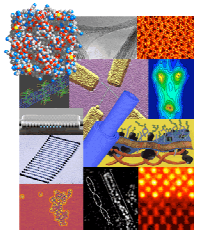
DOE Nanoscience Centers - overview

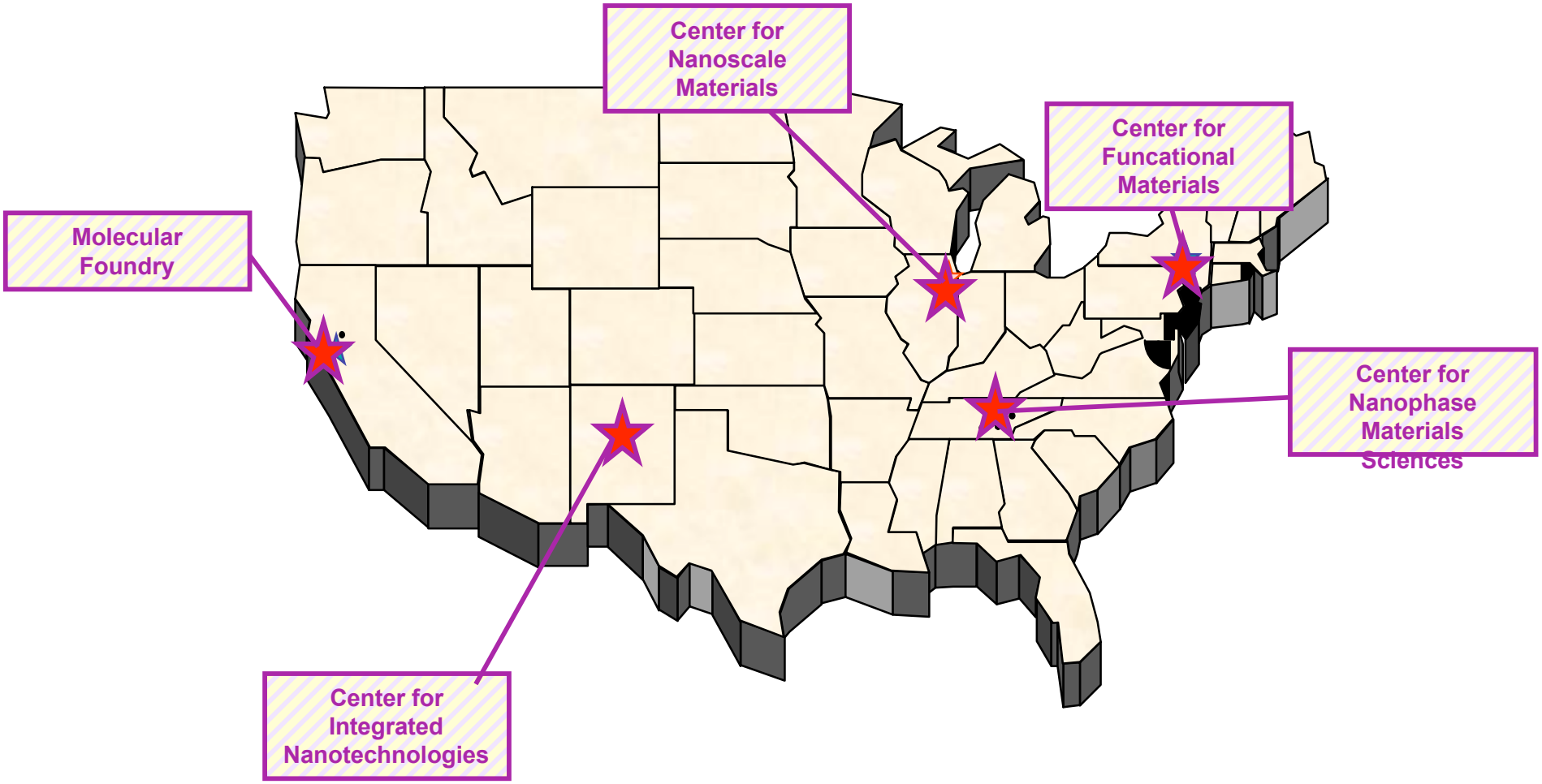


DOE NSRC National Workshop
February 27, 2003
Washington, DC

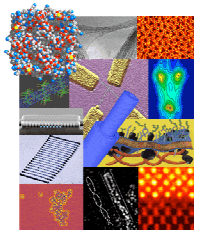
Presented by
Paul Alivisatos
Lawrence Berkeley National Lab

Sam Bader	Argonne	Bob Hwang	Brookhaven
Doug Lowndes	Oak Ridge	Terry Michalske	Sandia/Los Alamos

The Five Centers



Mission



•Enable scientists and engineers from all disciplines to participate in the design and development of advanced new materials based on nanoscale patterning and control

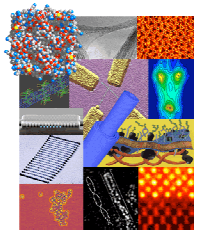
•Educate and train a new generation of scientists

•Determine which methods and processes can be widely disseminated and used, and provide the mechanisms for this dissemination

•Push the state-of-the-art in nanoscale materials creation

•Provide the means to solve important problems in energy science

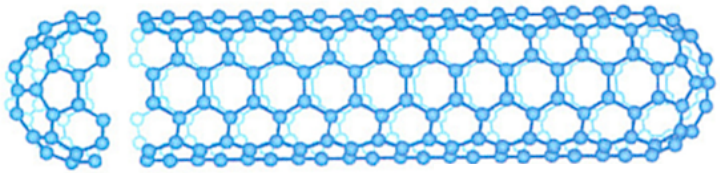
Some topics of interest

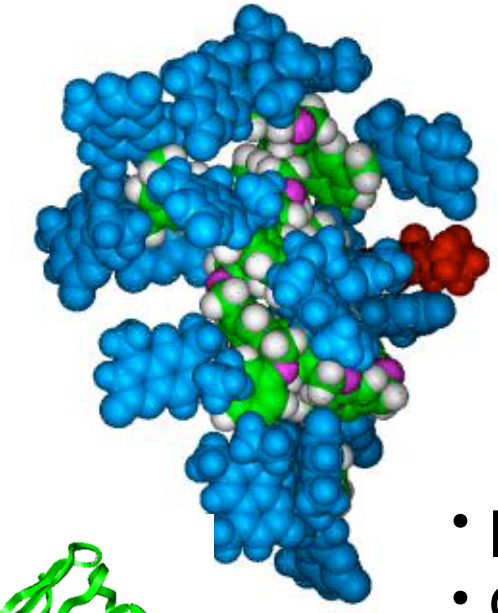


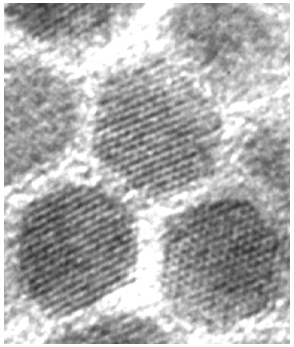
- Catalysis
- Hydrogen Storage
- Mechanical composites
- Solar Cells
- Fuel Cells
- Water Splitting
- Batteries
- Superconductors
- Magnetic Materials
- Lighting
- Thermoelectrics
- Chem-Bio Sensors
- Quantum Energy Converters
- …

Diversity of Nanoscale Building Blocks

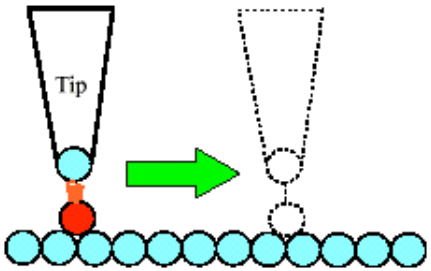
- nanocrystals
- nanorods, nanotubes
- dendrimers
- scanning probe tips

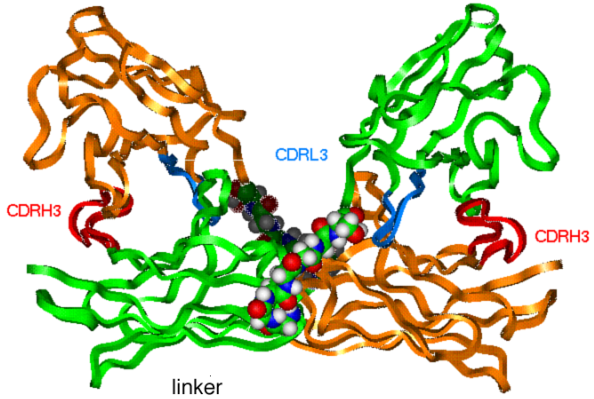


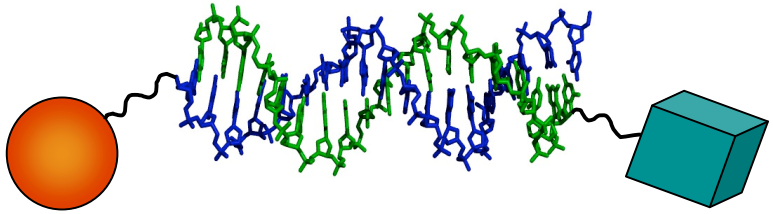




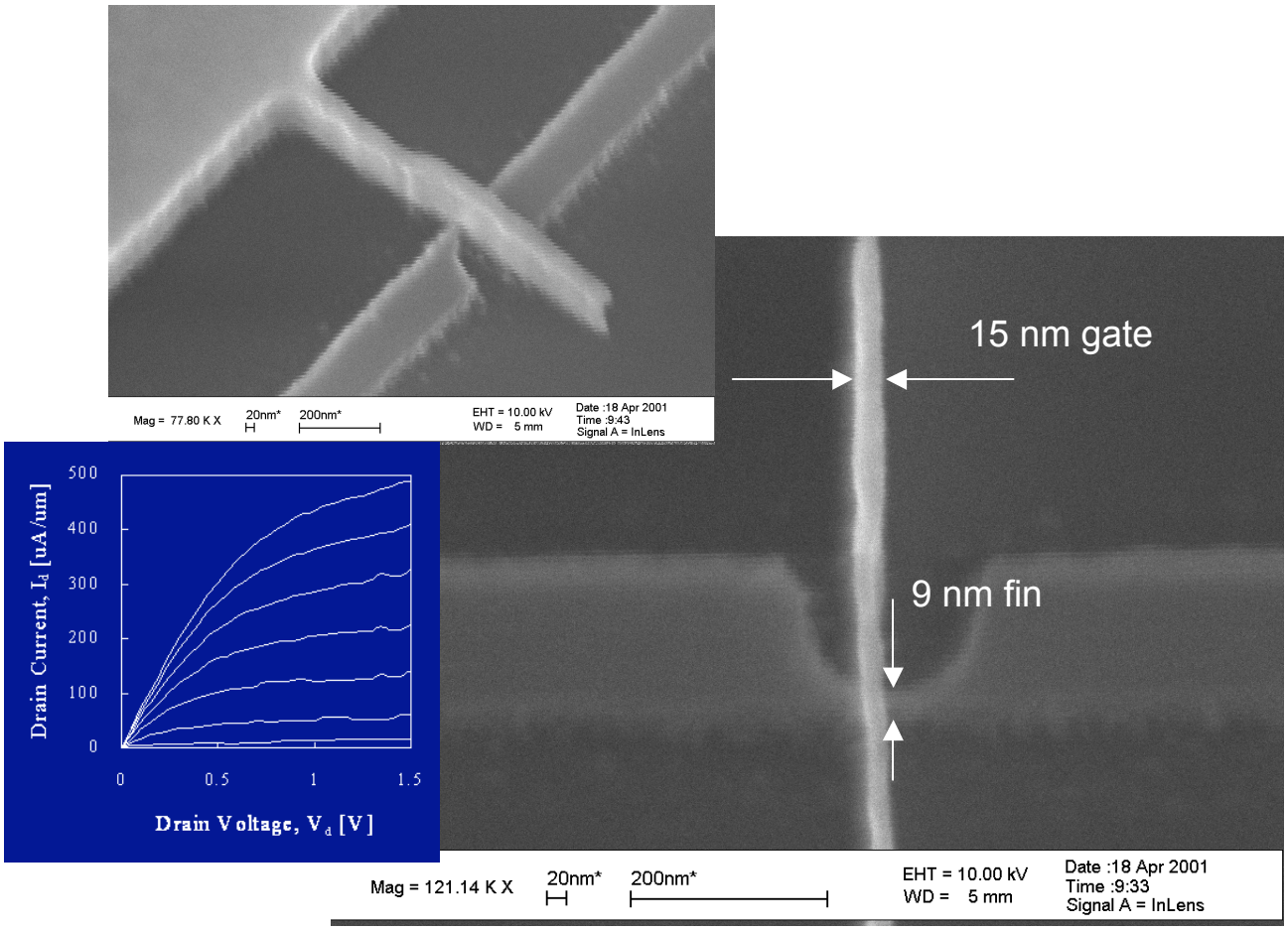
- patterned surface
- cell membranes
- DNA
- proteins







Integration with “conventional” electronics

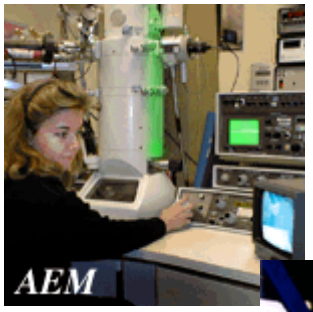


Nano-silicon FinFET with 15 nm gate and 9 nm fin. This is a fully functional MOS transistor with excellent electrical performance.

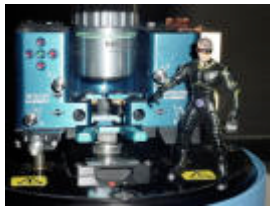
Hu and Bokor

Diversity of characterization tools

stm

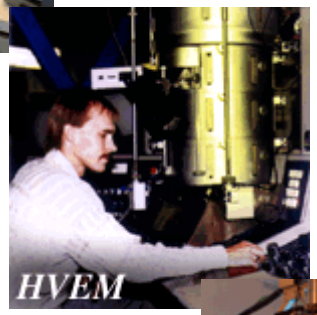


als



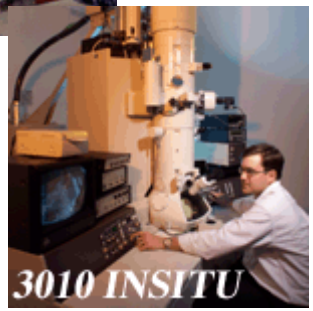
afm

aps

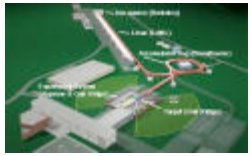


nsls

xrd



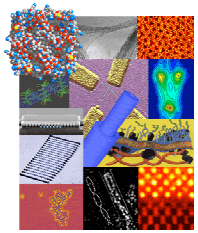
xps



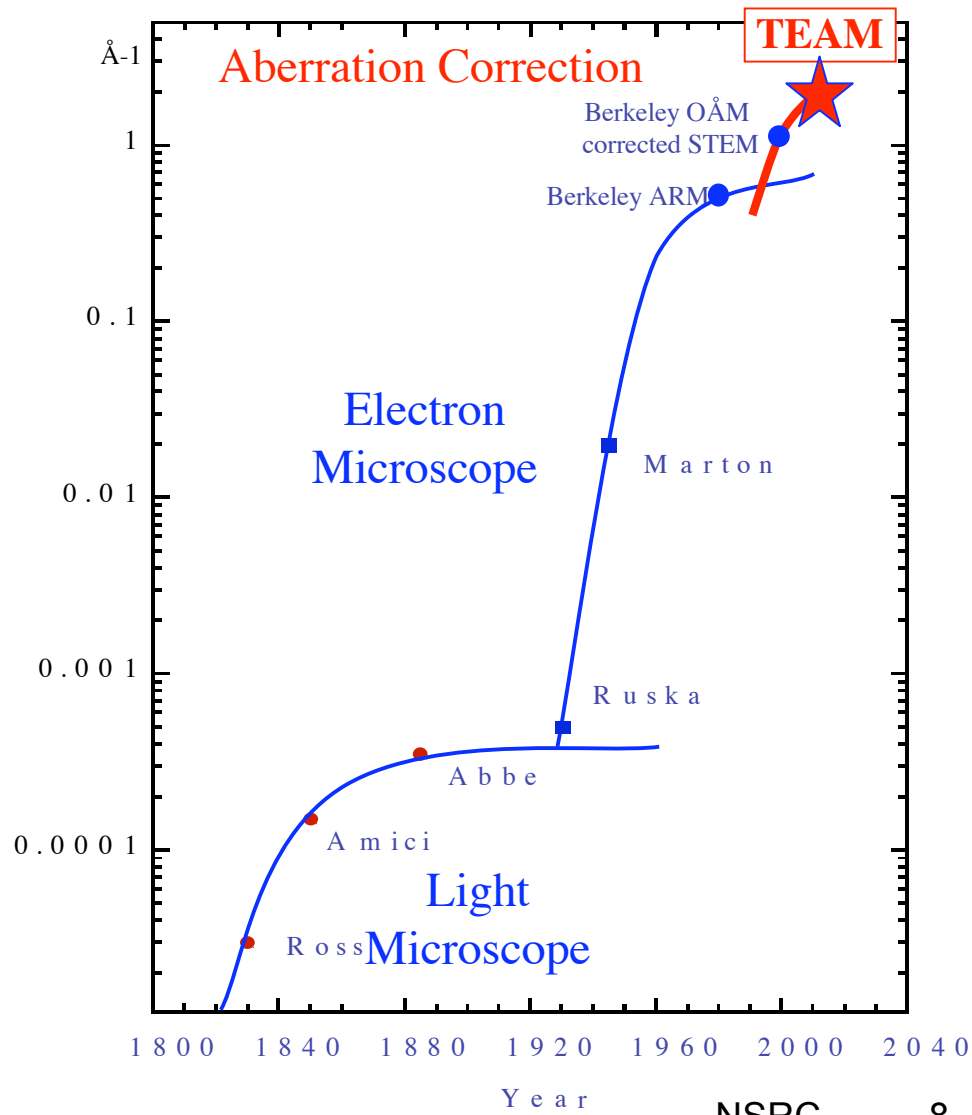
sns

TEAM

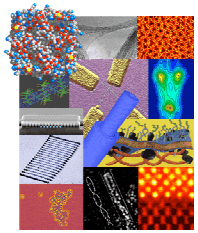
Transmission Electron Aberration-corrected Microscope



- **Key research tool for nanoscience - a new generation of electron microscopes.**
- **5-Lab project (LBNL, ANL, BNL, ORNL, FS-MRL), led by NCEM.**
- **Breakthrough in electron optics: aberration correction dramatically improves resolution, sensitivity.**
- **Simultaneous advances in electronics, detectors and computers open new opportunities for scientific investigation**
- **TEAM project - a platform for a new aberration-corrected microscope with unprecedented spatial, spectral and temporal resolution.**



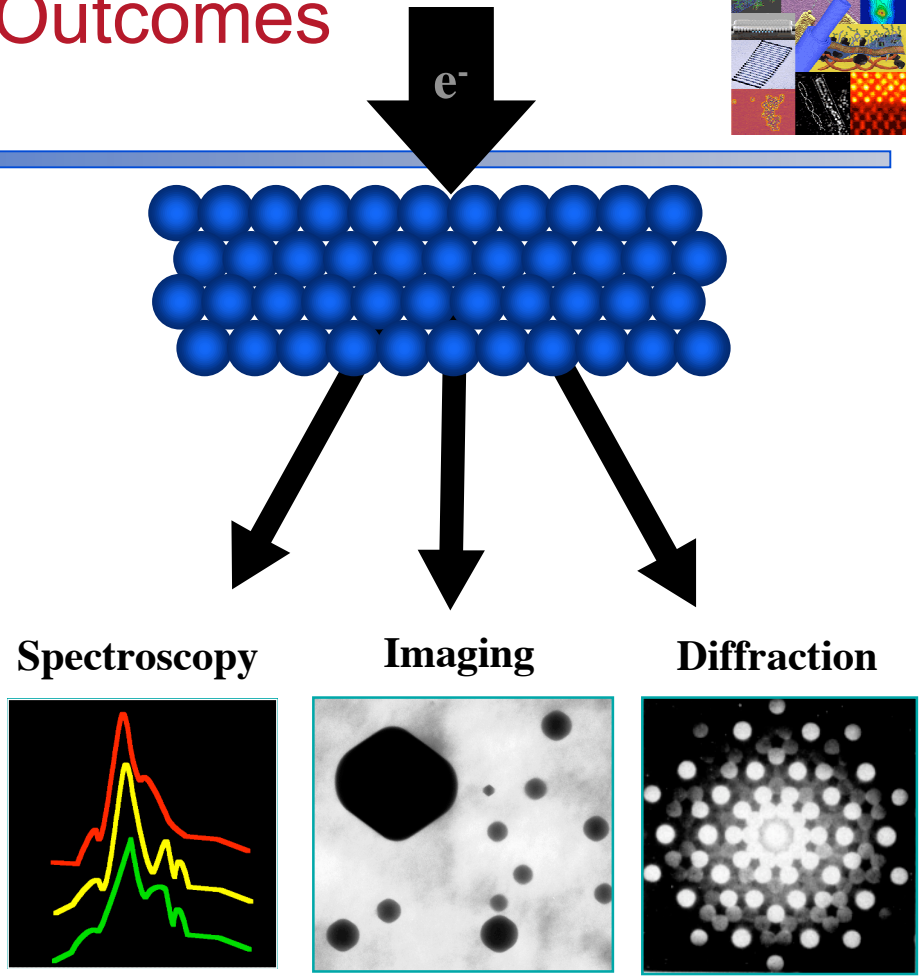
TEAM Project Outcomes



A unique tool for nanoscale characterization

Ability to image the inner structure and behavior of materials and their defects down to the atomic level.

From 2D to 3D
From static to dynamic

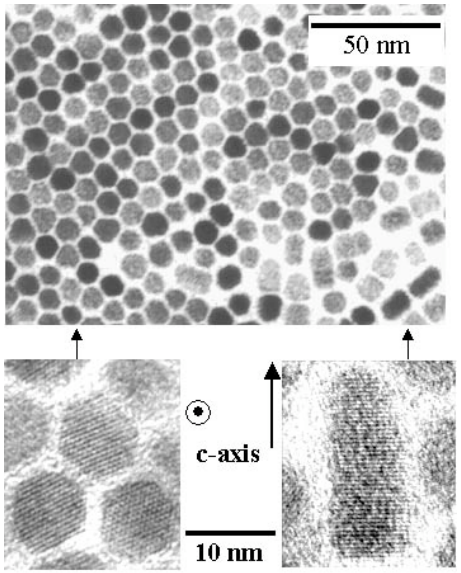


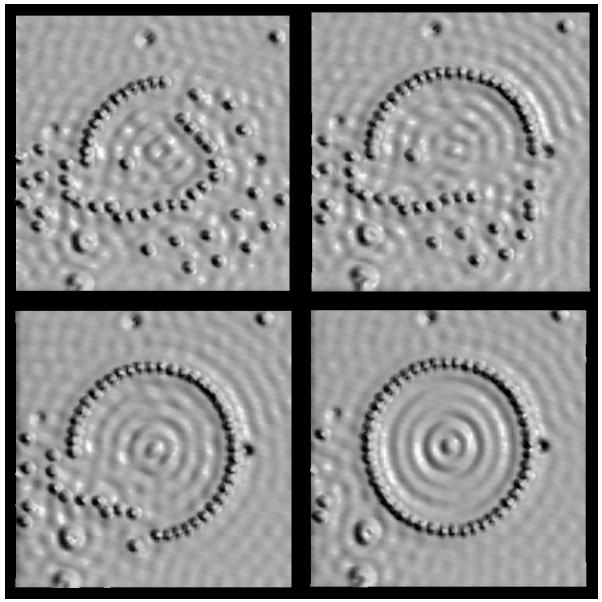
0.1eV spectral resolution for individual atomic column spectroscopy

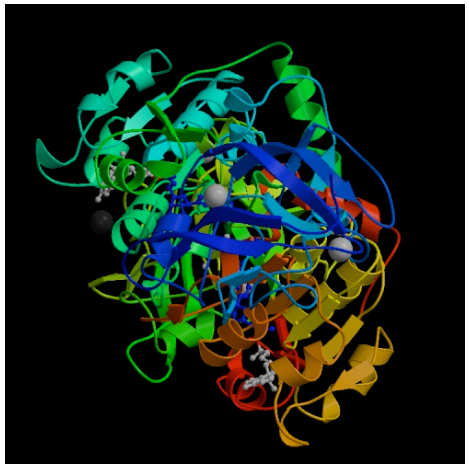
Deep sub-Angstrom resolution for atomic resolution tomography + structural imaging in real time.

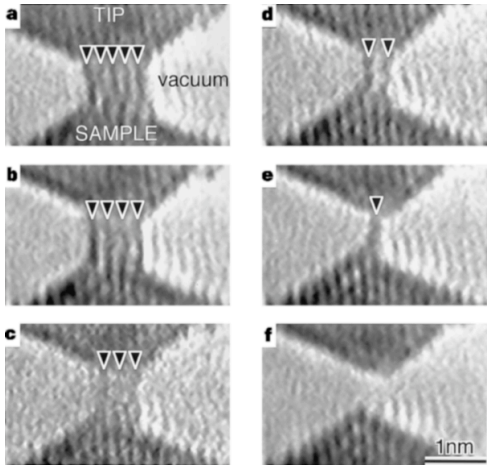
Position-sensitive coherent nanodiffraction for 3-D structure analysis

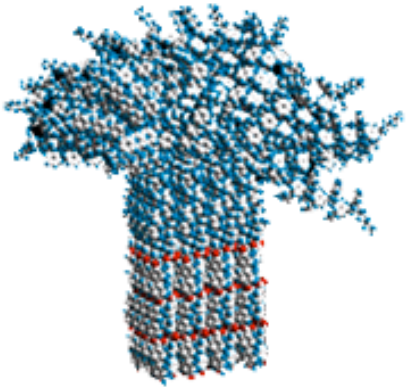
Building Blocks - Cottage Industries

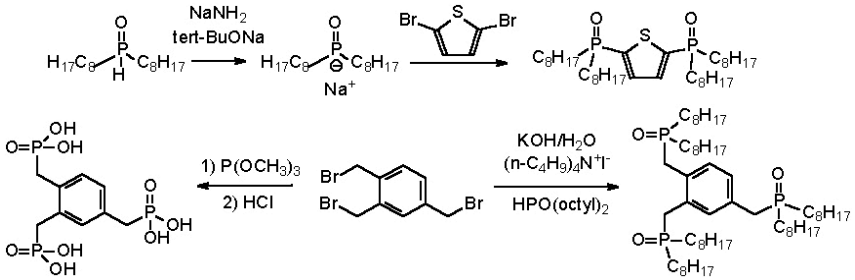




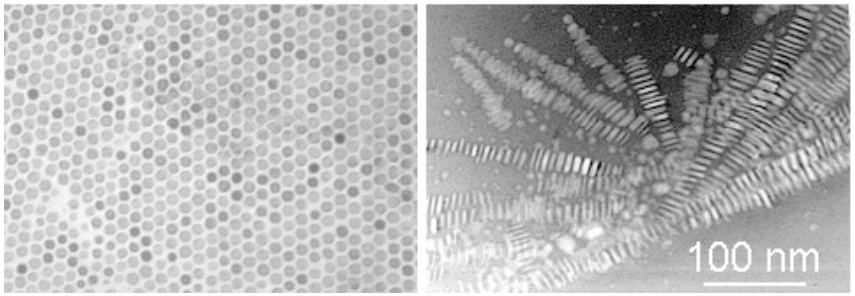


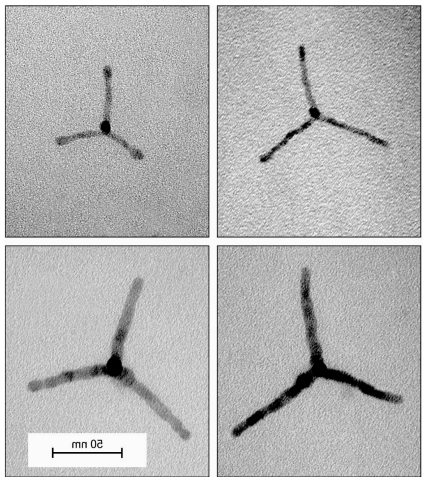


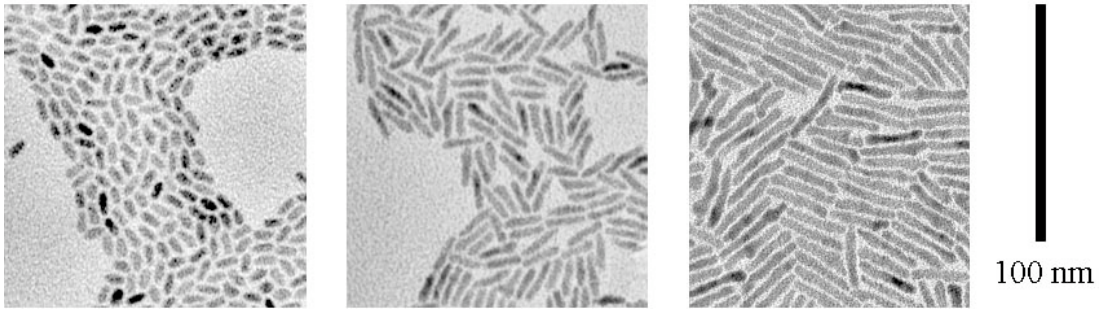


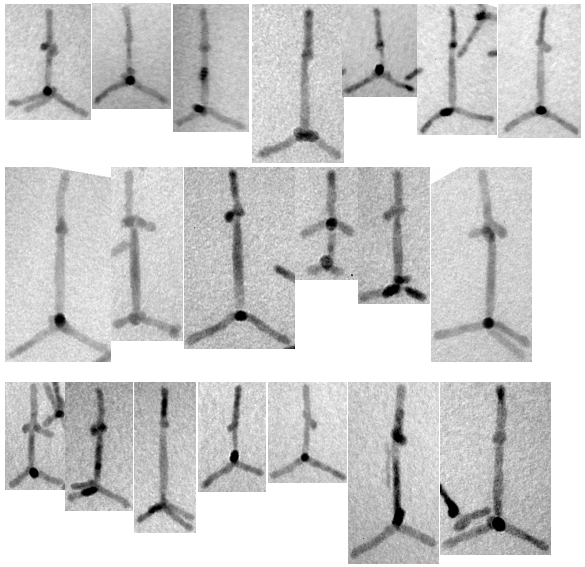


Accelerate the information flow in nanoscience

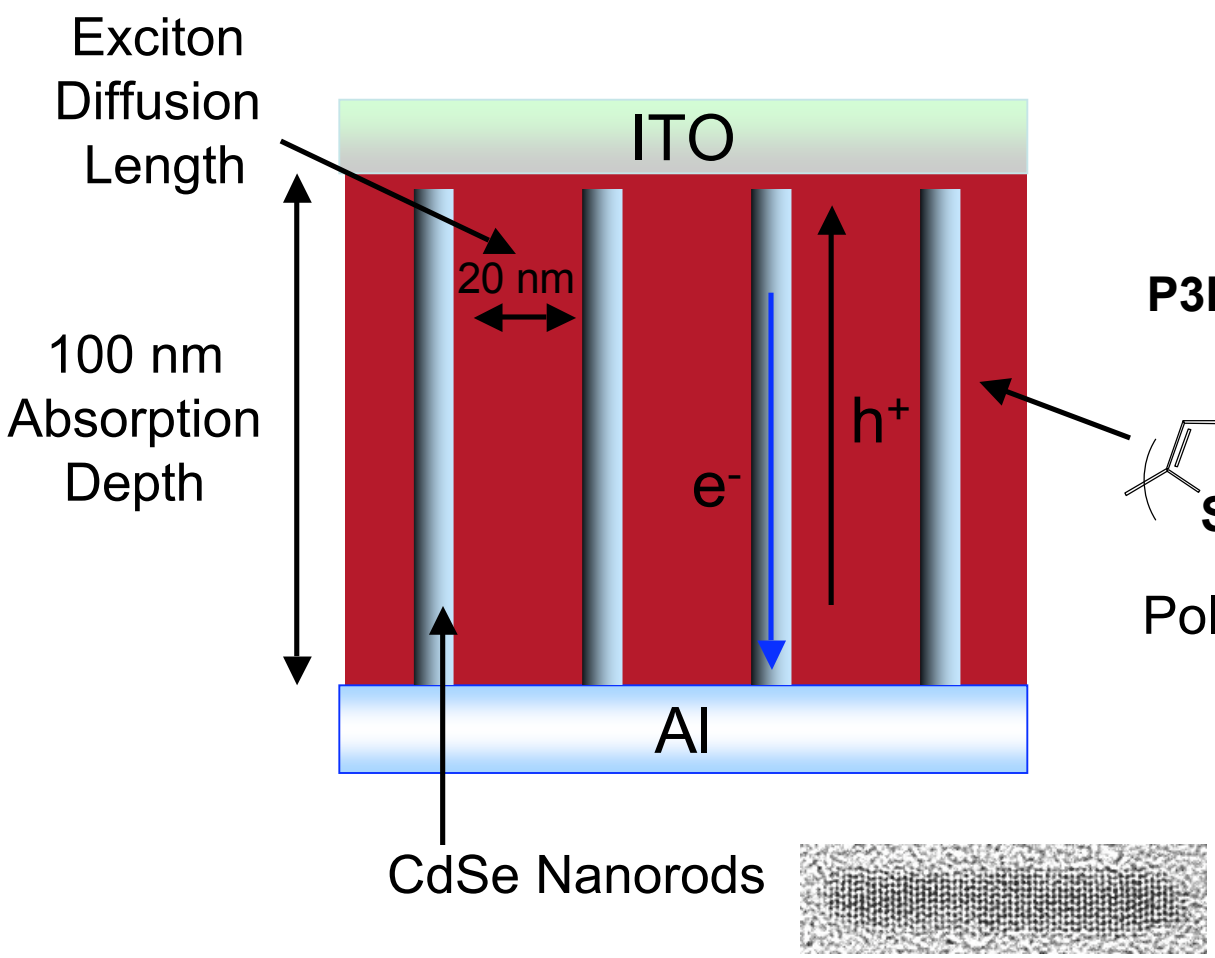


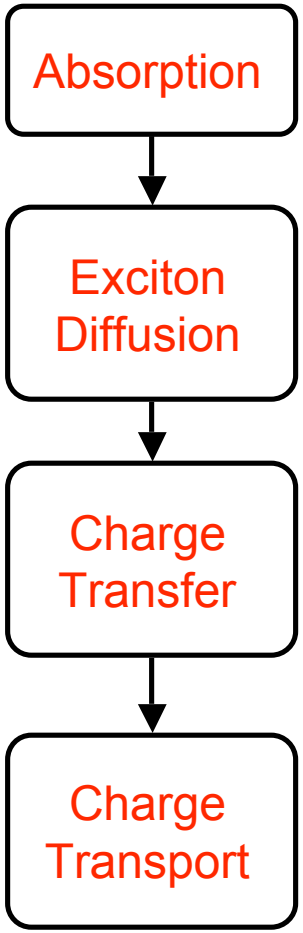






Hybrid solar cell
example of heirarchical design and assembly

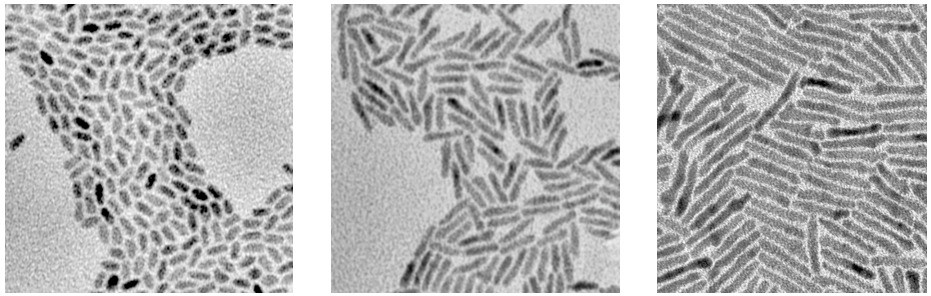




Transport: Bicontinuous Network

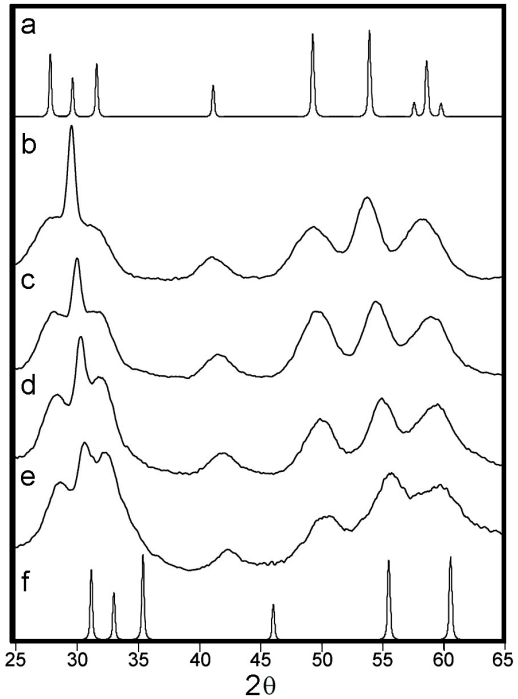
Theory, Microscopy, Diffraction

Imaging
NCEM

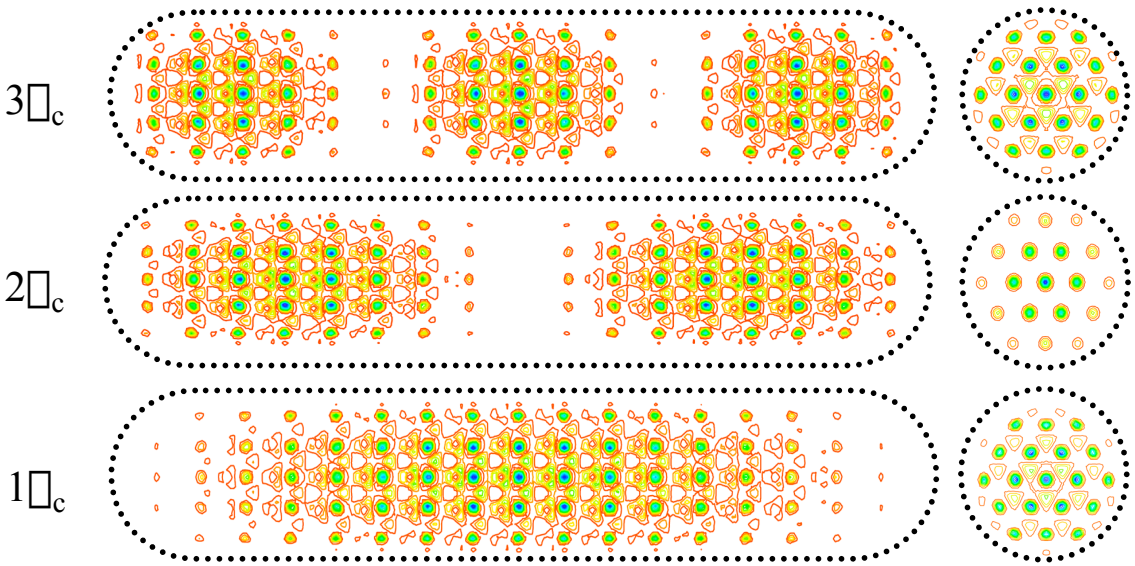


100 nm

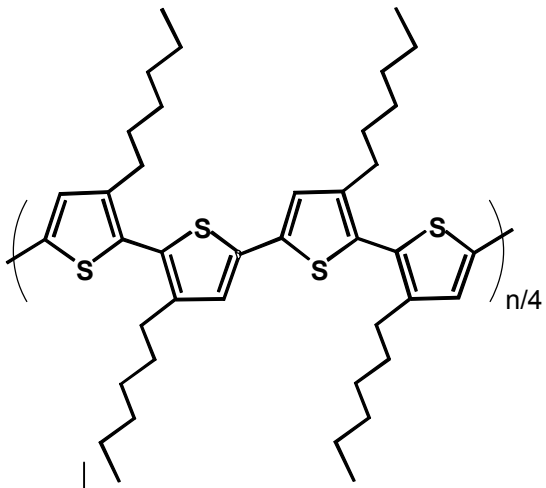
Diffraction-ALS

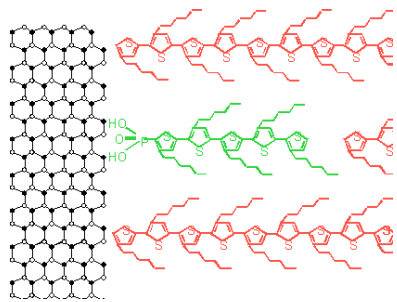


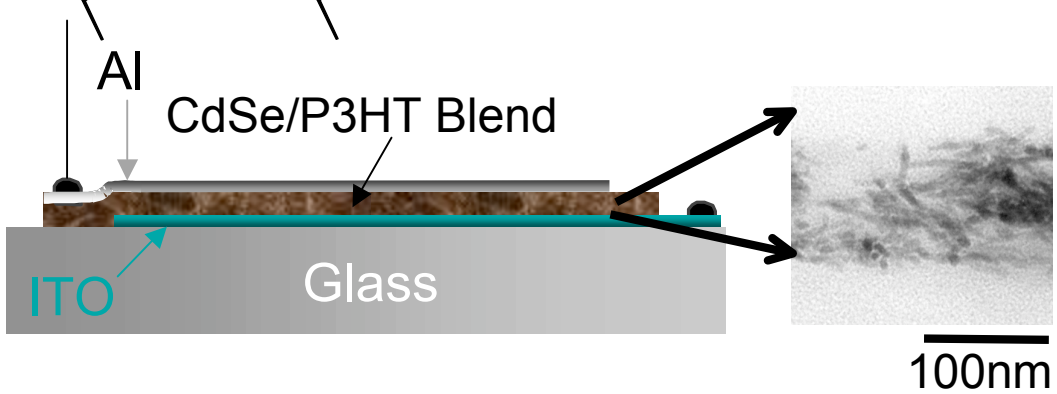
Energy Levels- NERSC



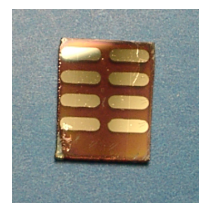
First results







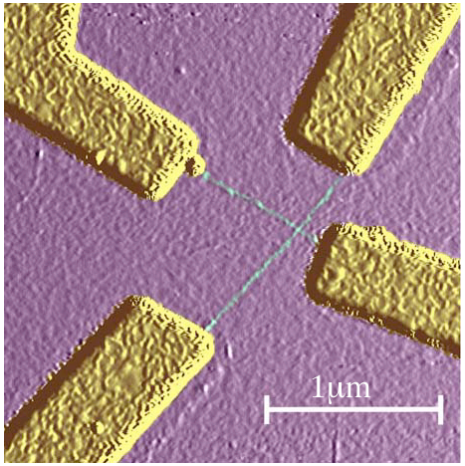
- Nanorod synthesis
- Polymer synthesis
- Electroactive Surfactant Design- Organic Synthesis Lab



"Hybrid nanorod-polymer solar cells." Science **295**(5564): 2425-2427

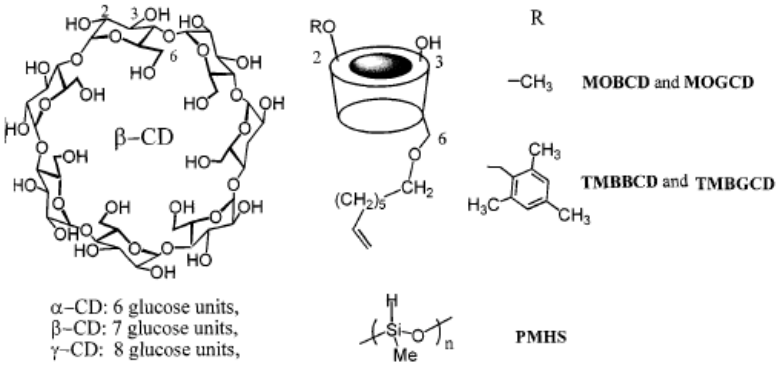
Chem-Bio Detection Example

Electrical sensors -
Nanowires and nanotubes



1 d conductor
Maximum **sensitivity**
Zettl and McEuen
Berkeley

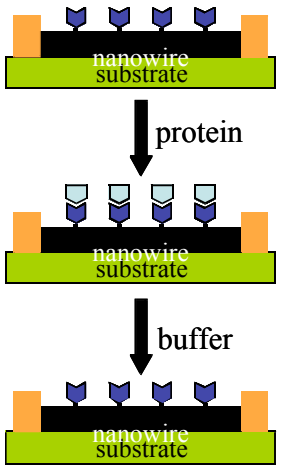
Artificial Binding Pockets
- Selectivity -

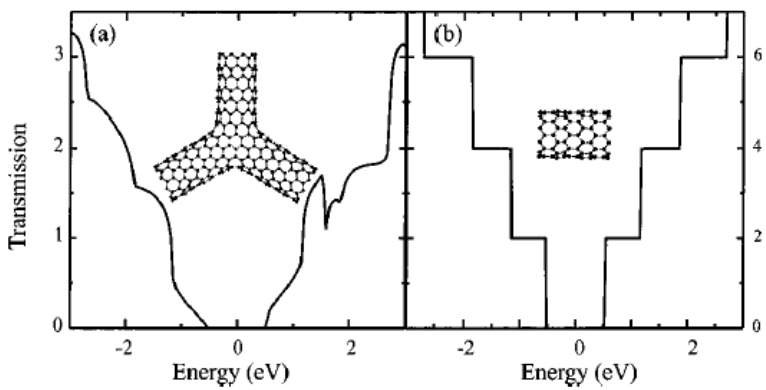


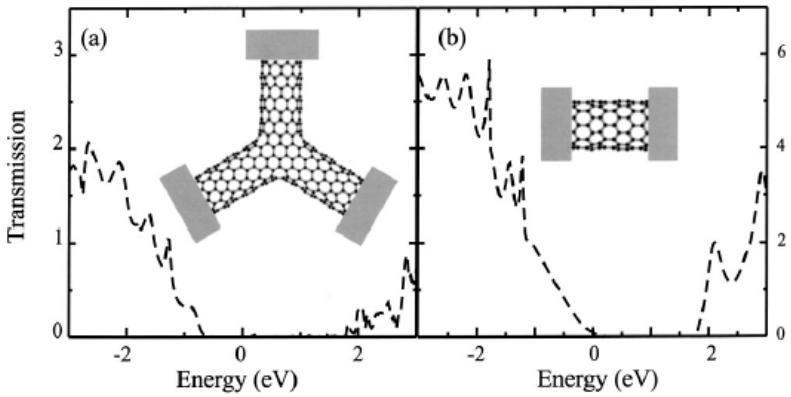
B. Swanson et. al. – Los Alamos

TALANTA 54 (3): 439-445 MAY 10 2001

Contacts and functionalization are key



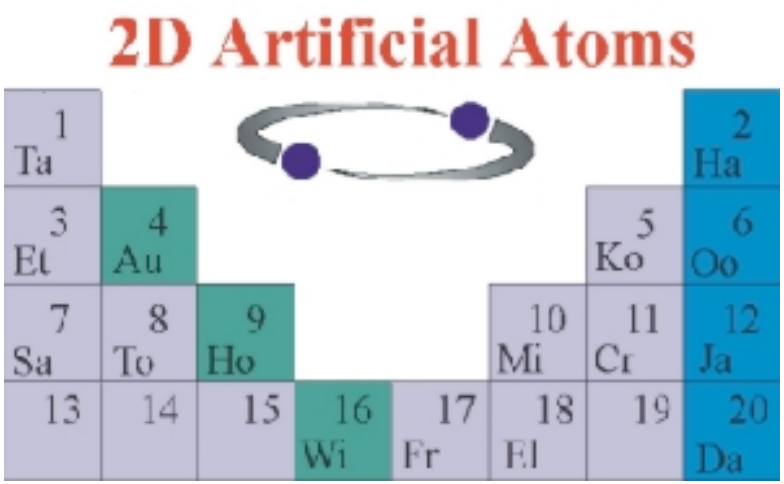




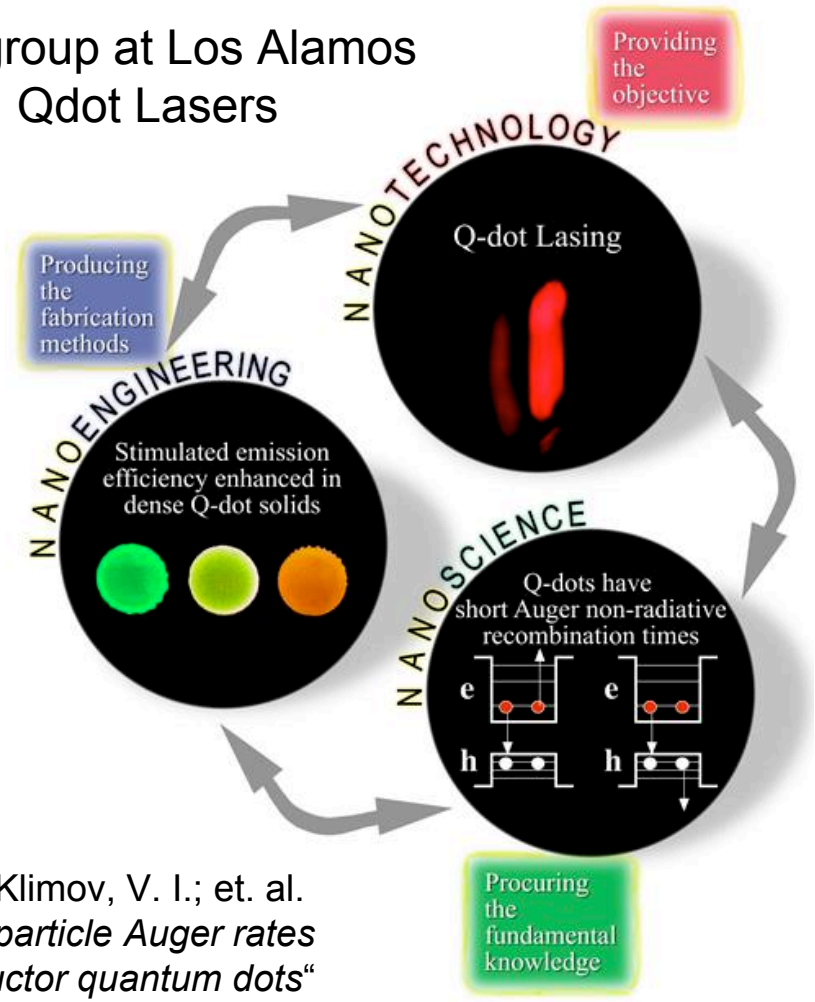
Meunier et. al .Oak Ridge
Appl. Phys. Lett., Vol. 81, No. 27, 30 December 2002

“Limits of energy conversion” example

Quantum Boxes to control electron waves



Klimov group at Los Alamos
Colloidal Qdot Lasers



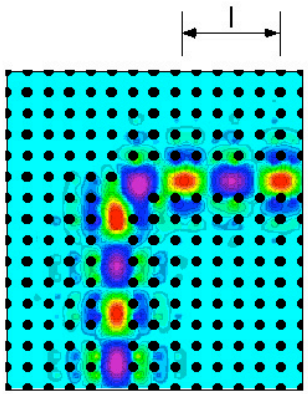
Klimov, V. I.; et. al.
"*Quantization of multiparticle Auger rates in semiconductor quantum dots*“
Science **2000**, *287*, 1011.

Limits of energy conversion

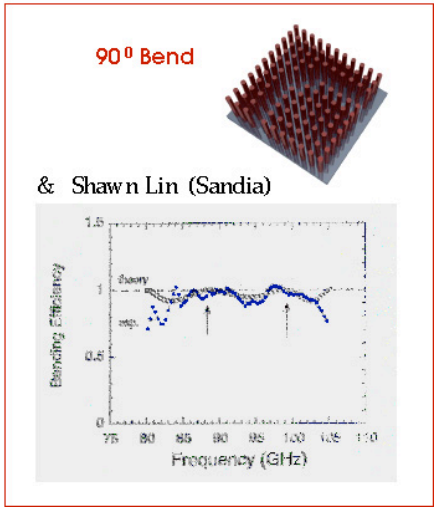
Control of Photon
Density of states in 2 and 3 D

Sharp Bends in PBG Waveguides

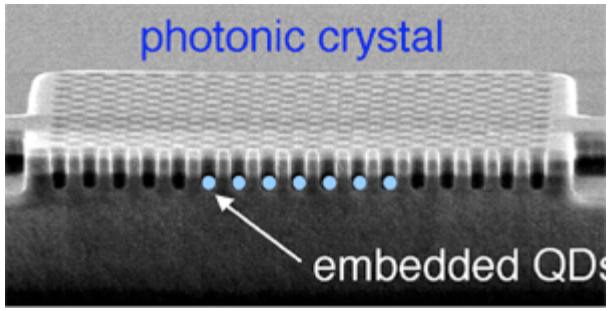
Maps onto the problem of 1D resonant electron scattering



Sharp 90 degree bend
100% transmission!

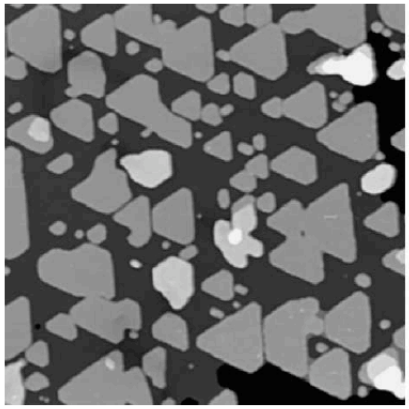


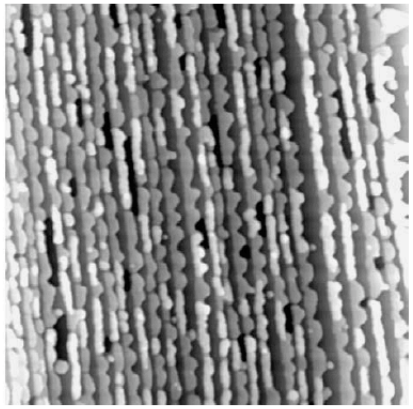
Shawn Lin and coworkers
Sandia

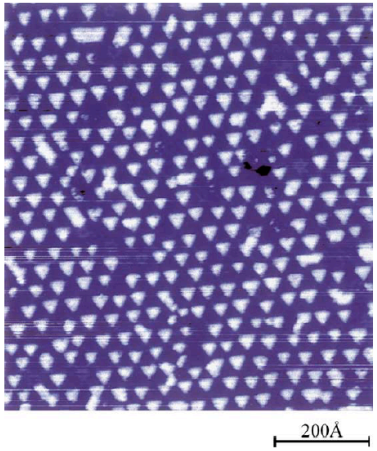


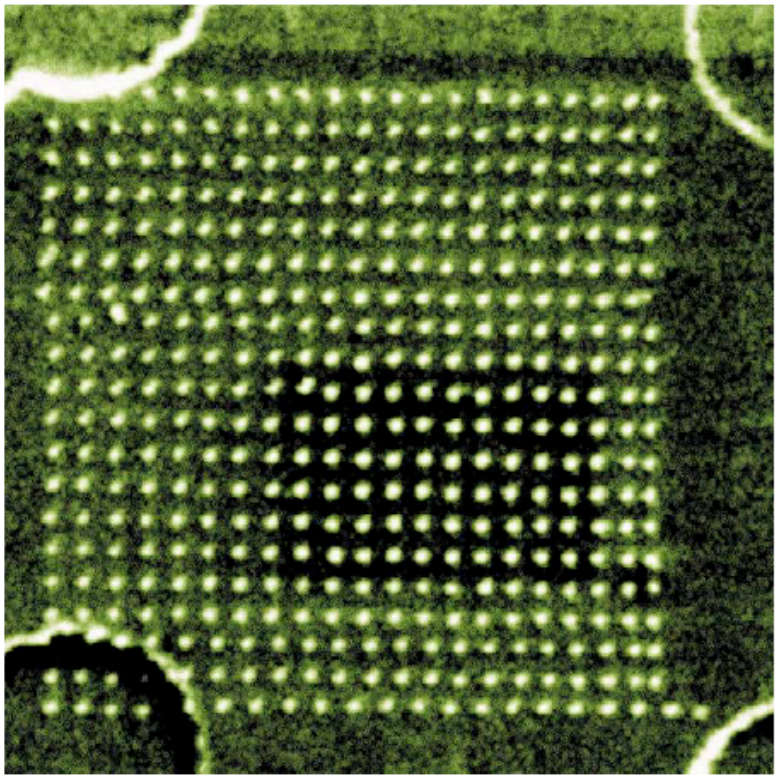
Combine control of electronic and photonic density of states
“energy funnels”

New magnetic materials





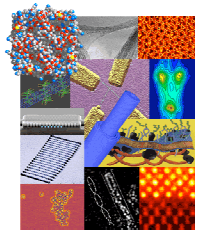


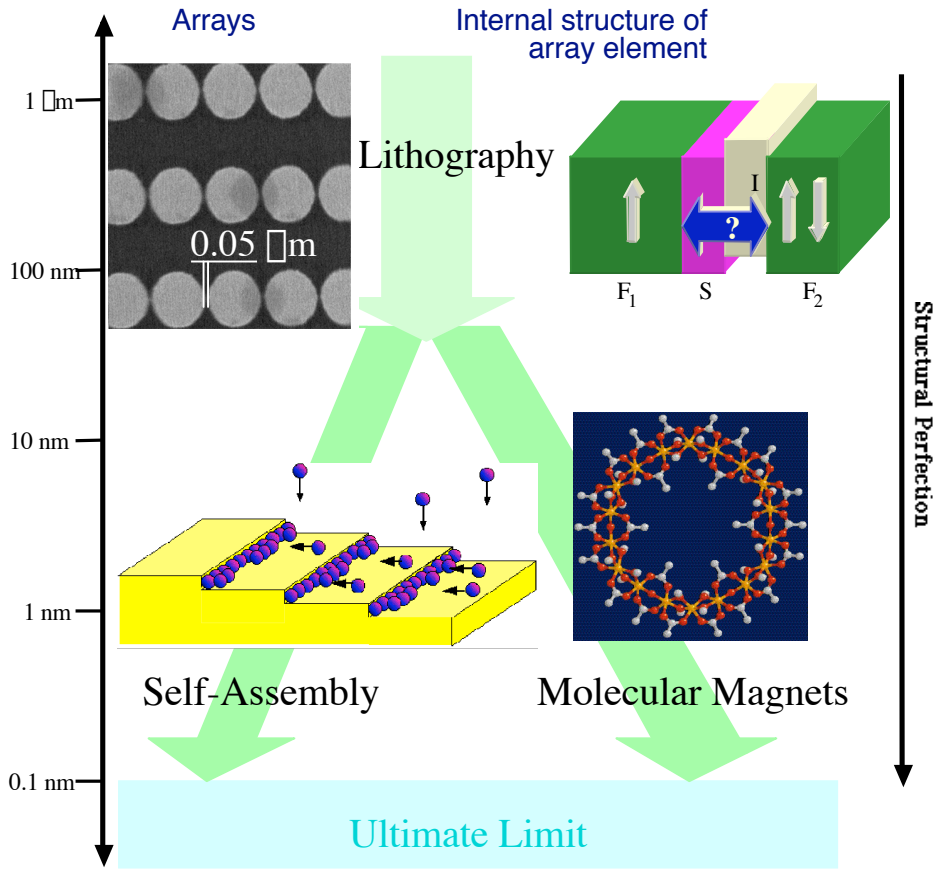


"Magnetism in low dimensionality," S.D. Bader, Argonne National Laboratory, Surface Science 500 (2002) 172–188

"Tailoring magnetism in artificially structured materials: the new frontier," J. Shen (Solid State Division, **Oak Ridge National Laboratory**), J. KirschneR (Max Planck Institut f€ur Mikrostrukturphysik), Surface Science 500 (2002) 300–322

New magnetic materials

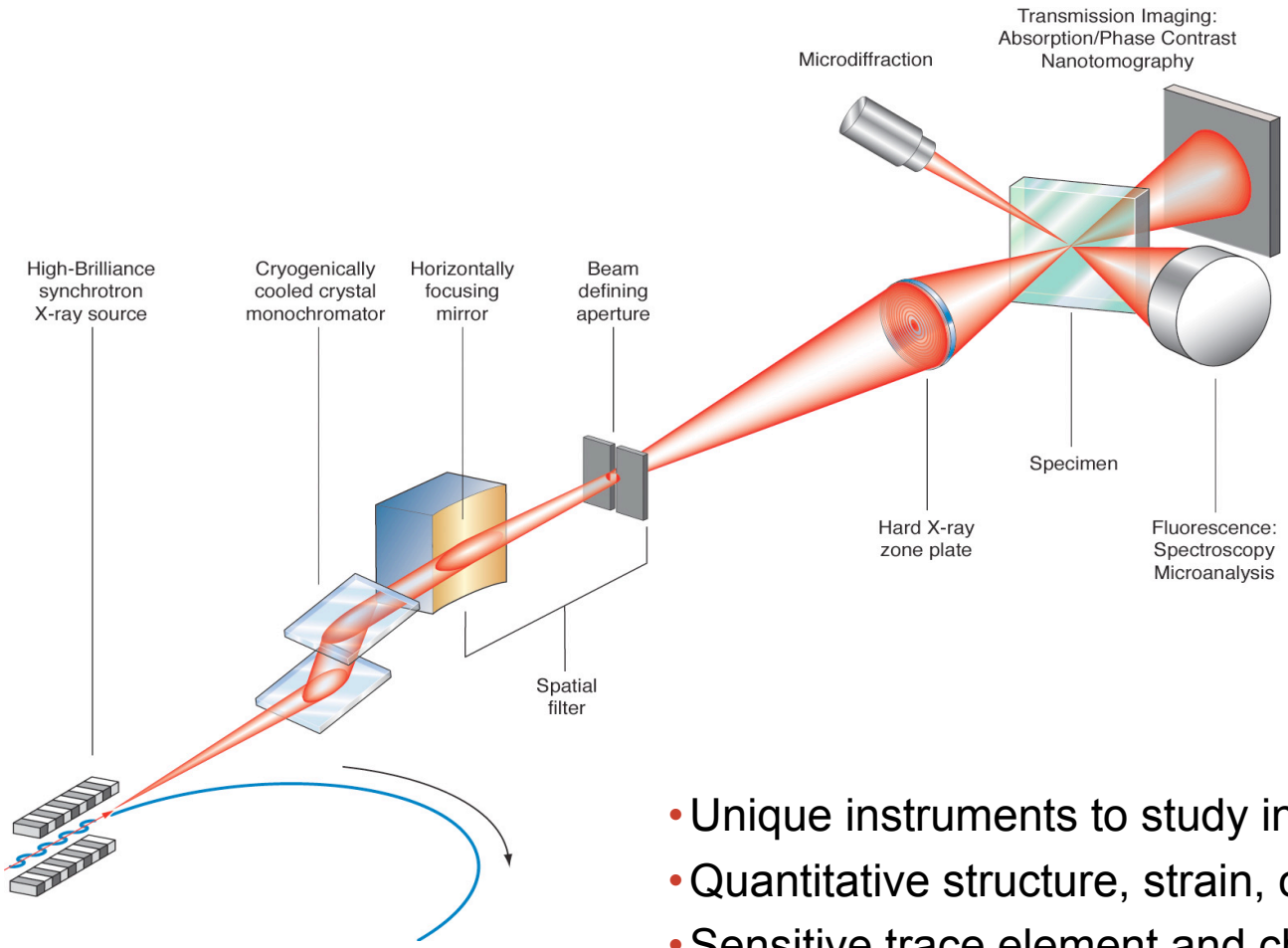




magnetic electronics - basic research to harness the spin as well as the charge of the electron to create new functionalities.

Argonne/Oak Ridge

Beamlines for studying growth of nanostructures



Brookhaven
Argonne

- Unique instruments to study individual nanostructures
- Quantitative structure, strain, orientation imaging
- Sensitive trace element and chemical state analysis

The people

Facility Directors

PIs responsible for particular areas of expertise

Foundry staff scientists

- Specialists in particular fabrication/characterization methods
- Responsible for user relationships
- Independent research activity

Postdoctoral Associates

- Research project in association with a mentor
- Relationship with one user group

Graduate and undergraduate participation

The buildings
(construction start dates)

Oak Ridge Q1 ‘03

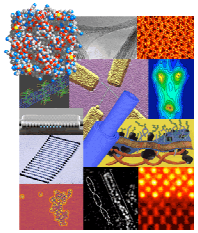
Berkeley Q4 ’03

Brookhaven ‘05

Argonne
Summer ‘03

Los Alamos – Sandia
‘04

The labs

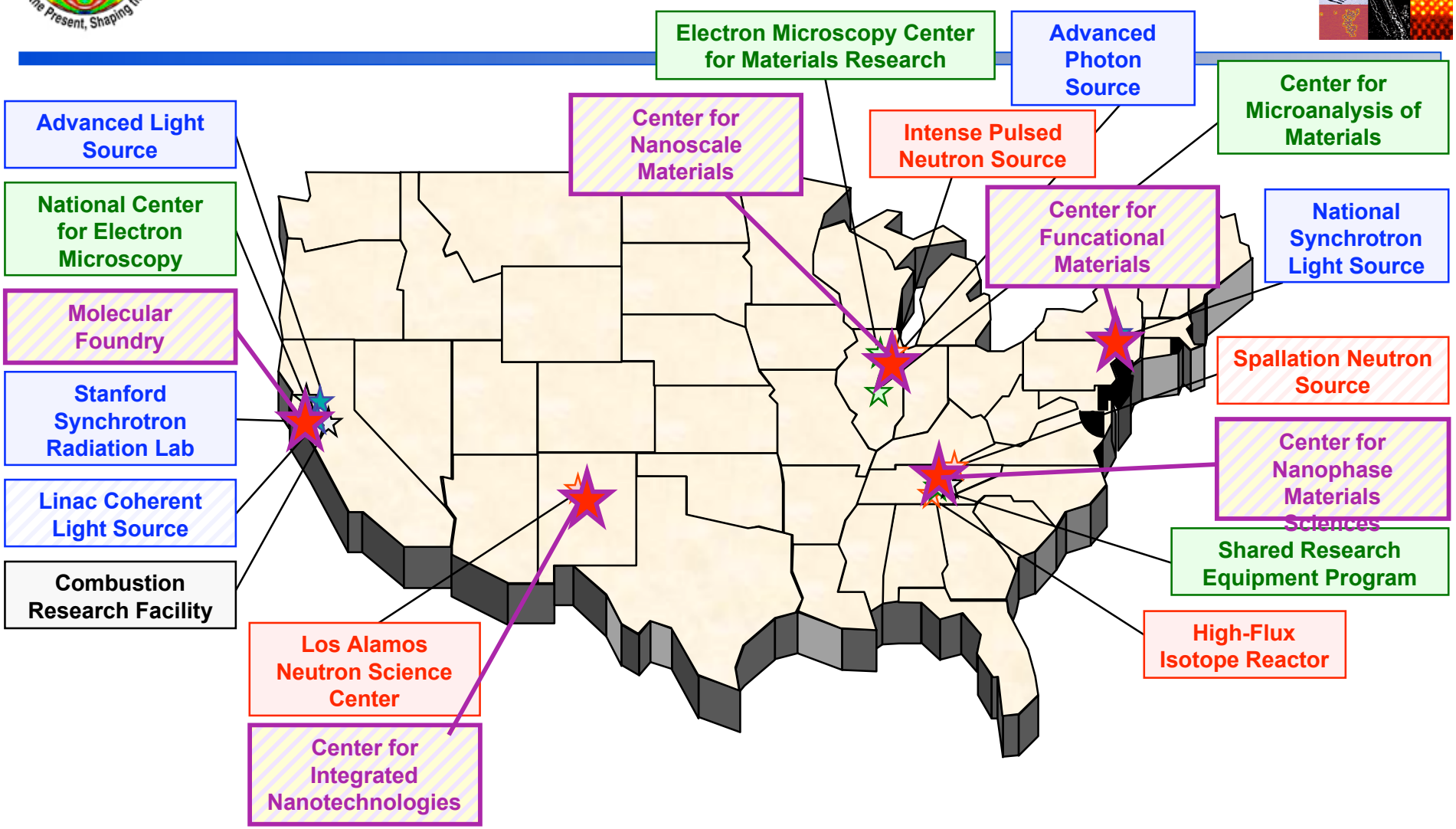


Synthesis and patterning techniques
- Nano e-beam lithography
- Soft lithography and pattern transfer
- Inorganic nanocrystals
- Nanotubes
- Polymer Synthesis
- Cell Culture
- Custom Bio-macromolecules

Theory
- Electronic structure
- Short time dynamics
- Molecular Dynamics
- Greens Function methods

Characterization Tools
- Scanning Probe Techniques
- Electron Microscopies
- Applications of X-ray spectroscopies and diffraction
- Neutron diffraction

Portals to the BES User Facilities



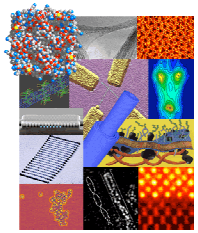
Under construction

In design/engineering

In design/engineering

- *4 Synchrotron Radiation Light Sources*
- *Linac Coherent Light Source (CD0 approved)*
- *4 High-Flux Neutron Sources (SNS under construction)*
- *4 Electron Beam Microcharacterization Centers*
- *4 Special Purpose Centers*
- *5 Nanoscale Science Research Centers*

NSRC jump-start programs



- Start this fiscal year
- Limited operations in delocalized facilities
- Mainly postdoctoral programs for now
- Beta-user programs
- Users should contact the facilities here at this meeting
- Proposal requests this spring
- Proposal study panels
- Pre-beta users from UCSB, Air Force Research Lab, UC Davis