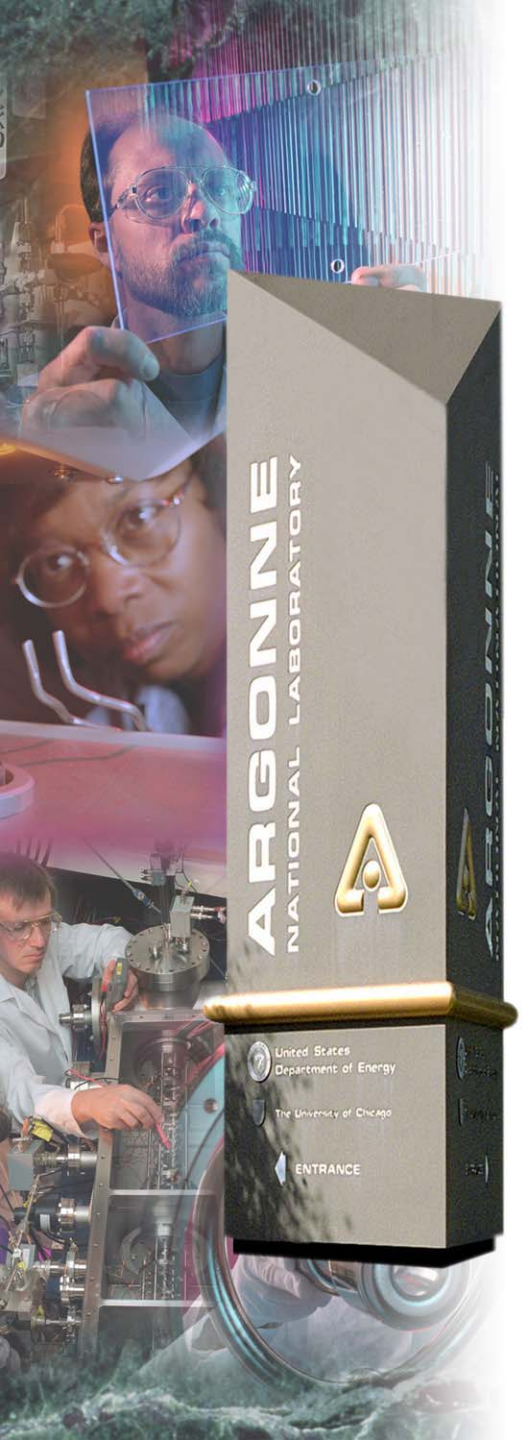


The Center for Nanoscale Materials and Nanosciences at ANL

Eric Isaacs

The University of Chicago Review
for the Advanced Photon Source
at Argonne National Laboratory

September 17-19, 2003

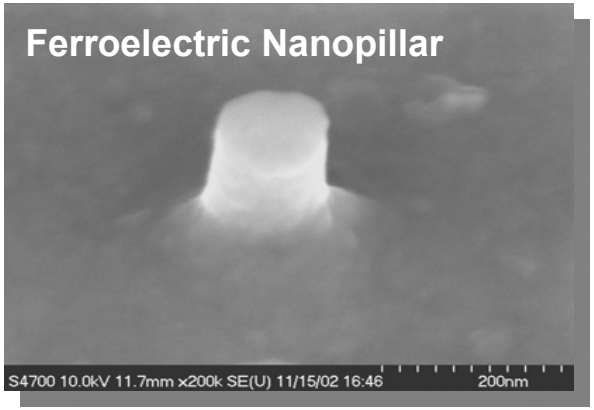
Office of Science
U.S. Department of Energy

A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago

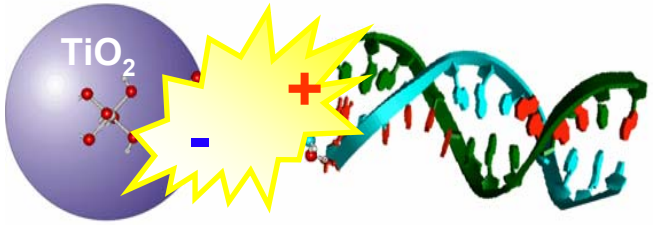
Outline

- **Introduction to the Center for Nanoscale Materials (CNM)**
  - Collaborative access facility
- **Nanoscience research at CNM and ANL**
  - Scientific highlights

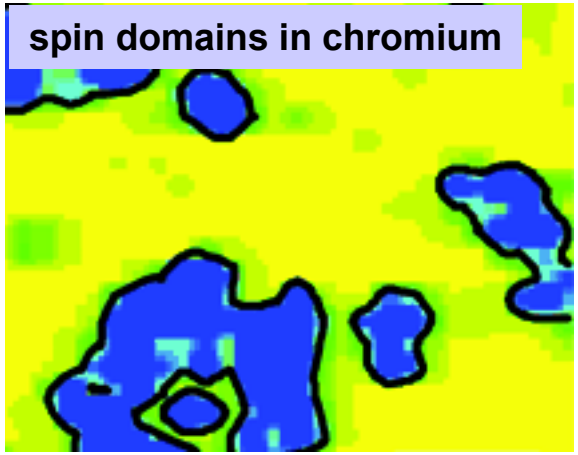
The Vision of Nanoscience …



New geometries,
[quantum] confinement, proximity…



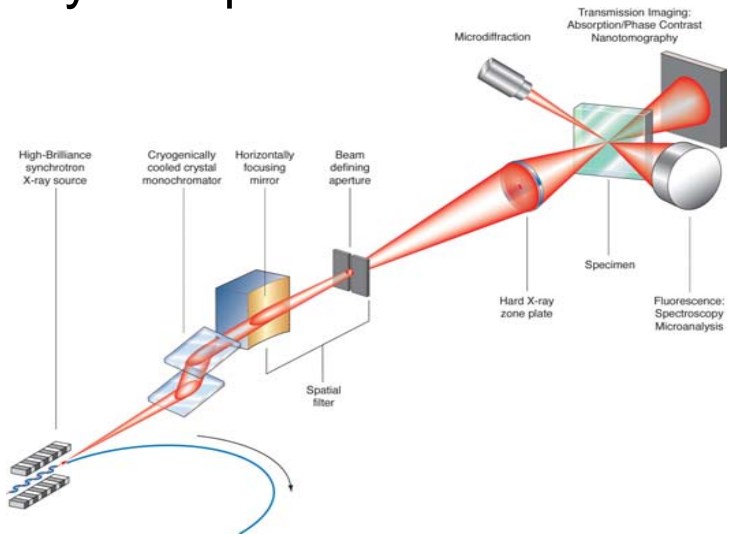
Nano-phases in bulk

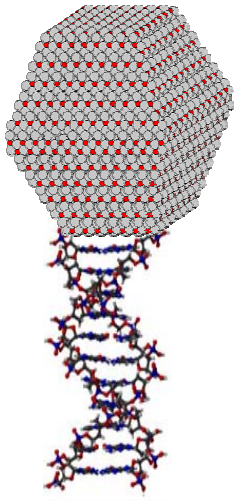


Novel composites:
bio-inorganic integration

Built on Novel Modeling, Synthesis, and Characterization Tools

New nanoprobes:
X-ray nanoprobe at APS

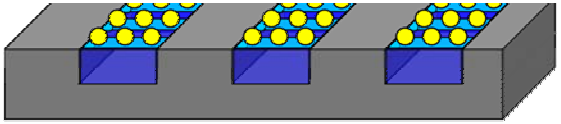




Simulate atom-by-atom, multi-scale modeling, integration

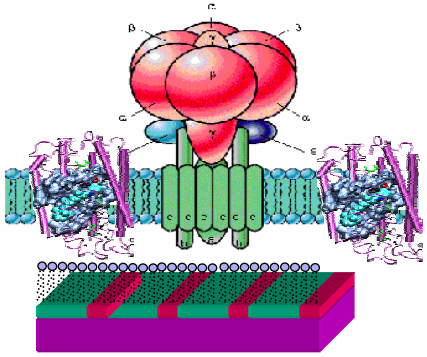
Novel fabrication:
lithographically assisted self-organization

n-Mag array on PMMA templates

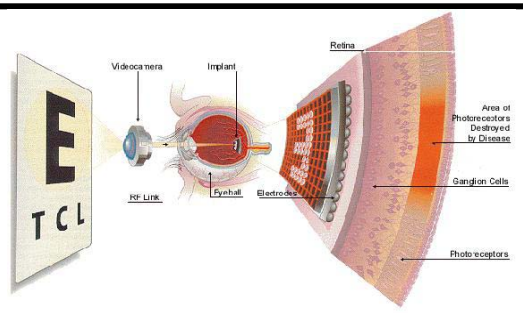


Laying the Foundations for Future Nanotechnologies…

- **Nanostructured materials *"by design"***
  - Stronger, lighter, harder, self-repairing, and safer
- **Smaller, better, faster, cheaper electronics**
  - Bio-electronics, optoelectronics, and magnetics
  - Computers and memory, communication devices
- **Environment, safety, energy efficiency/security**
  - Catalysis
- **Advanced nanodevices for sensors**
  - Chem/bio analysis
  - Homeland security
- **Advanced healthcare, therapeutics, and diagnostics**



Supramolecular Machines



Artificial retina with nanocrystalline diamond electrodes

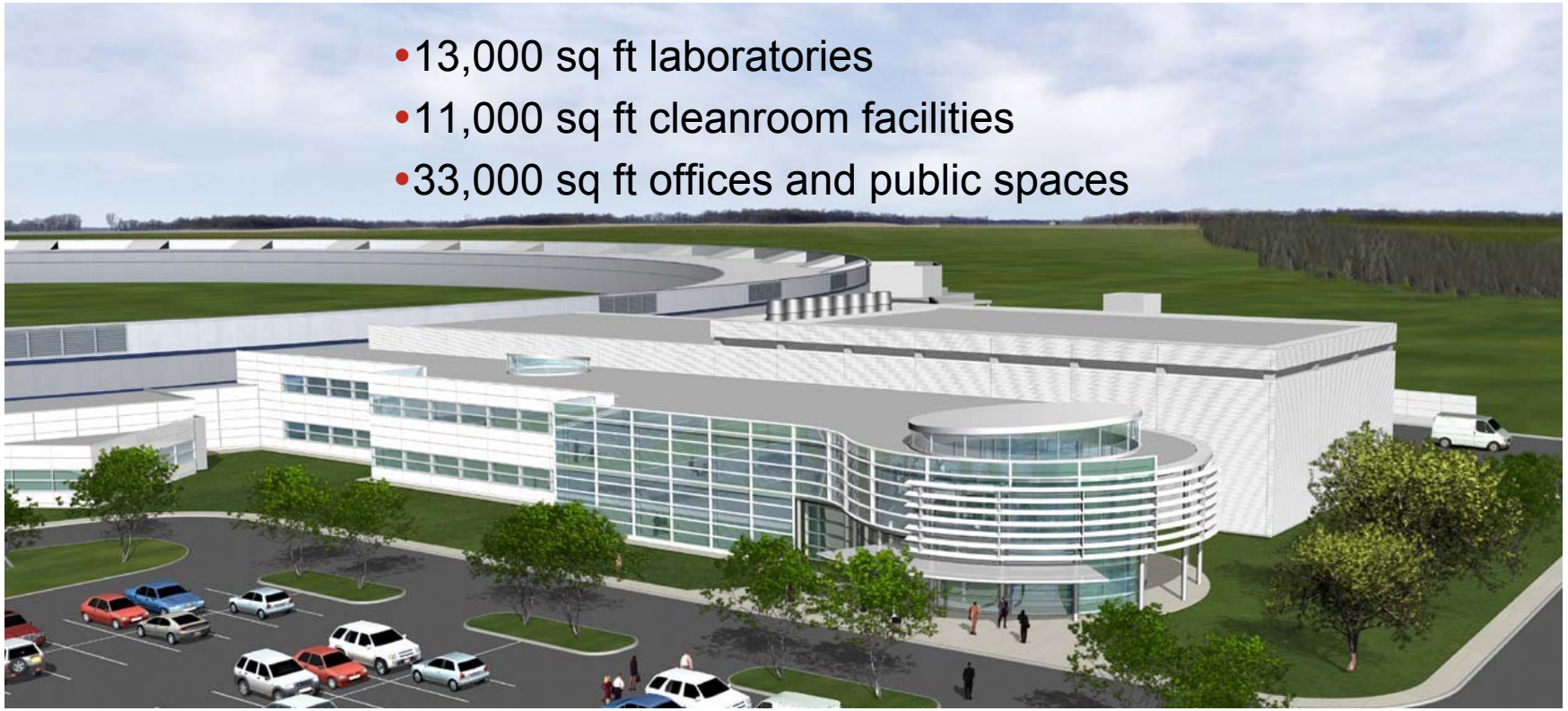
What is the Center for Nanoscale Materials?

Collaborative Access Facility for Nanoscience Research

- Exciting science, new nanomaterials, novel nanodevices
- Facilities for synthesis and characterization of nanomaterials
  - *Operated by staff expert in techniques*
  - *Development of new nanoinstrumentation, including a new nanoprobe beamline at the Advanced Photon Source*
- Open access for internal and external users
  - *best science - peer review access like APS*
- Brings new science and capabilities to ANL, the region, and the nation
- Leverages Argonne's and regional strengths

Center for Nanoscale Materials Building

~85,000 gross square feet, including:



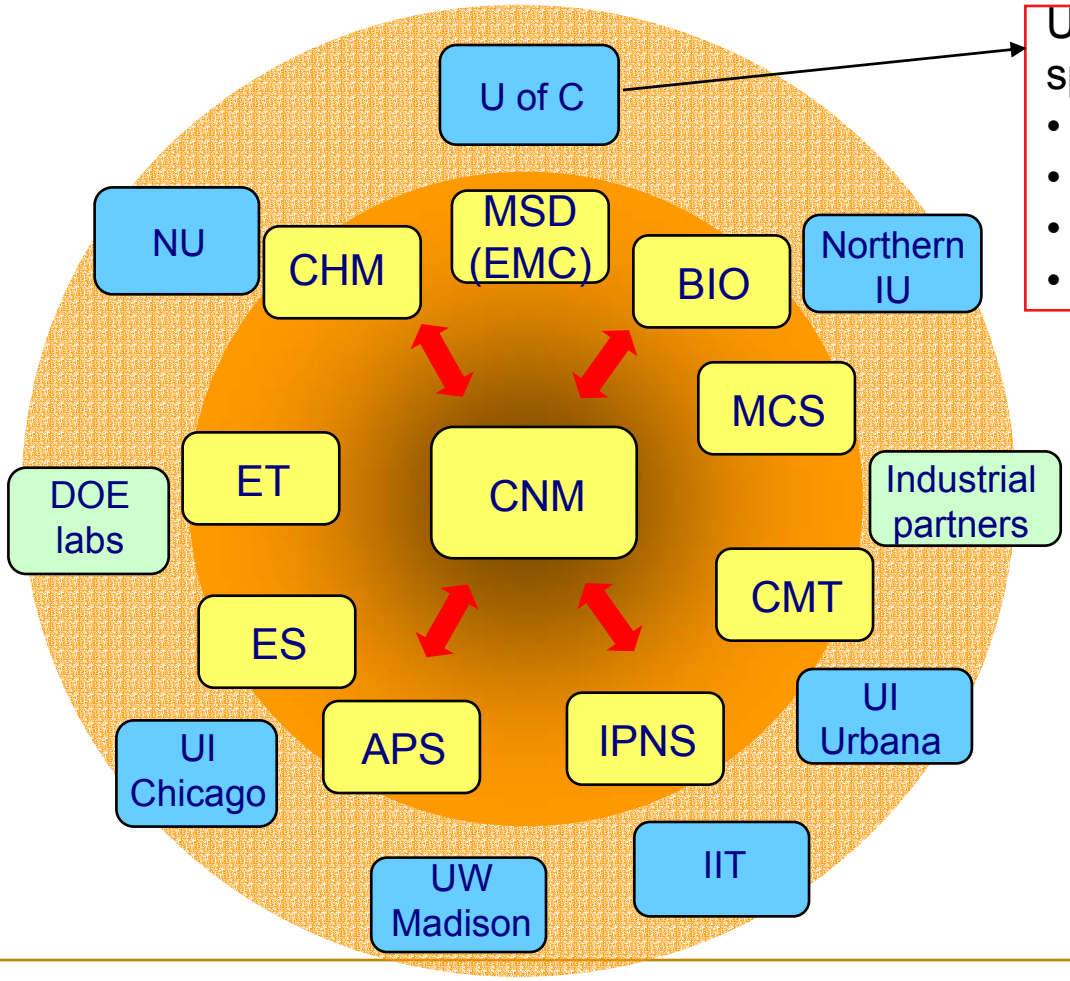
• IL	$36 M	Building construction (FY06)
• DOE	$36 M	Instrumentation (FY04 start)
• DOE	$18M / year	Operations (FY06 start)

Initial CNM Programmatic Focus Areas

- The Bio-Inorganic Interface (*D. Tiede, MSD*)
- *n*-Carbon (*D. Gruen, MSD*)
- *n*-Magnetism (*S. Bader, MSD*)
- Complex Oxides (*O. Auciello, MSD*)
- Nanophotonics (*G. Wiederrecht, CHM*)
- The Virtual Fab Lab (*S. Gray, CHM, and P. Zapol, MSD*)

Center for Nanoscale Materials Partnerships

- **Interdisciplinary research – CNM will play a powerful role at ANL and beyond in driving multi-divisional/institutional collaborations**



U. of C. to play special role
- strong nanoscience
- ANL oversite
- joint hires
- post-docs, students

ANL partnerships with CNM

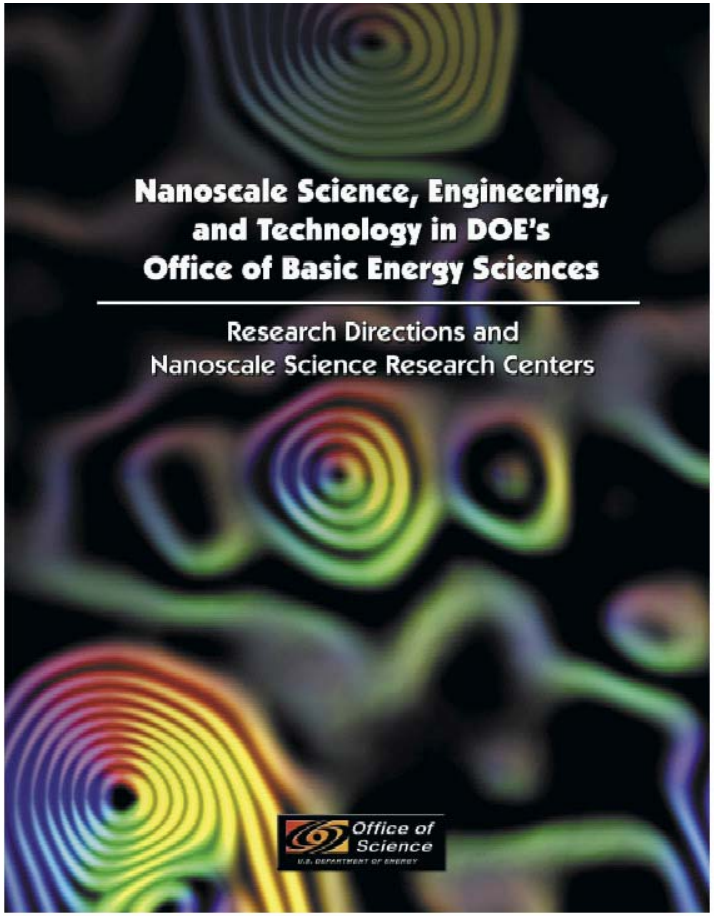
- **World-class nanoscience research**
- **Gateway for CNM users**
- **APS provides successful user access model**
  - General users, partner users, “one-stop shopping,”…
- **Electron Microscopy Center (EMC) and TEAM (MSD)**
- **Founding Directors – Murray Gibson, Sam Bader**
- **CNM project managers**
  - Nanolithography and processing – Leo Ocola (APS, CNM)
  - CNM Project Manager – Derrick Mancini (APS)
  - X-ray Nanoprobe beamline at APS - Brian Stephenson (MSD)
  - Nanosynthesis and characterization - Steven Streiffer (MSD)
- **CNM scientific theme leaders**
  - Orlando Auciello, Dieter Gruen, Sam Bader, Peter Zapol
- **Hiring of CNM distinguished post-docs**
  - Amanda Barnard, Dolly Batra, Yi Gi, Oliver Williams
- **Joint hires/appointments**

Leveraging CNM Partnerships for Funding

- **Establishing CNM user community**
  - $1.5 M DOE funding to “jumpstart” user programs (ramps to $18 M, FY06)
- **State of Illinois – $36 M for CNM building**
- **ANL LDRD funds to seed nanoscience research**
- **DOE funding in partnership with APS, ANL divisions and universities**
- **Partnerships with other DOE labs**
  - zone-plate development (BNL, LBNL and Lucent)
  - synchrotron-based, low-T facility (BNL)
- **Consortium for Nanoscience Research (CNR) – outside funding in collaborations with regional universities - NSF, DOD, DARPA, etc.**
- **Industrial partnerships/users (TBD)**

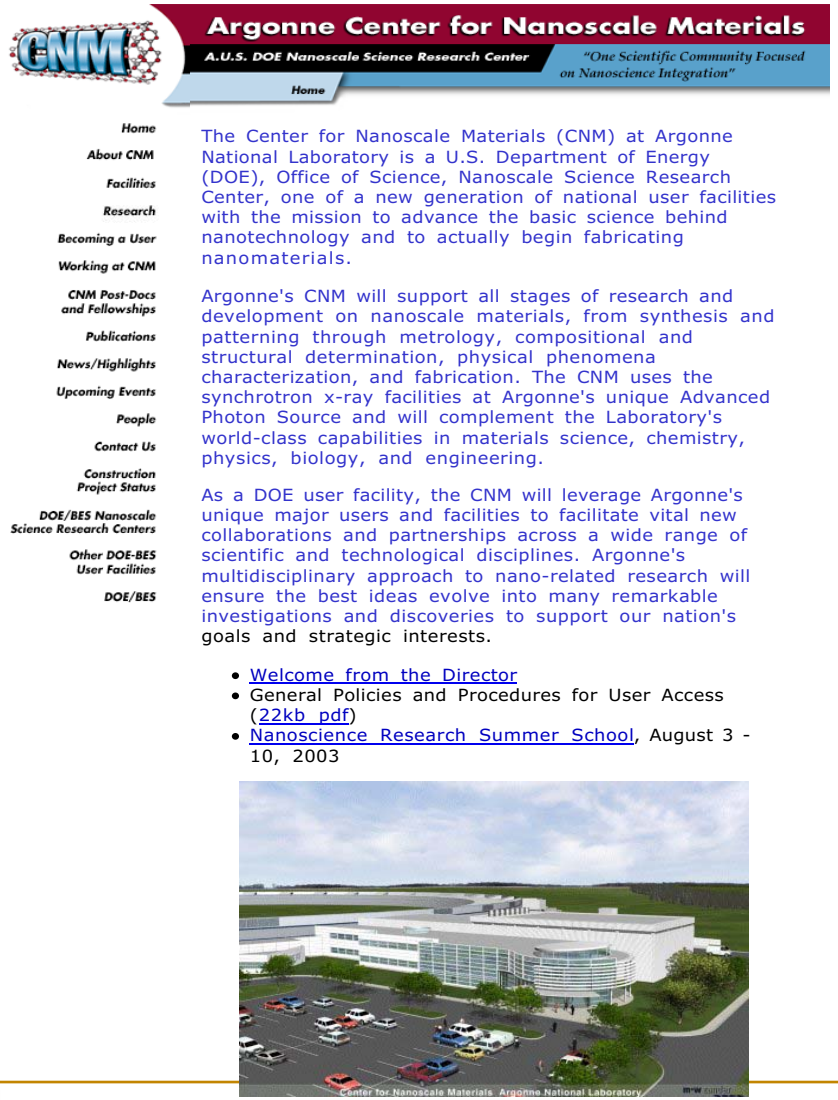
CNM is one of DOE/BES' Five Nanoscale Science Research Centers

- Lawrence Berkeley: Molecular Foundry
- Sandia/Los Alamos: Center for Integrated Nanotechnologies (CINT)
- Oak Ridge: Center for Nano-phase Materials Sciences (CNMS)
- Brookhaven: Center for Functional Nanomaterials (CFN)
- Argonne: Center for Nanoscale Materials (CNM)



www.science.doe.gov/bes/NNI.htm

CNM is Opening for Business



Argonne Center for Nanoscale Materials

A.U.S. DOE Nanoscale Science Research Center

"One Scientific Community Focused on Nanoscience Integration"

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Other DOE-BES User Facilities
DOE/BES

The Center for Nanoscale Materials (CNM) at Argonne National Laboratory is a U.S. Department of Energy (DOE), Office of Science, Nanoscale Science Research Center, one of a new generation of national user facilities with the mission to advance the basic science behind nanotechnology and to actually begin fabricating nanomaterials.

Argonne's CNM will support all stages of research and development on nanoscale materials, from synthesis and patterning through metrology, compositional and structural determination, physical phenomena characterization, and fabrication. The CNM uses the synchrotron x-ray facilities at Argonne's unique Advanced Photon Source and will complement the Laboratory's world-class capabilities in materials science, chemistry, physics, biology, and engineering.

As a DOE user facility, the CNM will leverage Argonne's unique major users and facilities to facilitate vital new collaborations and partnerships across a wide range of scientific and technological disciplines. Argonne's multidisciplinary approach to nano-related research will ensure the best ideas evolve into many remarkable investigations and discoveries to support our nation's goals and strategic interests.

- Welcome from the Director
- General Policies and Procedures for User Access (22kb pdf)
- Nanoscience Research Summer School, August 3 - 10, 2003

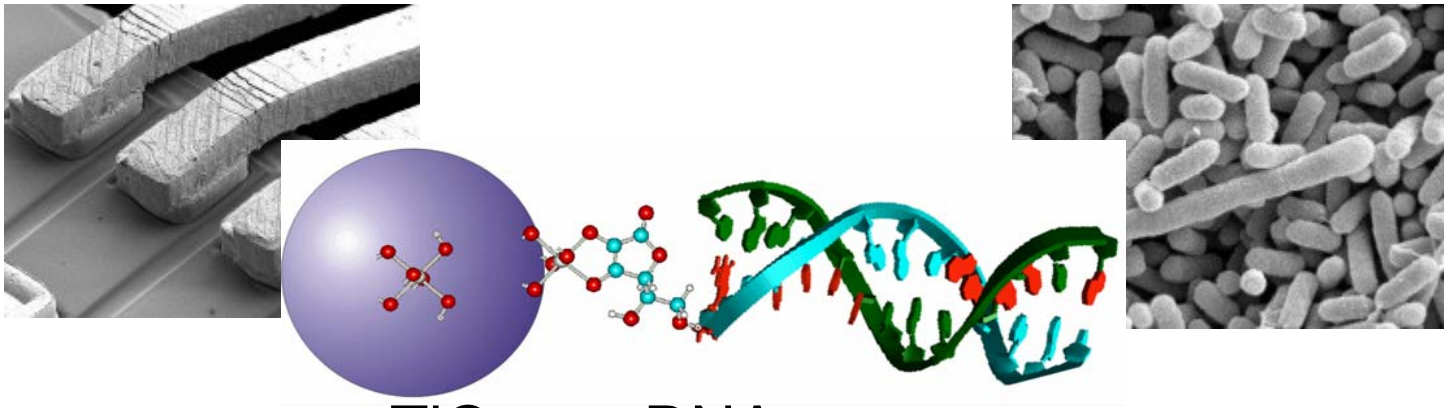
http://nano.anl.gov

Initial CNM Scientific Themes

- The Bio-Inorganic Interface
- *n*-Carbon
- *n*-Magnetism
- Complex Oxide
- Nanophotonics
- The Virtual Fab Lab
- Major fabrication and characterization tools in CNM
  - X-ray Nanoprobe beamline at APS

The Bio-Inorganic Interface

Bio-Inorganic Composites - Creating New Classes of Materials



TiO_2 - DNA

***Objective*: To design and synthesize nanostructured biocomposites that combine the unique features of biomaterials and inorganics**

Challenges:

- **Formation of functional arrays of biomolecules, proteins, etc.**
- **Integration of soft and hard materials**
- **Sequential coupling of processes to create functional components**

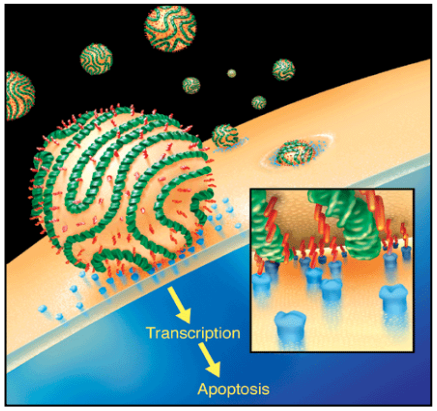
Example of X-ray Fluorescence Imaging at the APS: TiO_2-DNA Nanocomposites in Cells

- Map Ti distribution using XRF, to quantify the success of transfection and visualize target of nanocomposite
- Here, affinity of transfected DNA for ribosomes causes localization to the nucleolus
- Hard X-ray Nanoprobe will allow such imaging at 30 nm resolution, significantly improving applicability to nanoscience

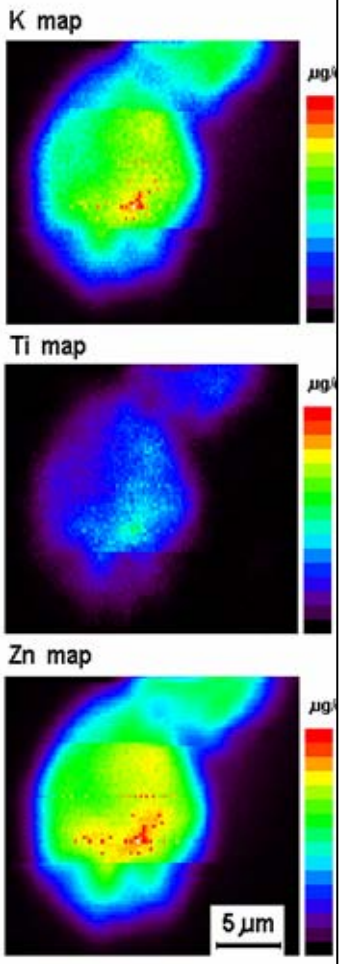
T. Paunesku *et al.,* to appear in *Nature Materials* (Northwestern/ANL collab.)

TiO_2-DNA Nanoparticles for *in vivo* Gene Surgery

X-ray elemental imaging of the cell chromosome showing location of the single stranded DNA-TiO_2 nanoparticle

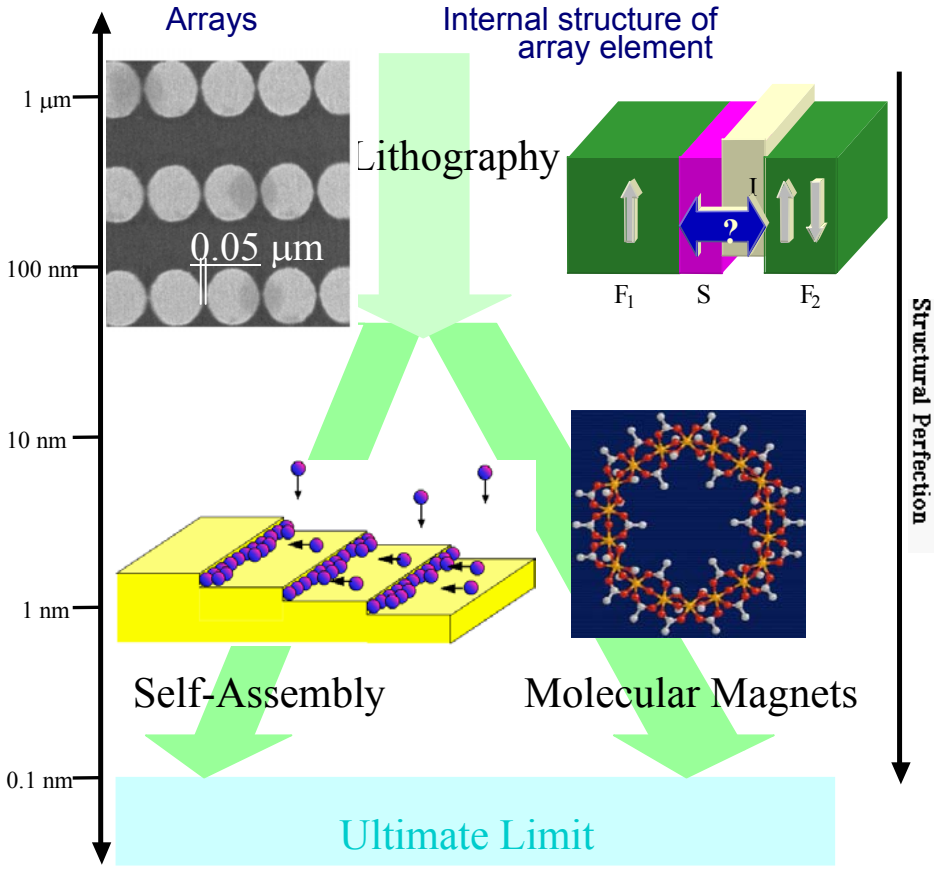


DNA-nanoparticle crossing cell wall



Nanomagnetism

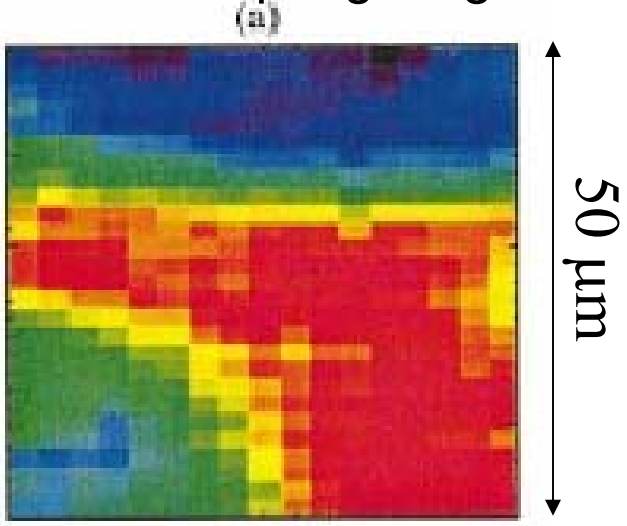
Develop methods to assemble magnetic constituents at the nanoscale so as to control spin interaction and communication



- **Goal:** The quest for magnetic electronics (spintronics) involves basic research to harness the spin as well as the charge of the electron to create new functionalities
- **Scope:** Explore cutting-edge pathways to create and characterize novel magnetic nanostructures

Examples of Magnetic Domain Imaging at the APS

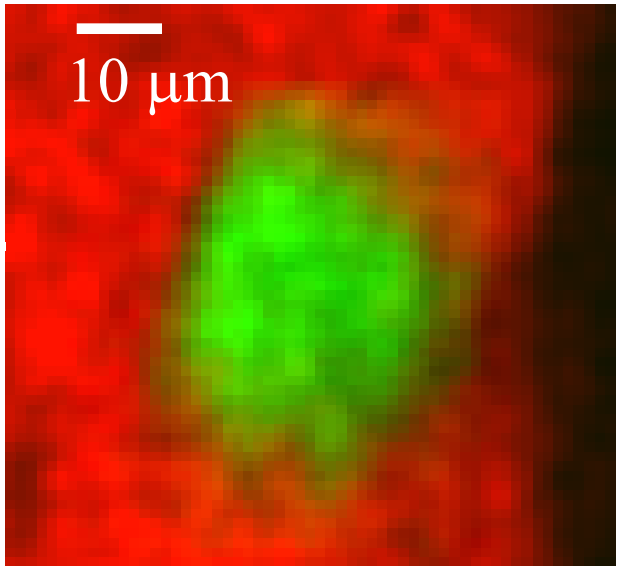
SmCo spring magnet



Hard X-ray MCD @ 4ID

J. Pollmann et al
JAP **89**, 7165 (2001).

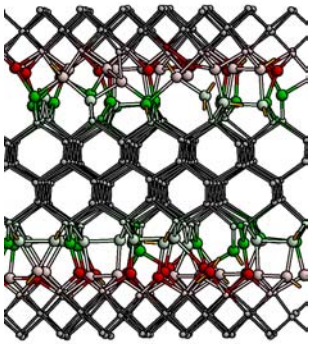
Antiferromagnetic domains in Chromium



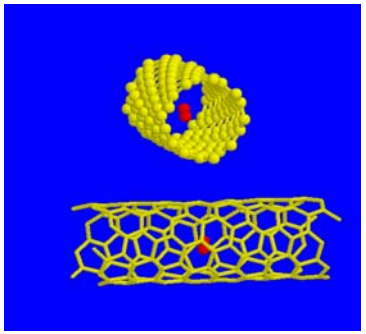
Hard X-ray μ-diffraction @ 2ID

P. G. Evans et al.,
Science **295**, 5557, 1042-1045 (2002)

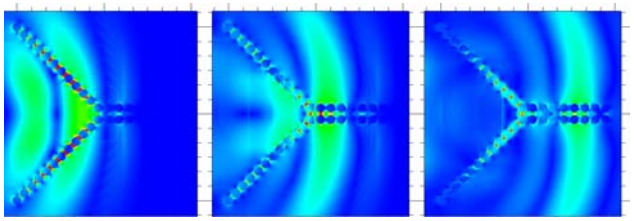
Virtual Fab Lab – Theory and Simulation



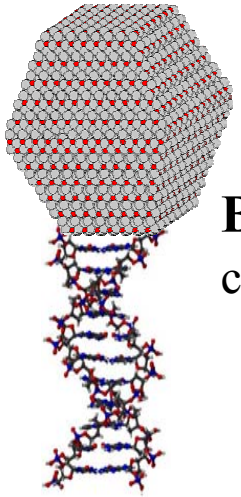
Create new nanomaterials with user-defined properties using theory and simulations



Nanocarbon materials: Electronic structure calculations (nanodiamond, nanotubes…)



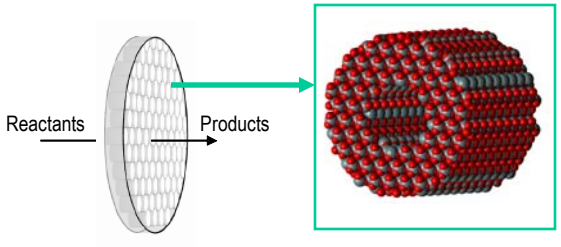
Nanophotonics: Time domain electrodynamics simulation of light propagation in metal nanoparticle arrays



Bioinorganic interfaces: Quantum chemical studies

- S. Gray, et al, PR B 68, 045415 (2003).
- P. Zapol, et al, PRB **65**, 045403 (2002).

Nanocatalysis: Reaction mechanisms, pore structure, kinetics, diffusion, reactor (*multi-scale modeling*)



Enabling Nanoscience through Technical Capabilities

Synthesis

- Self-assembly (chemical, electrochemical, size-selected nanoparticles, etc.)
- Thin-film synthesis

Sculpting

- Nanolithography, nanoinprint
- Milling and etching

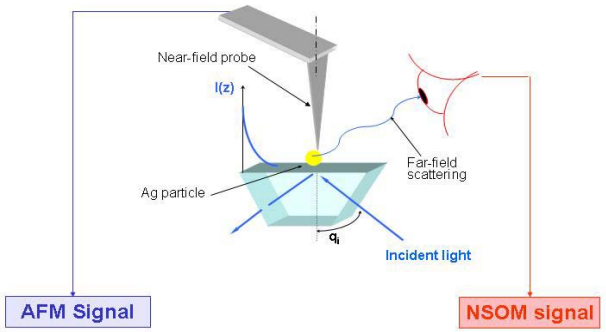
Characterization

- Investigate the synthetic process
- Explore chemistry, physics, materials structure & properties

Theory and Simulation

- Leverage resources from ANL's petaflop initiatives and DOE/SC computing infrastructure investment

Aligned
Polymer Scaffolds



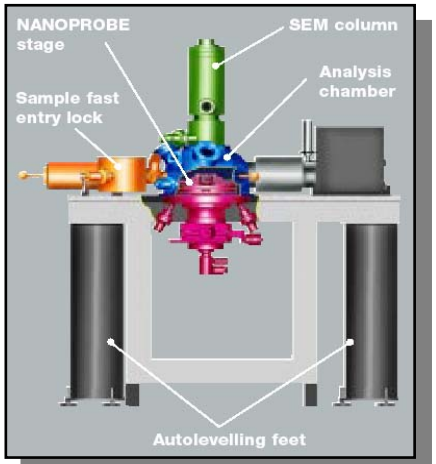
Apertureless NSOM

Key Fabrication and Characterization Tools…

e-beam lithography
L. Ocola

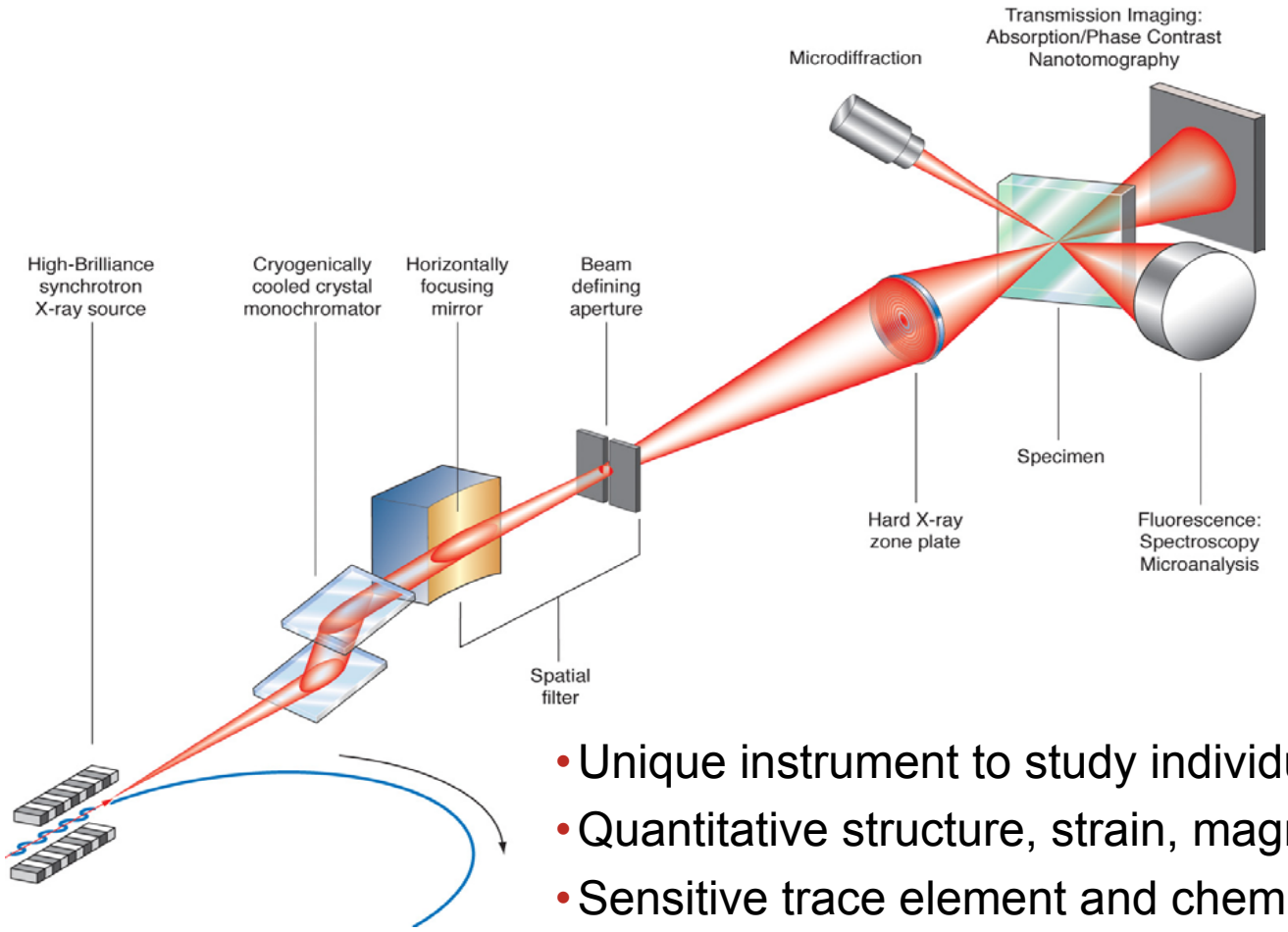
Representative Example:
JEOL 9300FS at Bell Labs
New Jersey Nanotechnology Consortium

Combined
SEM/SPM
S. Streiffer



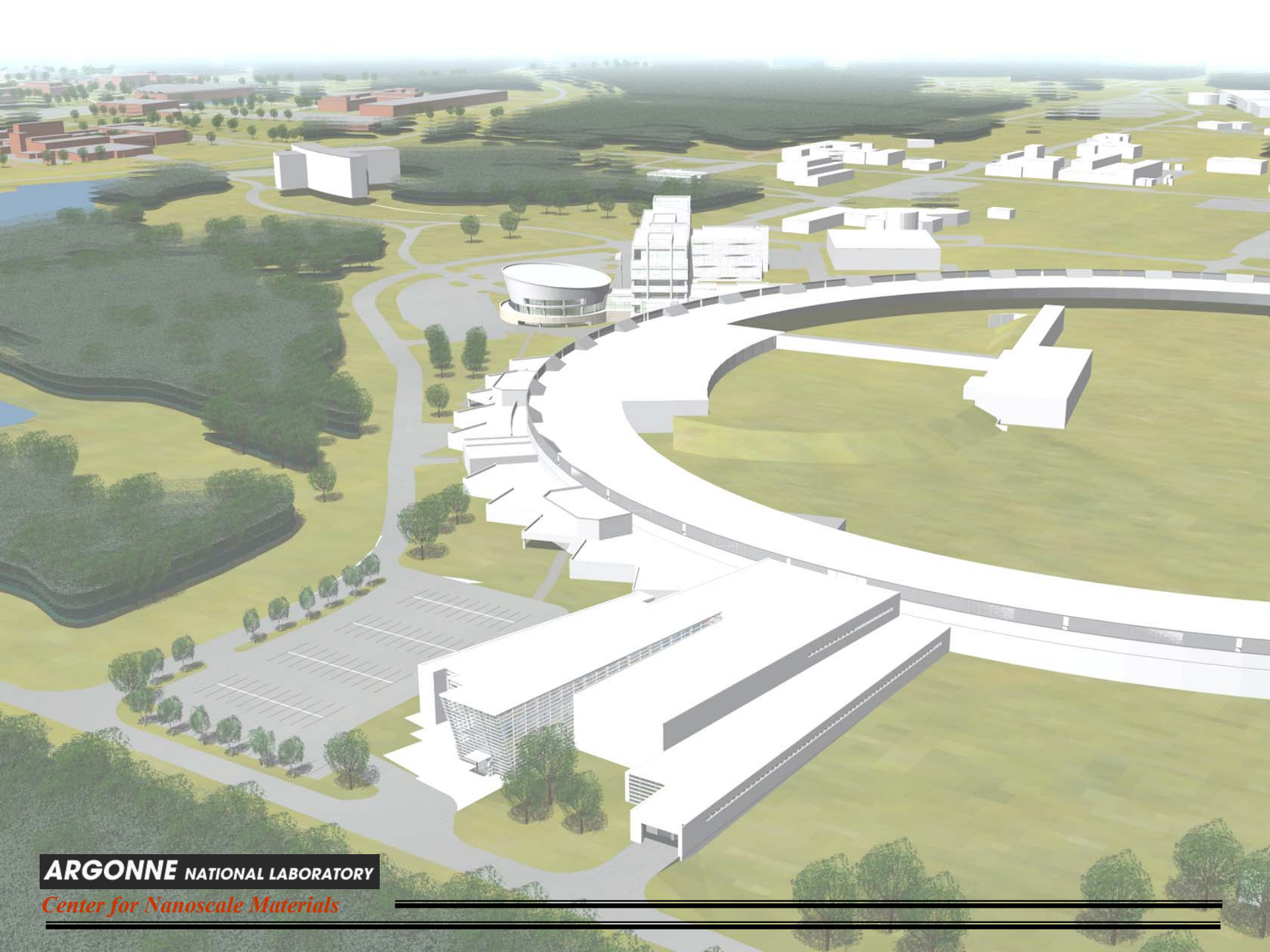
Electron Microscopy Center (MSD)
TEM, TEAM…

The Hard X-ray Nanoprobe at the APS



Project leader,
G.B. Stephenson

- Unique instrument to study individual nanostructures
- Quantitative structure, strain, magnetization…, imaging
- Sensitive trace element and chemical state analysis
- Ability to penetrate overlayers, environments, fields
- 30 nanometer or better spatial resolution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Center for Nanoscale Materials