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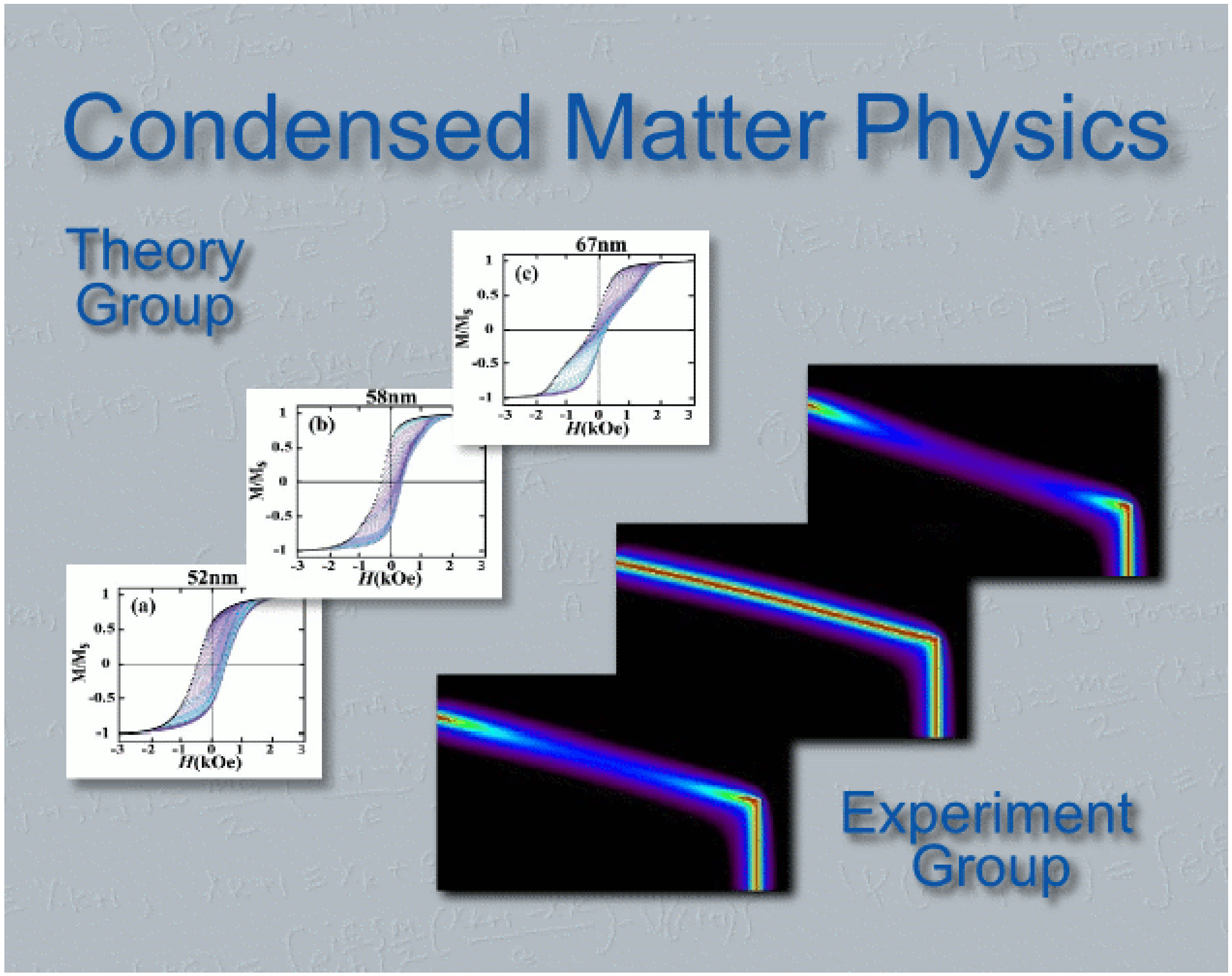
http://www.physics.ucdavis.edu/condensed_matter.html



A brief introduction to Condensed Matter Physics at Davis and an overview of the Condensed Matter Experiment Group

The Past-- 30 Years of Nobel Prizes in Condensed Matter Physics— 1980-present

HIGHLIGHTED → (UCD CM EXPERIMENT AND CM THEORY FACULTY RESEARCH)

1. 2011 GROUNDBREAKING EXPERIMENTS REGARDING THE TWO-DIMENSIONAL MATERIAL GRAPHENE → NOVEL CIRCUIT ELEMENTS? (PICKETT, SAVRASOV, SINGH)
2. 2009 TRANSMISSION OF LIGHT IN FIBERS FOR OPTICAL COMMUNICATION & FOR THE INVENTION OF AN IMAGING SEMICONDUCTOR CIRCUIT – THE CCD →OPTIC FIBERS, THE CCD
3. 2007 DISCOVERY OF GIANT MAGNETORESISTANCE, LEADING TO SPINTRONICS → HARD DRIVE READ HEADS, MAGNETIC RAM/LOGIC (FADLEY, LIU, SINGH, ZIMANYI,…)
4. 2003 PIONEERING CONTRIBUTIONS TO THE THEORY OF SUPERCONDUCTORS AND SUPERFLUIDS → SUPERCONDUCTIVITY (PICKETT, SAVRASOV, ZIEVE, …)
5. 2001 ACHIEVEMENT OF BOSE-EINSTEIN CONDENSATION IN DILUTE GASES OF ALKALI ATOMS, AND FOR EARLY FUNDAMENTAL STUDIES OF THE PROPERTIES OF THE CONDENSATES →BOSE EINSTEIN CONDENSATION OF ATOMS
6. 2000 DEVELOPMENT OF SEMICONDUCTOR HETEROSTRUCTURES USED IN HIGH-SPEED- AND OPTO-ELECTRONICS, AND INVENTION OF THE INTEGRATED CIRCUIT → THE INTEGRATED CIRCUIT, THE IT WORLD
7. 1998 DISCOVERY OF A NEW FORM OF QUANTUM FLUID WITH FRACTIONALLY CHARGED EXCITATIONS → THE QUANTUM HALL EFFECT, FRACTIONAL CHARGE--THEORY
8. 1997 DEVELOPMENT OF METHODS TO COOL AND TRAP ATOMS WITH LASER LIGHT →LASER TRAPPING OF ATOMS
9. 1996 DISCOVERY OF SUPERFLUIDITY IN HELIUM → SUPERFLUID HELIUM
10. 1994 DEVELOPMENT OF NEUTRON SPECTROSCOPY & DEVELOPMENT OF THE NEUTRON DIFFRACTION TECHNIQUE →NEUTRON DIFFRACTION AND SPECTROSCOPY
11. 1991 DISCOVERING THAT METHODS DEVELOPED FOR STUDYING ORDER PHENOMENA IN SIMPLE SYSTEMS CAN BE GENERALIZED TO MORE COMPLEX FORMS OF MATTER, IN PARTICULAR TO LIQUID CRYSTALS AND POLYMERS →THEORY OF POLYMERS AND LIQUIDS CRYSTALS
12. 1987 THE DISCOVERY OF SUPERCONDUCTIVITY IN CERAMIC MATERIALS →HIGH TEMPERATURE SUPERCONDUCTIVY (CURRO, PICKETT, SAVRASOV,…)
13. 1986 FUNDAMENTAL WORK IN ELECTRON OPTICS, AND FOR THE DESIGN OF THE FIRST ELECTRON MICROSCOPE & DEVELOPMENT OF THE SCANNING TUNNELING MICROSCOPE → ELECTRON AND SCANNING PROBE MICROSCOPIES (CHIANG,FADLEY)
14. 1985 DISCOVERY OF THE QUANTIZED HALL EFFECT → THE QUANTUM HALL EFFECT, FRACTIONAL CHARGE--EXPERIMENT
15. 1982 THEORY FOR CRITICAL PHENOMENA IN CONNECTION WITH PHASE TRANSITIONS → PHASE TRANSITIONS (SINGH)
16. 1981 CONTRIBUTION TO THE DEVELOPMENT OF LASER SPECTROSCOPY → LASER SPECTROSCOPY AND DIFFRACTION (ZHU) & CONTRIBUTION TO THE DEVELOPMENT OF HIGH- RESOLUTION ELECTRON SPECTROSCOPY → PHOTOELECTRON SPECTROSCOPY/PHOTOEMISSION (CHIANG, FADLEY)

Approximately half of Noble Prizes in Physics are in Condensed Matter. UCD faculty involved in many areas.

Related Recent Nobel Prizes in Chemistry

2007 STUDIES OF CHEMICAL PROCESSES ON SOLID SURFACES →SURFACE CHEMISTRY, CATALYSIS (CHIANG, FADLEY)

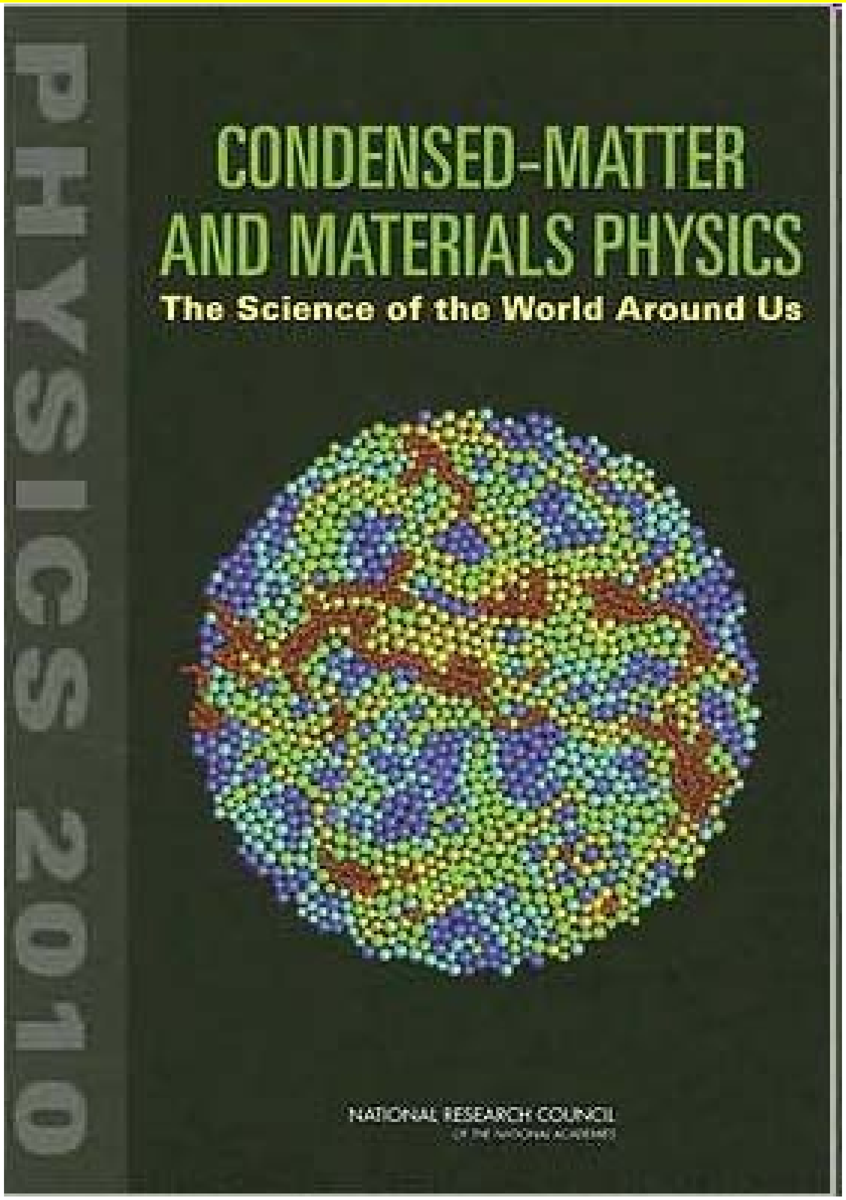
2000 DISCOVERY AND DEVELOPMENT OF CONDUCTIVE POLYMERS →POLYMERIC INTEGRATED CIRCUITS

1998 DEVELOPMENT OF THE DENSITY-FUNCTIONAL THEORY THAT CAN BE USED FOR THEORETICAL STUDIES OF THE PROPERTIES OF MOLECULES AND THE CHEMICAL PROCESSES IN WHICH THEY ARE INVOLVED → ELECTRONIC STRUCTURE THEORY (FONG, PICKETT, SAVRASOV, COX)

1996 DISCOVERY OF FULLERENES → NANOTUBES, NANOCIRCUITS (YU)

1991 DEVELOPMENT OF THE METHODOLOGY OF HIGH RESOLUTION NUCLEAR MAGNETIC RESONANCE (NMR) SPECTROSCOPY → NMR SPECTROSCOPY (CURRO)

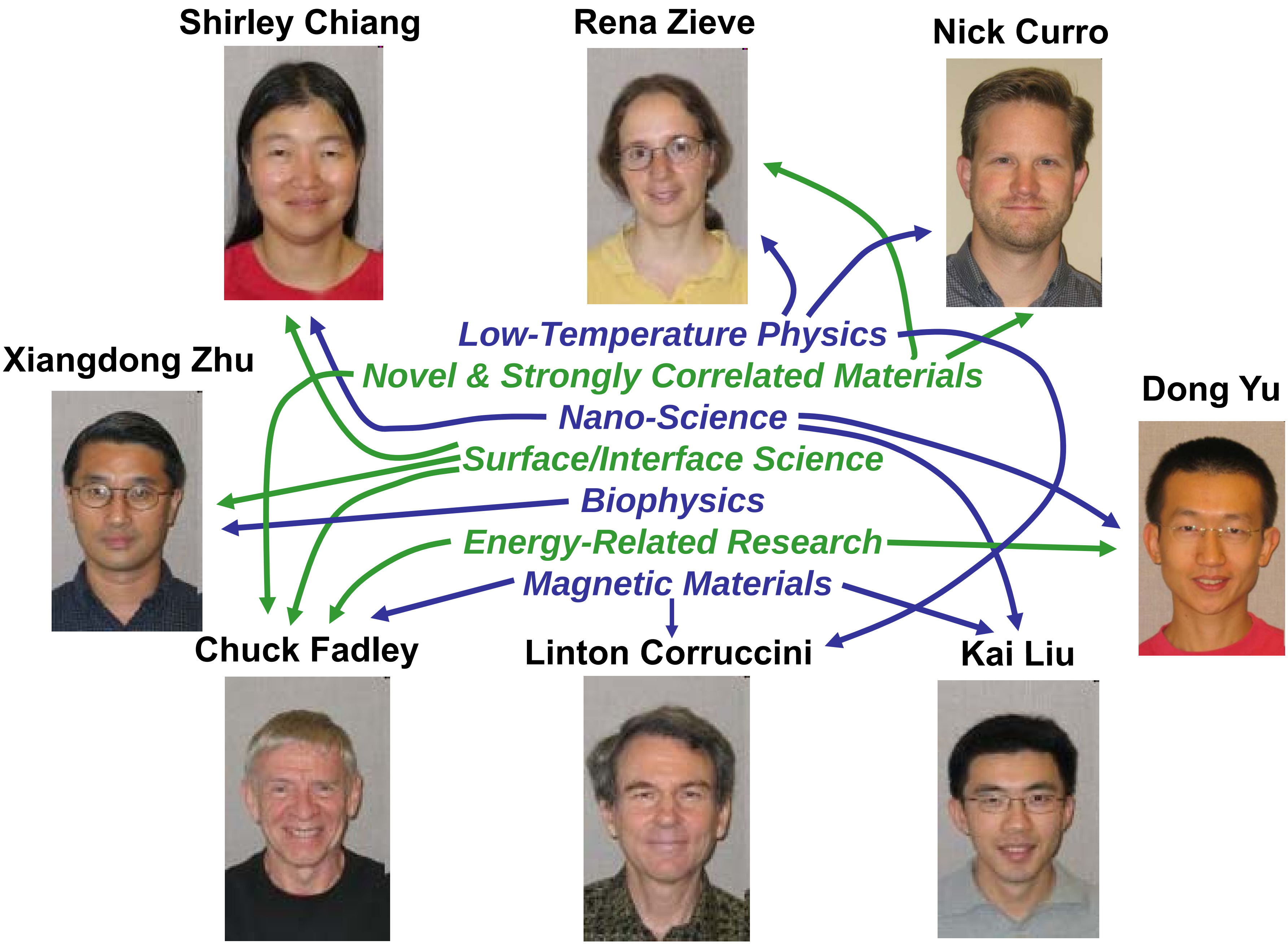
A Look at the Future--
Condensed Matter Physics—The Science of the World Around Us



- ***How Do Complex Phenomena Emerge from Simple Ingredients?*** → ***Strongly correlated materials***
- ***How Will the Energy Demands of Future Generations Be Met?*** → ***Solar cells, fuel cells,…***
- ***What New Discoveries Await Us in the Nanoworld?*** → ***Surfaces and interfaces, novel nanodevices***
- ***How Will the Information Technology Revolution Be Extended?*** → ***Nanoscale logic and memory, spintronics***
- ***What Happens Far from Equilibrium and Why?*** → ***Many nanoscale systems***
- ***What Is the Physics of Life?*** → ***Biophysics***

Publisher: National Academies Press
Pub. Date: December 2007
ISBN-13: 9780309109697
286pp

UC Davis Experimental Condensed Matter Physics-People



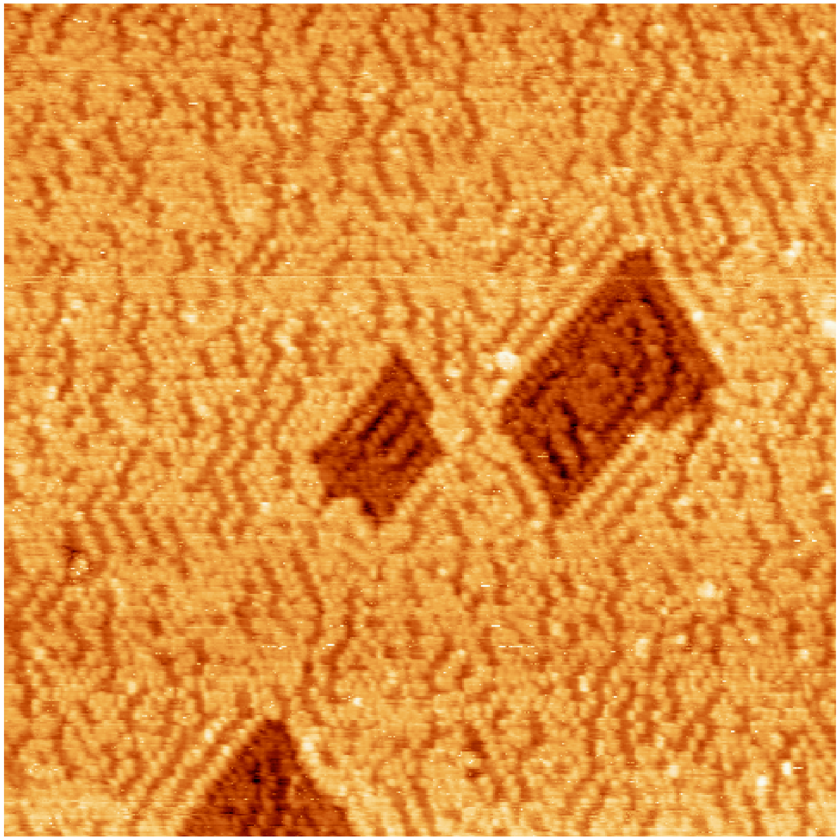
UC Davis Experimental Condensed Matter Physics
Special opportunities and facilities

- State-of-the-art in-house facilities + external facilities
- Small-group hands-on experimental work → diverse experience
- Excellent track record of funding and RA support: ~20% of graduate students are in CME
- Dept./Campus central facilities: X-ray diffraction, nanofabrication, clean room, electron microscopy, NMR, electron spectroscopy,…
- Connection to special campus initiatives:
  - Nanomaterials in the Environment, Agriculture & Technology (NEAT)-Liu, Fadley
  - Energy@UC Davis, Lawrence Livermore National Laboratory–Yu
- Unique nearby national facilities:
  - Lawrence Berkeley National Laboratory– Advanced Light Source-Fadley, National Center for Electron Microscopy, Molecular Foundry
  - Lawrence Livermore National Laboratory– microscopy, high pressure facilities
- Multiple collaborations & interdisciplinary research: UCD, national, international
- Proximity to high-tech industry in Silicon Valley: a major asset

Growth and Surface Dynamics of Metals on Semiconductors: Ag/Ge

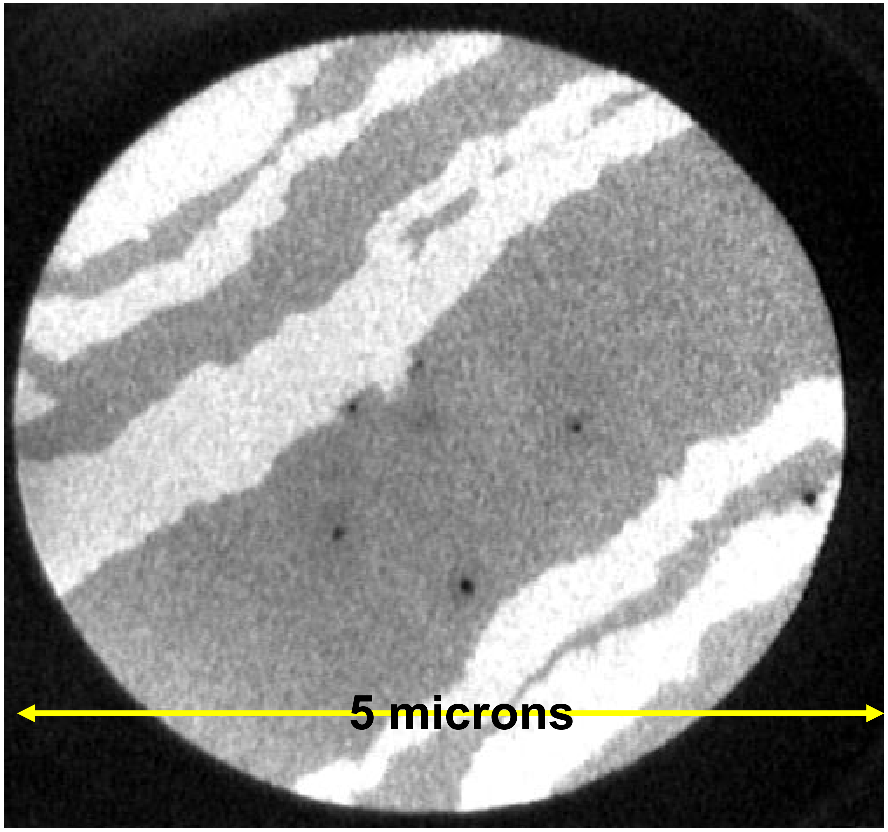
Shirley Chiang

Ag/Ge(110), 0.25 ML
Scanning Tunneling Microscopy (STM)



100 nm x 100 nm, V_{sample}=-2.0V, I_t=0.5nA

Ag on stepped Ge(111), 0.78 ML at 250°C
Low Energy Electron Microscopy (LEEM)
Bright = Ag in (√3x√3)R30º, Dark = Ag in (4x4)

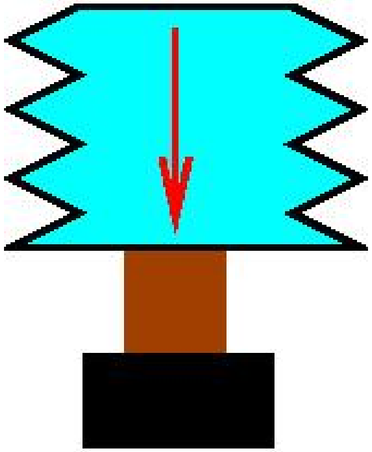


FOV=5μm, 5.5eV electron energy, Real-Time movies

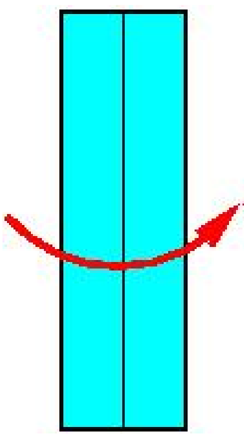
http://www.physics.ucdavis.edu/stm/index.html

Low-temperature physics: superconductivity, magnetism, high pressure

Rena Zieve



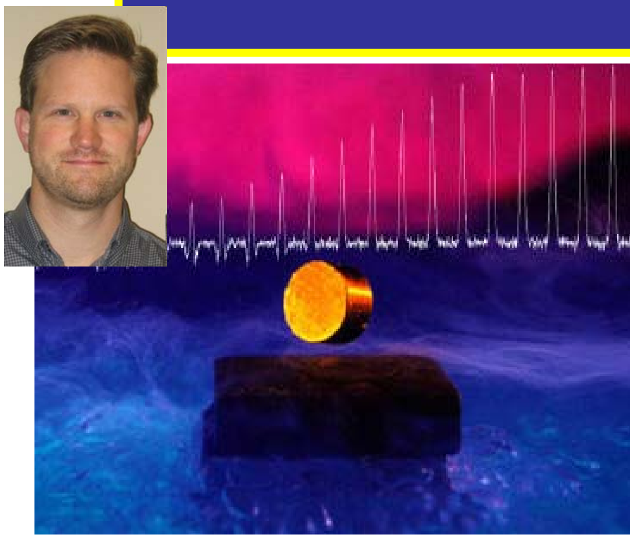
- squeeze samples to drive phase transitions
- study superconductivity, magnetism
- 2 graduate students



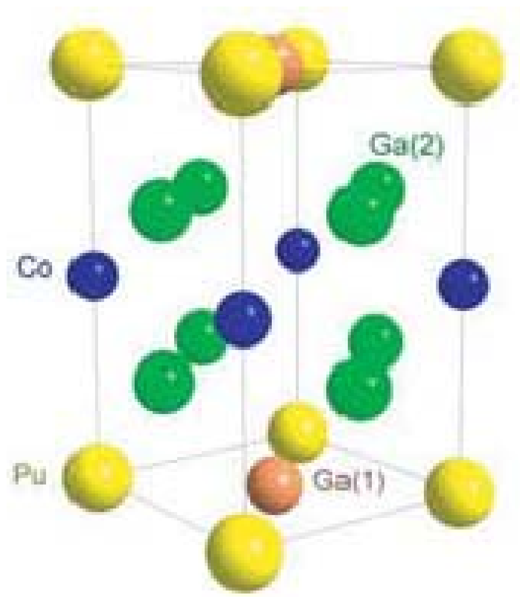
- rotate superfluid helium, creating quantized vortices
- study vortex motion, waves, and energy loss
- 2 graduate students

http://london.ucdavis.edu/

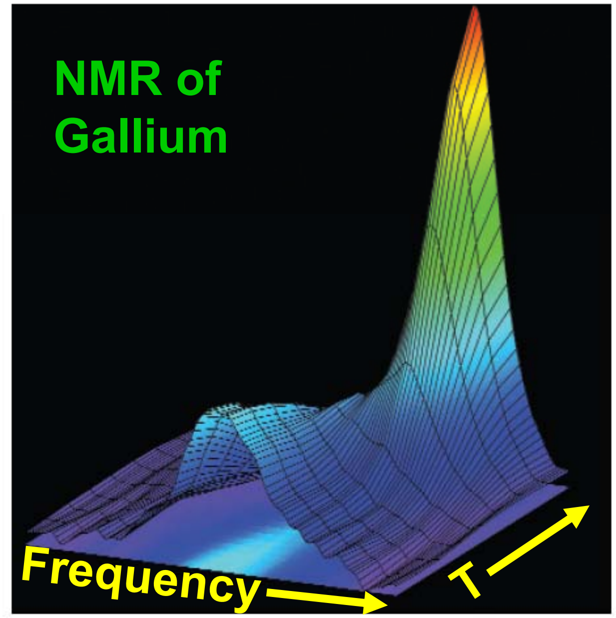
NMR of Strongly Correlated Electron Systems
Nicholas Curro



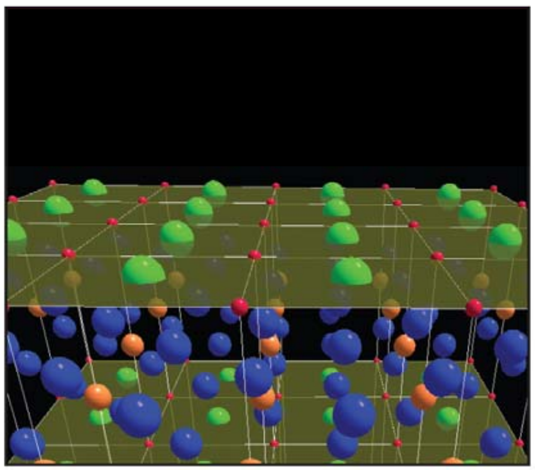
$PuCoGa_5$



Nature 434, 622 (2005)



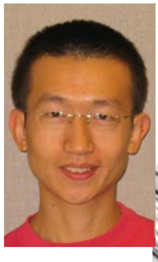
The above image shows the nuclear magnetic resonance spectra of the gallium as the temperature evolves from below *Tc* (superconducting state) to above *Tc* (normal state). The lower axis of the plane, parallel to the edge of the figure, is frequency, and the axis moving into the page is temperature. The spectra shift to lower frequency in the superconducting state, reflecting the fact that the Cooper pairs form a spin singlet.

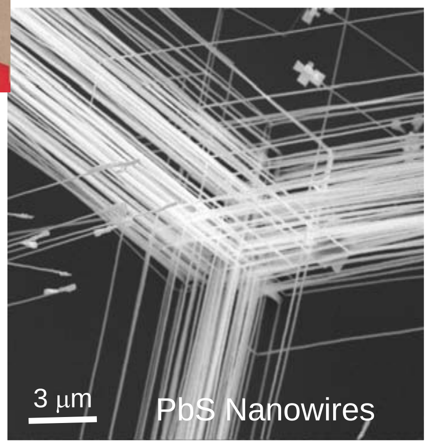


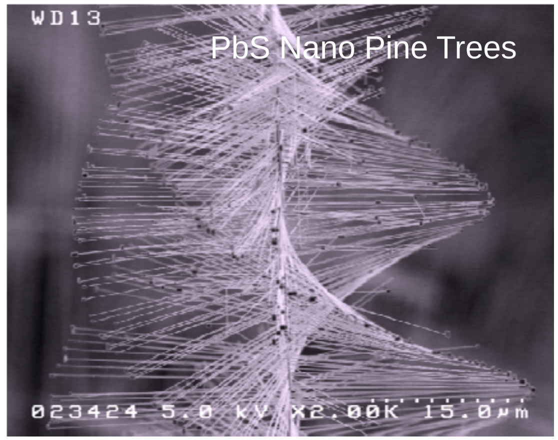
- **Unconventional superconductivity and magnetism, heavy fermion physics, quantum phase transitions**
- **Studies of nuclear magnetic resonance in extreme conditions:**
  10mK to 1000 K, 0-60 T, and 0-3 GPa

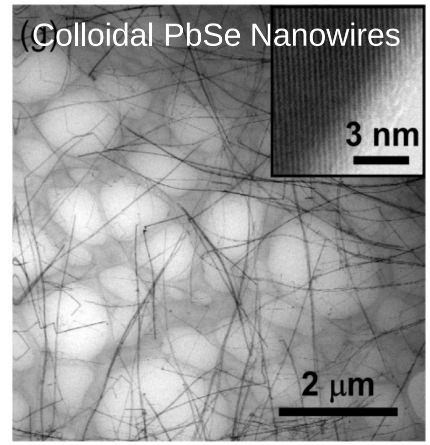
http://www.physics.ucdavis.edu/~curro/

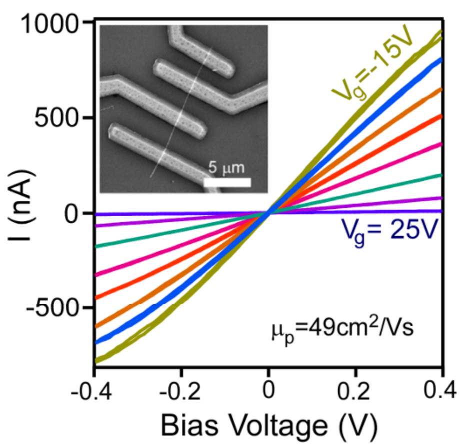
Nanostructure Solar Cells
Dong Yu

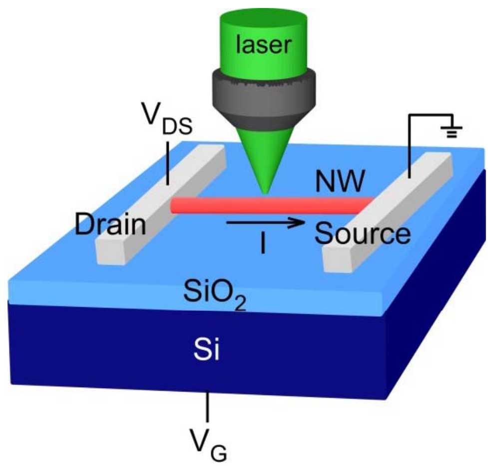


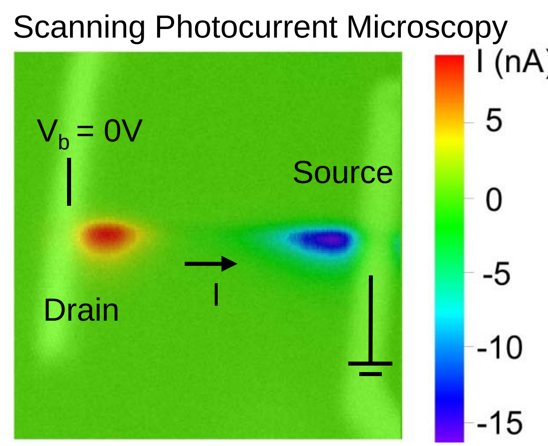








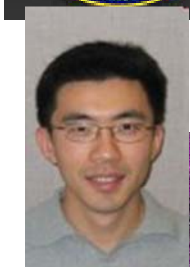




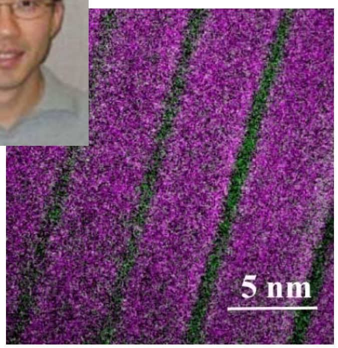
- **How do photons convert into charge carriers?**
- **How do sizes of semiconductors affect their properties?**
- **How to make efficient and low-cost solar cells?**

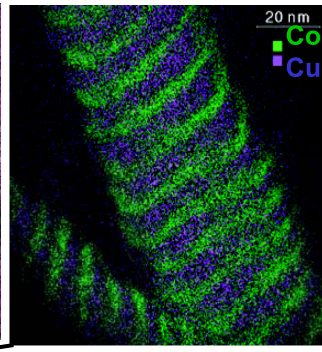
http://www.physics.ucdavis.edu/~yu/

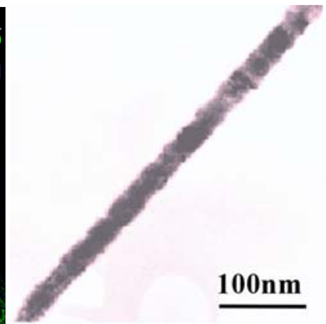
Nanomagnetism & Spintronics
Kai Liu

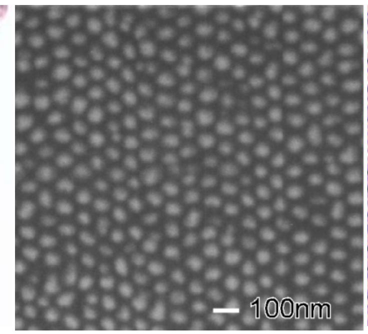


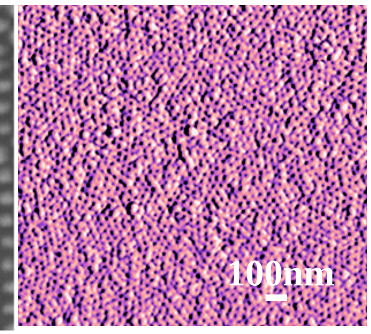
Nanoscale architectures



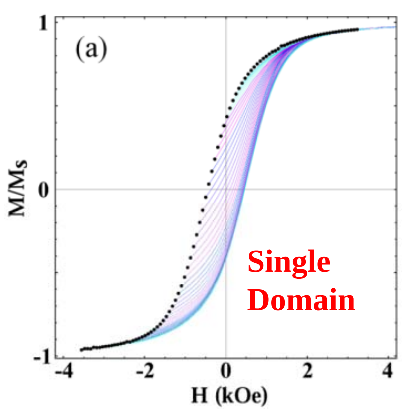


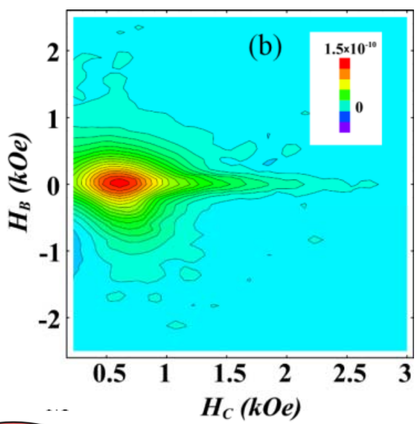


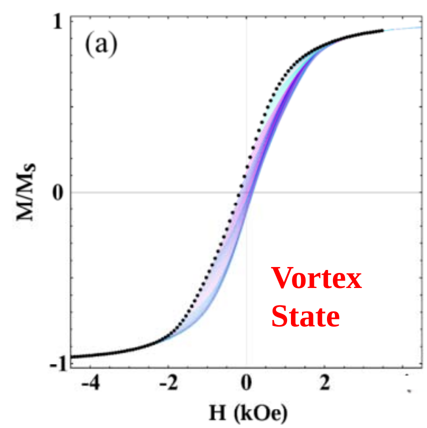


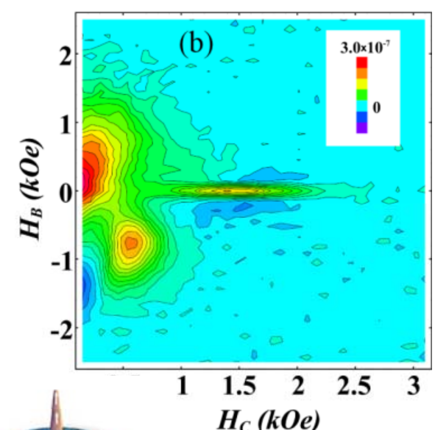


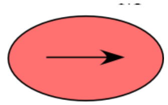
Multilayered Nanowires: Vortex state, giant magnetoresistance, Spin-transfer torque



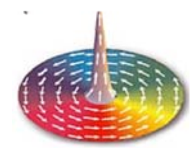








Single-domain Co

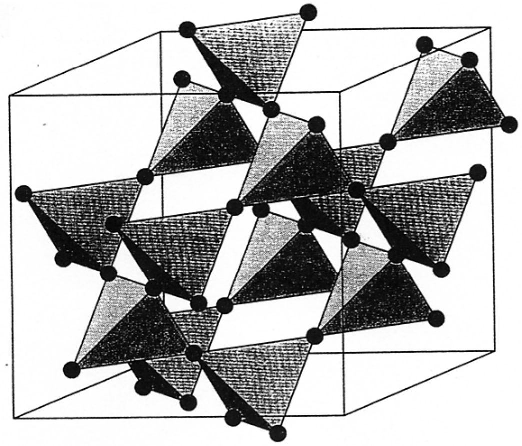


Vortex-state Co

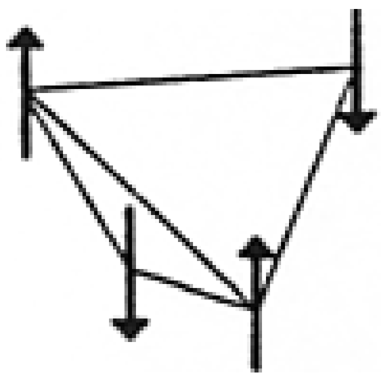
http://www.physics.ucdavis.edu/~kliu/

Magnetic Frustration at Ultralow Temperatures
Linton Corruccini

Low temperature magnetism

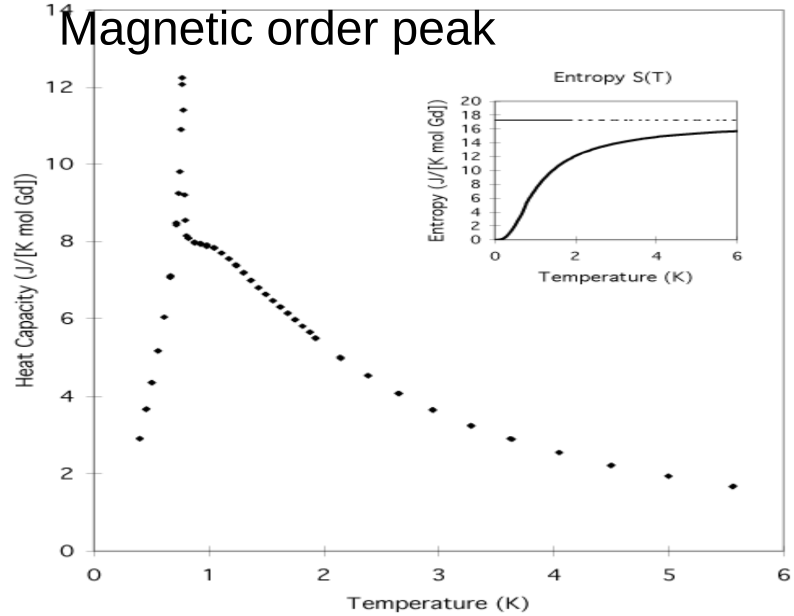


Cubic pyrochlore lattice

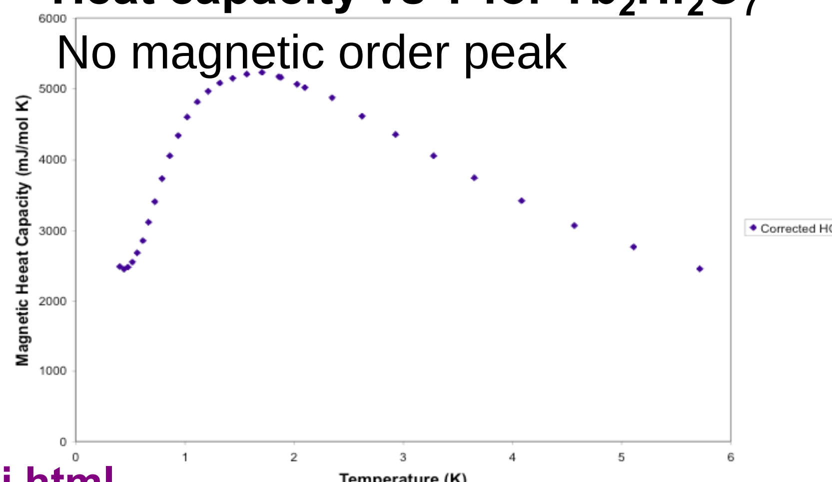


Magnetic “Frustration”

Heat capacity vs T for $Gd_2Zr_2O_7$



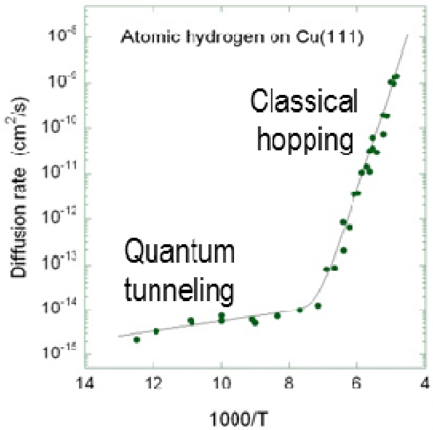
Heat capacity vs T for $Tb_2Hf_2O_7$

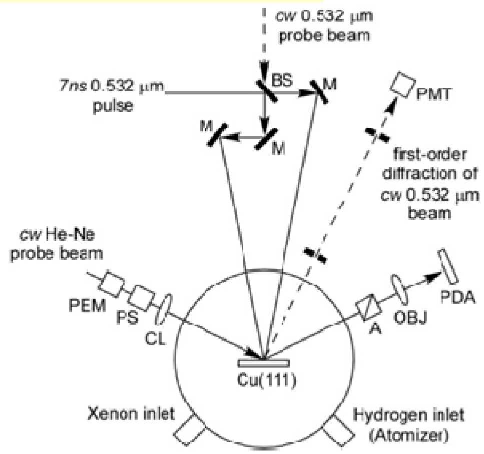


http://www.physics.ucdavis.edu/Text/Corruccini.html

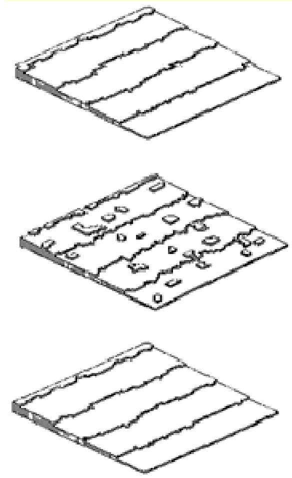
Optical Studies of Surfaces and Thin Films
Xiangdong Zhu

Adatom Diffusion on Metals (NSF)
Atomic hydrogen on Cu(111)





Kinetics in Ultra-Thin Film Epitaxy (NSF)
Xe on Nb(110)-optical reflectivity



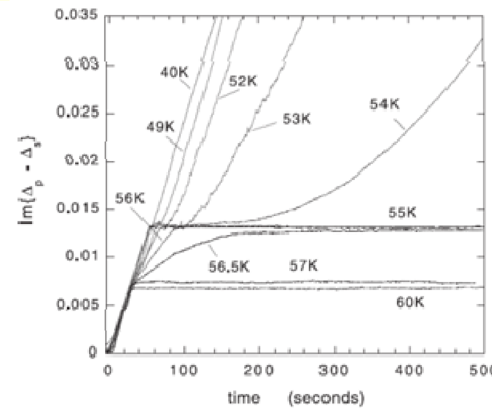
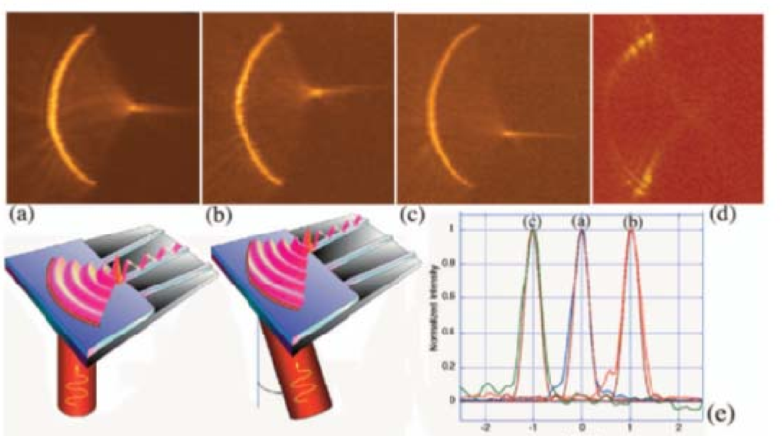
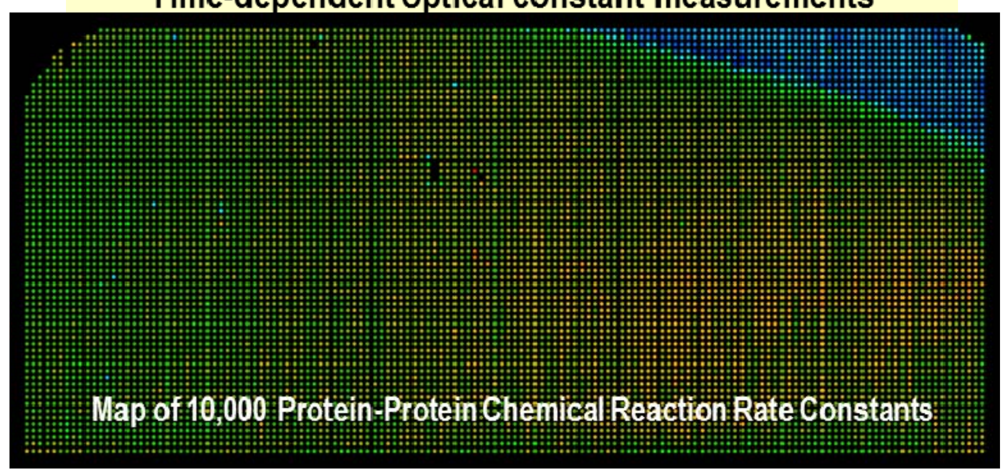


FIGURE 1 Optical reflectivity difference signal Im{$\Delta_p - \Delta_s$} vs. exposure time during Xe growth on Nb(110) from 40 K to 60 K. The Xe pressure is $p = 1.4 \times 10^{-7}$ Torr

Surface Plasmonics on Metals (ACS-PRF)
Light-generated plasmons for switching



Parallel Detection of Biomolecular Interactions (NIH, UC)
Time-dependent optical constant measurements



http://www.physics.ucdavis.edu/xdzhu/

Studies of Surfaces, Nanostructures, and Complex Materials with Novel X-Ray Synchrotron Radiation Methods

Chuck Fadley

JÜLICH FORSCHUNGSZENTRUM

HELMHOLTZ ZENTRUM BERLIN für Materialien und Energie

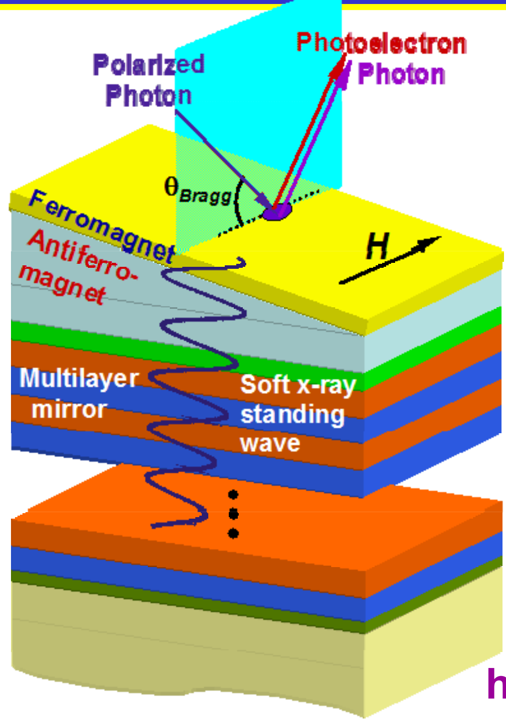
DESY

SPring-8 Japan

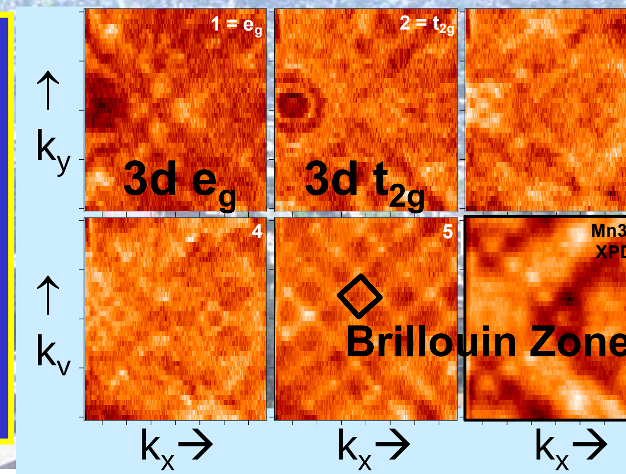
Department of Physics, University of California, Davis

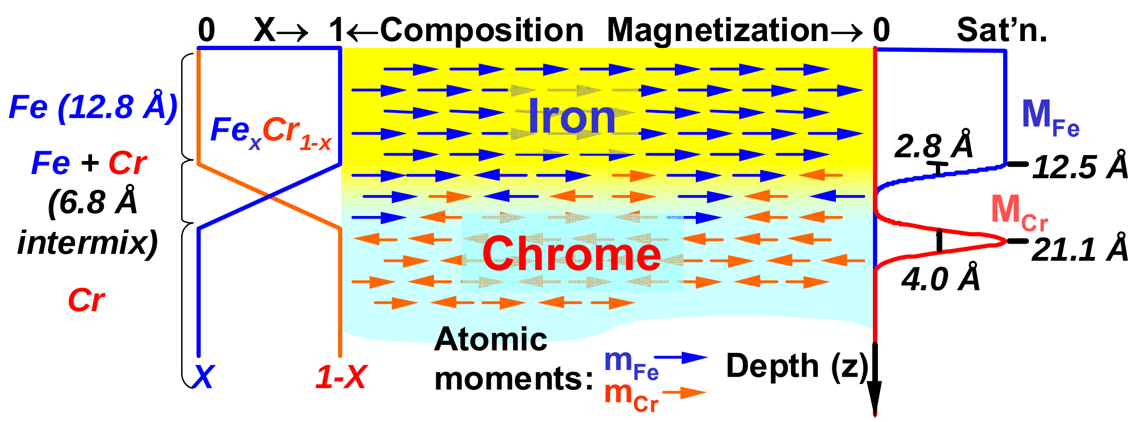
Materials Sciences Division, Lawrence Berkeley National Laboratory

"Spintronics"--Probing Buried Magnetic Interfaces with Soft X-ray Standing Waves



Depth resolved electronic energy bands in a colossal magnetoresistive oxide nanolayer (Sat. poster)





http://www.physics.ucdavis.edu/fadleygroup/