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)

<table>
<thead>
<tr>
<th>Year</th>
<th>Discovery/Invention</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>2011 GROUNDBREAKING EXPERIMENTS REGARDING THE TWO-DIMENSIONAL MATERIAL GRAPHENE → NOVEL CIRCUIT ELEMENTS? (PICKETT, SAVRASOV, SINGH)</td>
</tr>
<tr>
<td>2.</td>
<td>2009 TRANSMISSION OF LIGHT IN FIBERS FOR OPTICAL COMMUNICATION &amp; FOR THE INVENTION OF AN IMAGING SEMICONDUCTOR CIRCUIT – THE CCD → OPTIC FIBERS, THE CCD</td>
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<td>3.</td>
<td>2007 DISCOVERY OF GIANT MAGNETORESISTANCE, LEADING TO SPINTRONICS → HARD DRIVE READ HEADS, MAGNETIC RAM/LOGIC (FADLEY, LIU, SINGH, ZIMANYI,...)</td>
</tr>
<tr>
<td>4.</td>
<td>2003 PIONEERING CONTRIBUTIONS TO THE THEORY OF SUPERCONDUCTORS AND SUPERFLUIDS → SUPERCONDUCTIVITY (PICKETT, SAVRASOV, ZIEVE,...)</td>
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<tr>
<td>5.</td>
<td>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</td>
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<tr>
<td>7.</td>
<td>1998 DISCOVERY OF A NEW FORM OF QUANTUM FLUID WITH FRACTIONALLY CHARGED EXCITATIONS → THE QUANTUM HALL EFFECT, FRACTIONAL CHARGE--THEORY</td>
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<td>8.</td>
<td>1997 DEVELOPMENT OF METHODS TO COOL AND TRAP ATOMS WITH LASER LIGHT → LASER TRAPPING OF ATOMS</td>
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<td>9.</td>
<td>1996 DISCOVERY OF SUPERFLUIDITY IN HELIUM → SUPERFLUID HELIUM</td>
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<td>10.</td>
<td>1994 DEVELOPMENT OF NEUTRON SPECTROSCOPY &amp; DEVELOPMENT OF THE NEUTRON DIFFRACTION TECHNIQUE → NEUTRON DIFFRACTION AND SPECTROSCOPY</td>
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<td>11.</td>
<td>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 LIQUID CRYSTALS</td>
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<td>12.</td>
<td>1987 THE DISCOVERY OF SUPERCONDUCTIVITY IN CERAMIC MATERIALS → HIGH TEMPERATURE SUPERCONDUCTIVITY (CURRO, PICKETT, SAVRASOV,...)</td>
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<td>14.</td>
<td>1985 DISCOVERY OF THE QUANTIZED HALL EFFECT → THE QUANTUM HALL EFFECT, FRACTIONAL CHARGE--EXPERIMENT</td>
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<td>15.</td>
<td>1982 THEORY FOR CRITICAL PHENOMENA IN CONNECTION WITH PHASE TRANSITIONS → PHASE TRANSITIONS (SINGH)</td>
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<tr>
<td>16.</td>
<td>1981 CONTRIBUTION TO THE DEVELOPMENT OF LASER SPECTROSCOPY → LASER SPECTROSCOPY AND DIFFRACTION (ZHU) &amp; CONTRIBUTION TO THE DEVELOPMENT OF HIGH-RESOLUTION ELECTRON SPECTROSCOPY → PHOTOELECTRON SPECTROSCOPY/PHOTOEMISSION (CHIANG, FADLEY)</td>
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Approximately half of Noble Prizes in Physics are in Condensed Matter. UCD faculty involved in many areas.
<table>
<thead>
<tr>
<th>Year</th>
<th>Prize Description</th>
<th>Recipients</th>
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</thead>
<tbody>
<tr>
<td>2007</td>
<td>Studies of chemical processes on solid surfaces</td>
<td>Chiang, Fadley</td>
</tr>
<tr>
<td>2000</td>
<td>Discovery and development of conductive polymers</td>
<td>Polymeric integrated circuits</td>
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<td>1998</td>
<td>Development of the density-functional theory that can be used for theoretical</td>
<td>Fong, Pickett, Savrasov, Cox</td>
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<td></td>
<td>studies of the properties of molecules and the chemical processes in which they</td>
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<td>are involved</td>
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<td></td>
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<td>Electronic structure theory</td>
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<tr>
<td>1996</td>
<td>Discovery of fullerenes</td>
<td>YU</td>
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<tr>
<td>1991</td>
<td>Development of the methodology of high resolution nuclear magnetic resonance</td>
<td>NMR spectroscopy</td>
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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
- 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
286pp
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)

Ag on stepped Ge(111), 0.78 ML at 250°C
Low Energy Electron Microscopy (LEEM)
Bright = Ag in (√3x√3)R30°, Dark = Ag in (4x4)

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

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

Vortex State

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

Heat capacity vs T for Gd$_2$Zr$_2$O$_7$
Magnetic order peak

Heat capacity vs T for Tb$_2$Hf$_2$O$_7$
No magnetic order peak

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

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

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)

Fe (12.8 Å)
Fe + Cr (6.8 Å intermix)

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