCr J.* **6**, Part 4, July 2019.





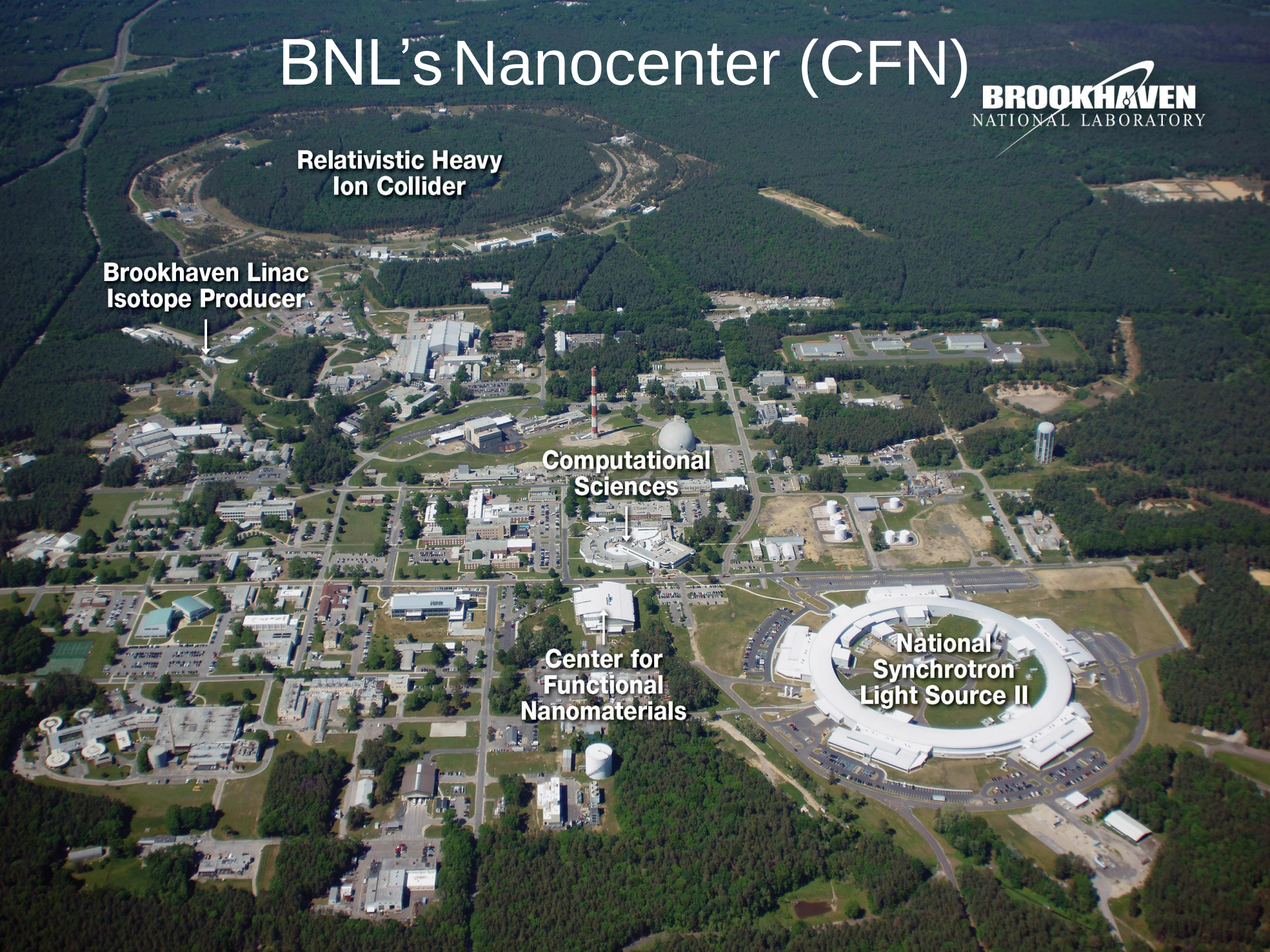
NSLS-II Summary

- NSLS-II is an advanced x-ray user facility
- Characterization tools are world-leading and often unique
- Extraordinary sensitivity and resolution
- Non-destructive and *operando*
- It's a user facility – we are here to help you get your research done
- Proposal deadline: September 30th, 2019, January 31st 2020

- Limited travel support. Contact Pamela Clarke, Director Research Development

BNL's Nanocenter (CFN)

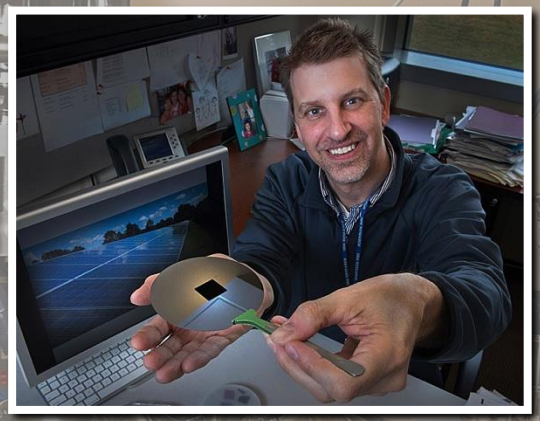
BROOKHAVEN NATIONAL LABORATORY



Inside the CFN

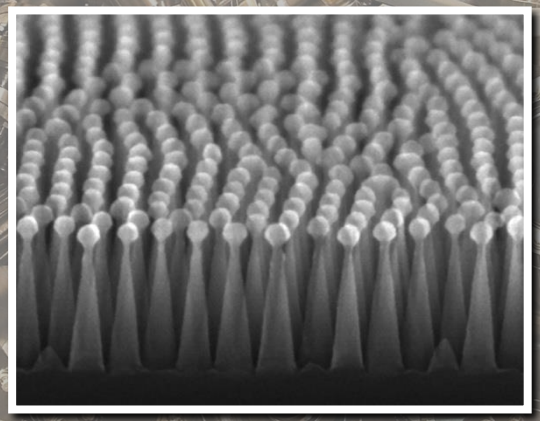
Research at the ultra-small nanoscale for big advances in energy, national security, more

- Designing structures measured in billionths of a meter
- Advancing nanoscience research and hosting hundreds of guests each year



Nanoscience for solar panels… and ski goggles?

- Antireflective surfaces: Inspired by insects' eyes, nanotextured surfaces can dramatically increase light collected by solar panels
- Hydrophobic surfaces: "Nanocones" prevent moisture from accumulating—water droplet literally bounces off

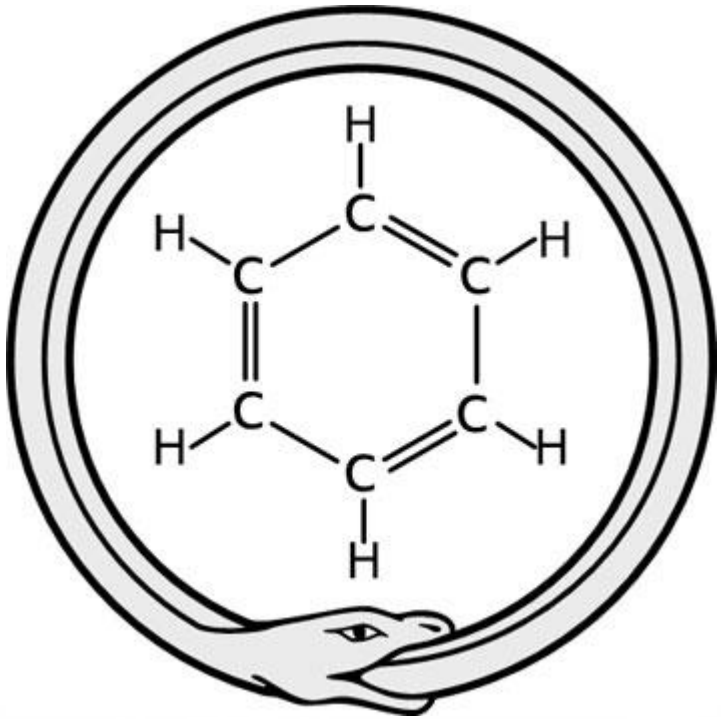


Breaking a world record at the CFN

- For electronics, "lithography" processes create complex materials with specific patterns and compositions
- CFN scientists became the first to use electron-beam lithography to pattern materials at the size scale of one nanometer

Imaging Individual molecules

Aromatic carbon molecules

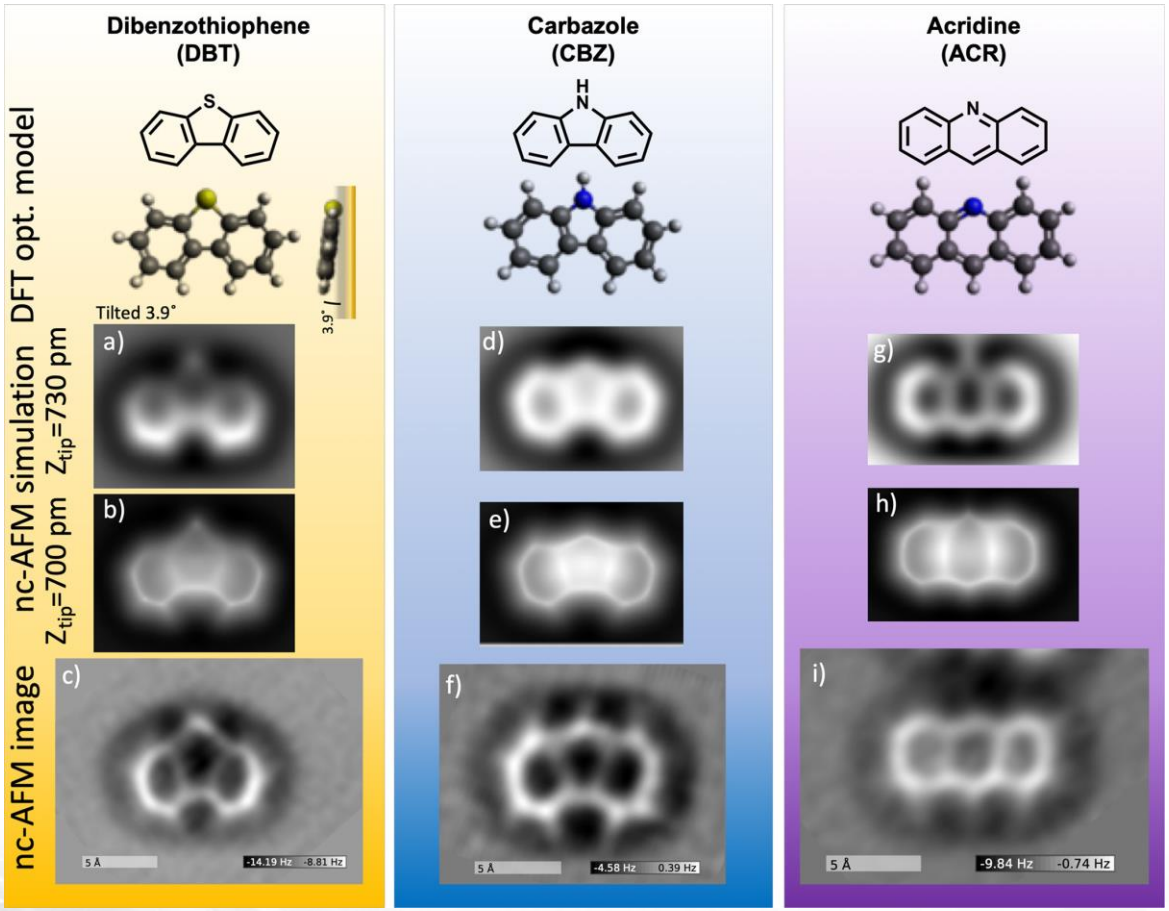


Benzene ring

Friedrich Kekule

Imaging Individual molecules

Aromatic carbon molecules



Non-contact AFM

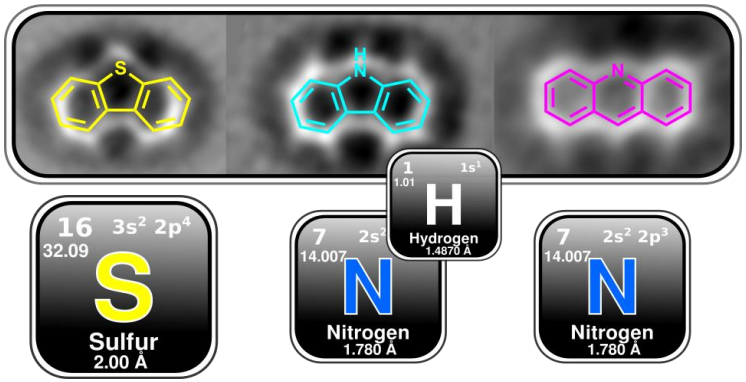
- Can image the molecules directly
- Can see non-carbon atoms (nitrogen and sulphur)

- Available to users!

Looking at Atoms to Make Cleaner Fuels from Petroleum

Percy Zahl and Y. Zhang, *Energy Fuels* **33**, 4775 (2019)

Dibenzothiophene Carbazole Acridine

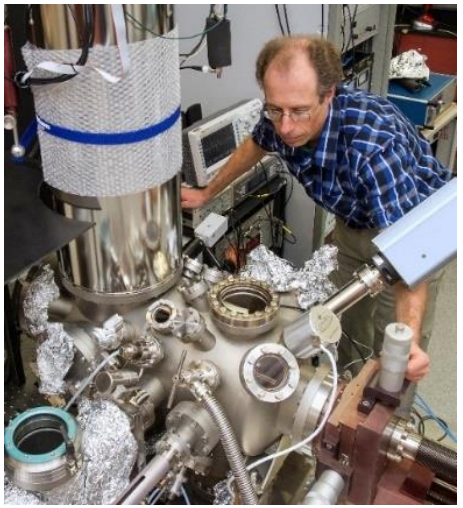


Scientific Achievement

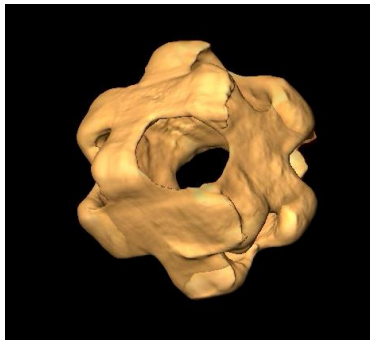
- Collaboration with ExxonMobil
- New approach to identifying heteroatoms found in aromatic hydrocarbon molecules (nitrogen and sulfur).
- CFN non-contact AFM can determine the chemical structure of molecules found in complex mixtures of crude oil.

Significance and Impact

- NO_x and SO_x are two major pollutants that result from the combustion of fossil fuels.
- Straightforward & robust methods for identifying N- and S-containing hydrocarbons can improve methods to produce cleaner fuels from crude oil.

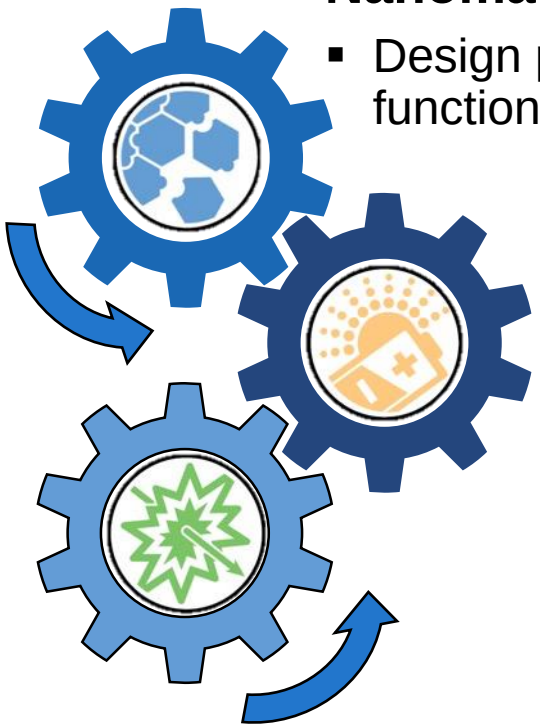


CFN: material design-to-function by component assembly



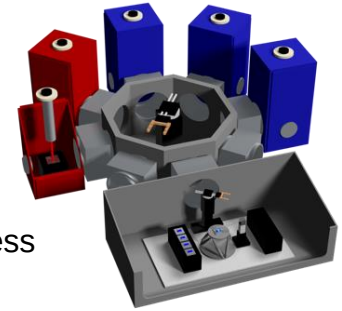
Nanomaterial synthesis by assembly

- Design precise architectures with targeted functionality by organizing nanoscale components

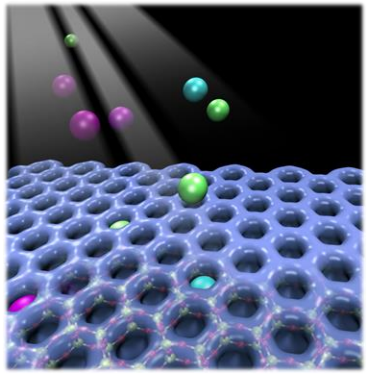


Accelerated nanomaterial discovery

- Integrate synthesis, advanced characterization, physical modeling, and data science to explore a wide range of material parameters



e.g., Quantum Material Press



e.g., trapping noble gas atoms [Adv. Func. Mat, (2019)]

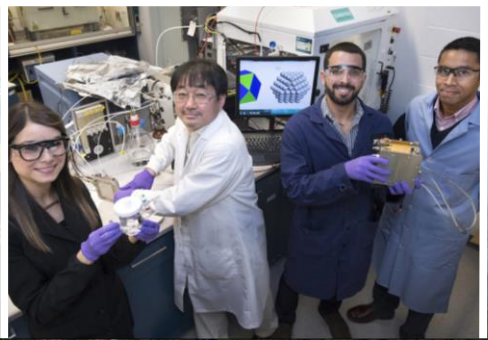
Nanomaterials in *operando* conditions

- Characterize materials and reactions at the atomic scale, in real-world environments

Proposal deadlines: September 30th 2019, Jan 31st 2020

Students Today, Scientists Tomorrow

30,000+ local students, teachers (grades 1–12) • 350+ college students, professors

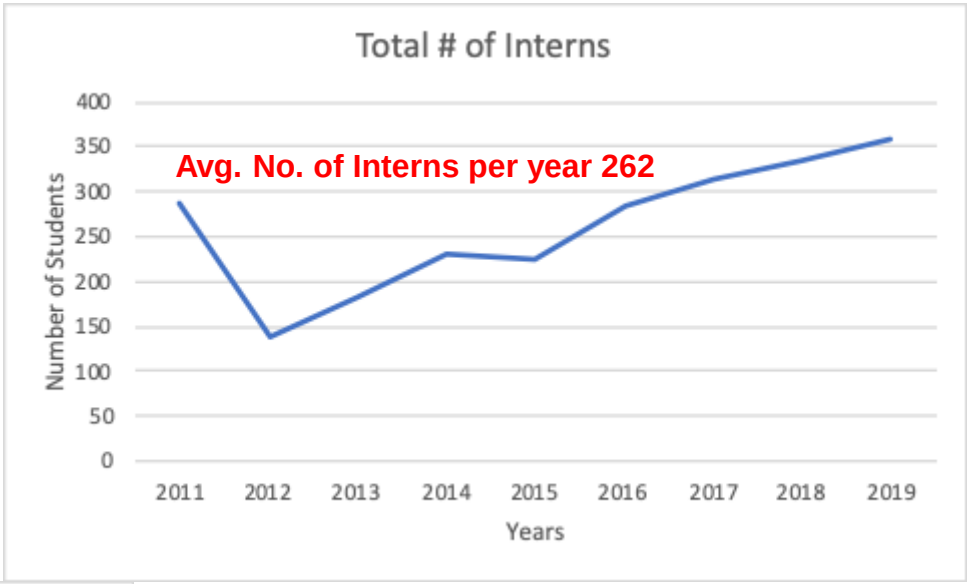


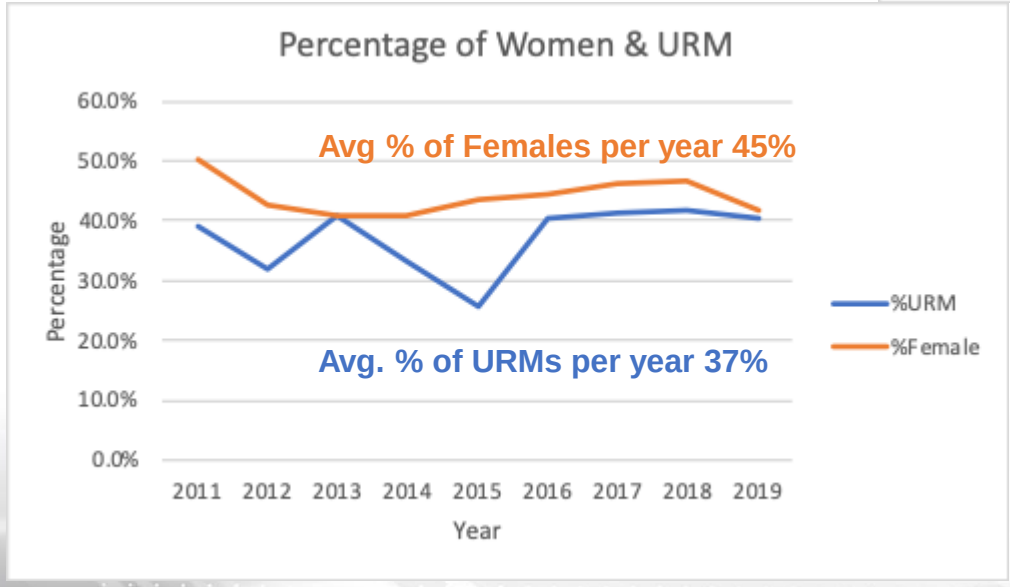
BNL's Office of University Relations and Internships

What We Do:

1. *Internship Programs – Design, implement and manage*
2. *Using College Relationships to develop collaborations*
3. *Assisting our researchers with broader impacts on grants*
4. *Promoting BNL's Science in the Classroom*
5. *Developing user pools for our facilities*
6. *A workforce development leader in DOE – WDTS programs*
7. *Expanding the reach for BNL's scientific community through workshops, meetings and conferences*

Office of Educational Programs Data:





University and College Programs at BNL

- DOE - Workforce Development for Teachers and Scientists (WDTS) Mini-Semester Program
- DOE - Science Undergraduate Laboratory Internship (SULI)
- DOE - Visiting Faculty Program (VFP)
- NSF - Faculty and Student Teams (NSF – FaST)

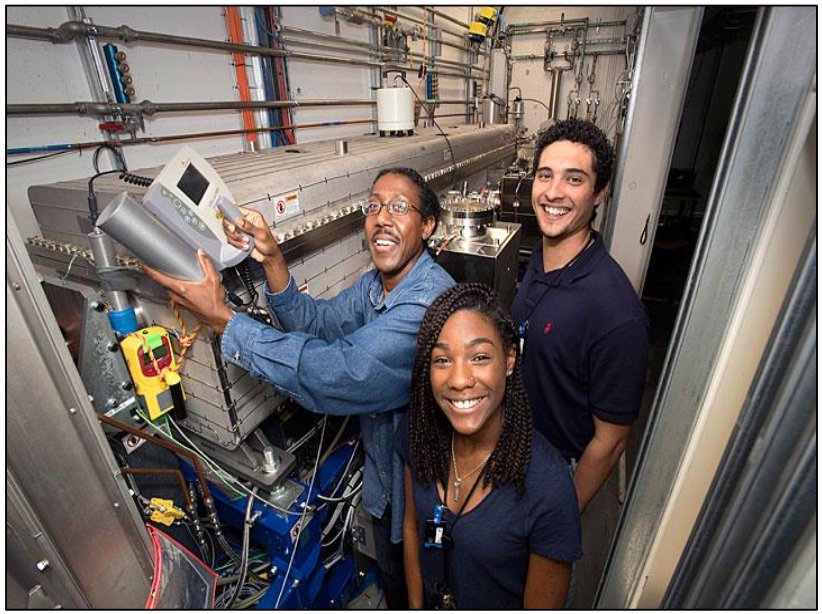
Workforce Development for Teachers and Scientists: Mini-Semester Program

housing and travel provided

- Open to 2 yr. and 4 yr. math and science majors
- 1-week Winter program, Jan. 6th – 10th, 2020
- Lectures and Tours
- Interactive research labs
- Reverse interview with BNL Scientists
- Computational Physics workshop
- Deadline October 25, 2019

Science Undergraduate Laboratory Internship (SULI)

- Open to soph., juniors & seniors majoring in math, physical and life sciences, engineering, computer science and technology
- 16-wk Fall and Spring semester programs
- 10-week Summer program
- Participate in enrichment modules
- Produce abstract, poster and research paper



$600/week + housing and travel

- Spring 2020 - Deadline October 7, 2019
- Summer 2020 - Deadline January 10, 2020

DOE - Visiting Faculty Program (VFP) & NSF – Faculty and Student Teams (NSF – FaST)

- One faculty with or without 1-2 undergraduate/graduate students working with BNL scientists on a research project
- 10 week paid Summer program
- Launch point to develop and strengthen university-lab research
- Create sustainable relationships

Summer 2020 - Deadline
January 10, 2020

Faculty: $13,000 + housing and travel
Students: $600/week + housing and travel

Summary

1. BNL is close to Howard and houses a number of world-class facilities
2. There are many opportunities to work with us at all levels to advance your science, your experience and your career
3. Upcoming deadlines
    1. User facilities: September 30th, 2019. Jan 31st 2020
    2. SULI Spring 2020: October 11th
    3. WDTS Mini semester: October 25th
    4. SULI Summer 2020: January 10th
    5. VFP Summer 2020:January 10th
4. Online Synchrotron Course. Fall 2020

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