Graduate Emphasis Area in Physics and Chemistry
Strategic Plan and AY 2010-1011 Hiring Priorities

Introduction

Research in the Physics and Chemistry graduate emphasis area spans the traditional disciplines of chemistry and physics and related interdisciplinary fields. Graduate education within the group is currently divided into three tracks--Physics, Physical Chemistry, and Organic Chemistry--which have different preliminary exams and course work. Thus, students are educated and must demonstrate proficiency in a particular discipline, but have the opportunity to pursue research that spans disciplines if they so desire. This emphasis area currently involves 17 faculty and 20 graduate students. All four of the third- and fourth-year students have successfully advanced to candidacy for the Ph.D.

While interdisciplinary collaboration between physics and chemistry is in many cases natural and desirable, the primary mission of a graduate emphasis area or graduate group (unlike a research institute) is the education of graduate students. The disciplines of physics and chemistry have considerably different cultures and coursework needs in this regard, and we feel that our students would be best served by having separate programs in physics and chemistry. In addition, we have observed that most prospective students are looking for programs in physics *or* chemistry, not a joint program. Our ability to recruit excellent graduate students would be enhanced by having two separate but closely interacting programs. Accordingly, over the past two years we have been moving toward separating many of the functions of the group. When we finally have adequate faculty strength to do so, we will seek system-wide recognition as two separate stand-alone graduate groups, one in physics and one in chemistry. This strategic plan is therefore the concatenation of a physics plan and a chemistry plan.

Below is a combined list of group hiring priorities for AY 10-11. These priorities are based on research and graduate education needs and do not address the vital role that all of these future faculty will play in undergraduate education at UC Merced.

Physics and Chemistry group searches currently underway for AY 09-10

- Organic chemistry, open rank
- Materials chemistry, open rank
- Theoretical/computational chemistry, untenured
- Biophysics, open rank
- Nanoscale physics, tenured
- Condensed matter physics, untenured

Physics and Chemistry group hiring plans for AY 10-11 (NOT in order of priority)

- Analytical chemist, applied to either materials or biology: This position could be either in materials-oriented areas such as electrochemistry, photoelectrochemistry, or surface chemistry, particularly as related to energy conversion and storage, or in biologically oriented areas such as biosensor development, single molecule techniques for monitoring

biological processes (e.g. enzyme catalysis), or the development of *in situ* technologies that non-invasively probe the chemical function of cells.

- Theoretical/computational chemist, applied to either materials or biology: This position seeks applicants who are trained in theoretical chemistry and have research interests that include both the development of new theoretical/computational methods and their application to problems related to materials or biology. Examples include calculations of electronic structure and of energy- and charge-transfer dynamics in extended systems, and large-scale simulations of macromolecular structure and dynamics. We seek candidates whose research interests are complementary to those of the person we hope to hire in this year's theory search.

- Experimental or theoretical biophysicist: This position seeks applicants who are trained in physics with research interests in bio-molecular self-assembly, biological membranes, biopolymers, molecular motors, cell level phenomena such as mitosis, morphogenesis, motility and chemotaxis, biological networks or the development of novel biophysical techniques. We seek candidates whose research is complementary to the work of existing faculty in the School of Natural Sciences.

- Atomic, molecular, and optical scientist: This position seeks individuals who are trained to explore atomic or molecular scale systems and quantum coherence phenomena. Examples of such work include ultrafast optical phenomena, attosecond studies, fundamental quantum processes and engineering, atomic cooling and trapping, precision measurement, and novel imaging techniques. New programs as well as research in areas complimentary to existing UC Merced faculty are both welcome.

- Condensed matter physicist: This position seeks individuals who are trained in condensed matter physics, broadly defined. We will consider both experimentalists and theorists, depending on hiring in the previous year. We aim to recruit at least one more condensed matter experimentalist among our condensed matter faculty. The areas of research of interest include strongly correlated systems, spintronics, quantum information in quantum many body systems, mesoscopic systems, molecular electronics, semiconductor photonics and soft condensed matter physics.

Chemistry

Chemistry is often known as "the central science" because of the key position it occupies in modern science and engineering. Most phenomena in the biological and earth sciences can be described in terms of the chemical and physical behavior of atoms and molecules, and chemical principles also underlie much progress in medicine and engineering. In addition, chemical systems are fascinating and often beautiful in their own right. George Whitesides, in his 2007 Priestley Medal address, states that "Chemistry is now the natural home of many of the most engaging problems in fundamental science and of the problems in applied science about which society cares the most." Herein we give a few examples of how chemistry has had a profound impact on other fields of science and technology. Just several years after the inception of UC Irvine, Sherwood Rowland and Mario Molina (Nobel Prize, 1995) used physical chemistry approaches to unravel the chemical mechanisms of ozone depletion. This discovery, which helped to pull us back from the brink of an environmental catastrophe, played no small part in catapulting Irvine to research powerhouse status. Chemistry plays an essential role in the development of nanoscience and technology due to chemists' expertise in understanding and controlling matter at the atomic and molecular scale. It is no coincidence that almost all the exciting nanomaterials, from quantum dots to carbon nanotubes to semiconductor nanowires, have been pioneered by chemists. The intimate connections between life sciences and chemistry result from the prowess of chemists at manipulating and measuring molecules, the building blocks of life. Recent examples include Bertozzi's chemical manipulation of oligosaccharides in biological systems, which opens up new avenues to understanding and regulating complex cell surfaces. Analytical chemists such as John Fenn (Nobel Prize, 2002), were responsible for developing mass spectrometric analyses of biological macromolecules, a cornerstone in proteomics. The advancement of single molecule spectroscopy by Sunney Xie, a molecular spectroscopist by training, has stirred much excitement in biophysics as it affords access to unprecedented details of life processes at the single molecule level.

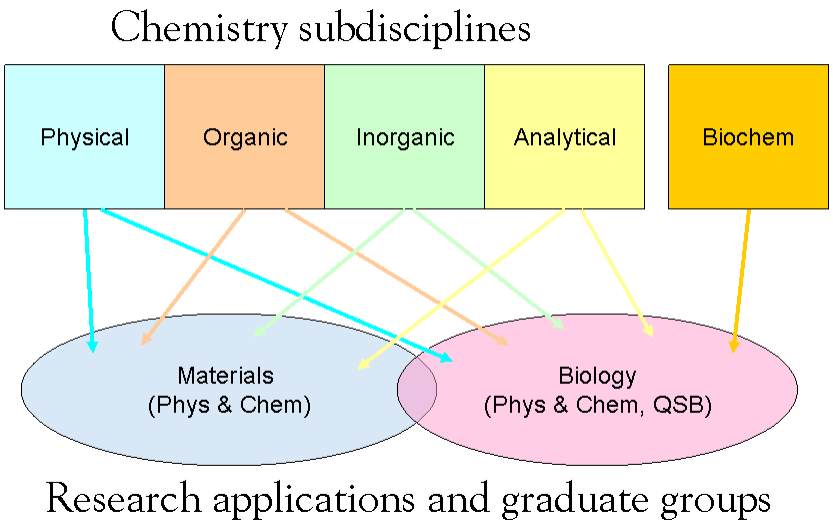
Because of the indispensible role of chemistry as a core discipline in science, one would be hard-pressed to think of any highly respected comprehensive research university that does not have a strong chemistry program that grants both bachelor's and Ph.D. degrees. Chemists may be classified according to their subdiscipline and/or by the nature of the problems on which they work. The four traditional subdisciplines of chemistry are organic, inorganic, physical, and analytical:

- Organic chemistry is the chemistry of carbon-based compounds. Organic chemists are concerned with synthesizing useful chemical compounds, developing new reactions to better achieve challenging syntheses, and determining the physical principles that are responsible for chemical behavior. Organic chemists are actively engaged in the synthesis of new materials for energy harvesting and storage, the manipulation and understanding of biological processes, and the development of efficient and ecologically benign catalysts and reactions.
- Inorganic chemistry is the chemistry of chemical compounds that are not primarily carbon-based. Inorganic chemists determine the structures of inorganic molecules, study their reactions, and develop procedures for their synthesis. The fundamental principles are applied to problems in environmental chemistry, bioinorganic chemistry, and solid-state materials chemistry.
- Physical chemistry applies the fundamental laws of physics to understand the properties of chemical compounds and the basis of chemical reactivity. Physical chemists study the energetics of molecular and macroscopic processes, the dynamics of chemical reactions, quantum chemistry, and interactions of molecules with light (spectroscopy,

photochemistry, and photophysics) using techniques that are experimental, theoretical, and/or computational.

- Analytical chemistry concerns the chemical analysis of substances. Analytical chemists develop instrumentation and methodologies to determine what chemical compounds are present in a sample and/or how much is present. Modern analytical chemistry is particularly concerned with very small systems, down to the single-molecule level, as well as applications to biology (proteomics, genomics) and environmental monitoring.

At UC Merced, we have the unique opportunity to build a modern chemistry program that combines disciplinary rigor and interdisciplinary reach. Ph.D.-level research in chemistry requires systematic training, and all four subdisciplines should be represented to some extent. Reflecting the expansive nature of chemical research and the interdisciplinary emphasis at UC Merced, the faculty have decided to focus our efforts on recruiting chemists working on problems in two broadly defined areas, biology and materials. The representation of traditional disciplines should not be viewed as an impediment to interdisciplinary research as we intend to recruit chemists who can bring novel chemical solutions and perspectives to materials and biology, just as the aforementioned prominent chemists have done. The figure below summarizes this scheme.



Biochemistry is a discipline closely allied with both chemistry and biology but distinct from both. Some universities have a combined department of chemistry and biochemistry while in others biochemistry is a separate department or is associated with another department. Under the present graduate group structure, it makes more sense for the biochemistry faculty to be associated with the Quantitative Systems Biology group than with Physics and Chemistry. This arrangement may be revisited once chemistry forms its own graduate group.

Current composition of the chemistry subgroup

Primary affiliation (Natural Sciences faculty)

- Anne Kelley, Professor (Physical and Analytical; Materials,)
- David Kelley, Professor (Physical; Materials)
- Erik Menke, Assistant Professor (Physical and Analytical; Materials)
- Matt Meyer, Assistant Professor (Organic and Physical; Biological)
- Meng-Lin Tsao, Assistant Professor (Organic; Biological)
- Tao Ye, Assistant Professor (Physical and Analytical; Materials and Biological)

Secondary affiliation (Engineering faculty)

- Valerie Leppert, Associate Professor (Materials)
- Jennifer Lu, Assistant Professor (Materials)
- Christopher Viney, Professor (Materials and Biological)

Searches are currently underway in organic chemistry (open rank), materials chemistry (open rank), and theoretical/computational chemistry (untenured).

Materials Chemistry research

Materials Chemistry is defined by the American Chemical Society journal in this field, *Chemistry of Materials*, as "Solid-state chemistry, both inorganic and organic, and polymer chemistry, especially as directed to the development of materials with novel and/or useful optical, electrical, magnetic, catalytic, and mechanical properties." Materials chemists may be focused predominantly on synthesis (organic or inorganic chemistry) or characterization (analytical or physical chemistry). These areas offer the possibility of many different types of collaborations, both within UC Merced between Natural Sciences and Engineering and at other nearby institutions including Hewlett-Packard, LLNL, and possibly NASA/Ames in the near future. This type of research is well funded and we expect it will continue to be well funded in the foreseeable future, as materials chemistry will be key to advances in new energy sources. Potential research areas for future Materials Chemistry hires include:

- *organic electronics*: design, synthesis, and physical properties of materials for organic light-emitting diodes (OLEDs), thin film transistors, and liquid crystal displays
- *solar photovoltaics*: design, synthesis, and physical properties of materials for organic, inorganic, or hybrid solid-state devices and/or electrochemical cells
- *photonic materials*: design, fabrication, and properties of materials for frequency conversion of lasers, optical limiting materials, contrast agents in nonlinear optical imaging technologies, electro-optic modulation, and photonic bandgap crystals
- *batteries:* new materials to enable lightweight, high capacity, multiply rechargeable battery technology
- *heterogeneous catalysts*: solid-state materials that catalyze a variety of desired chemical reactions
- *structural materials:* design, synthesis, and characterization of new materials having desirable properties (light weight, high strength, environmentally benign, biocompatible, *etc.*)
- *"smart" materials*: synthesis, characterization, and engineering of materials that can respond adaptively and autonomously to changes in their condition or the environment
- *plasmonics*: materials for, and study of, phenomena based on the coupling of light to the plasma oscillations of conduction electrons in small metallic nanostructures, and their coupling to other materials

Biological Chemistry research

The ACS Division of Biological Chemistry defines this subfield as "using the principals [*sic*] of chemistry to assist in the development of a deeper understanding of biological processes ". Much of the recent dramatic progress in the life sciences has been driven by quantitative approaches and a molecular-level understanding of complex biological systems. Experimental, computational and theoretical methods and techniques from chemistry have played a significant role in these

advances. In addition, the flow of knowledge and inspiration runs both ways: challenges posed by specific biological problems are driving the development of new analytical tools, prompting advances in the physical and chemical sciences. Biological chemistry has undergone explosive growth in recent years as experimental and computational tools from the physical sciences have become widely applied to biological problems. Biological chemistry is explicitly interdisciplinary between the physical and life sciences, and there should be extensive opportunities for collaboration across these groups. In addition, at least some biological chemistry faculty are expected to have research interests that overlap engineering, particularly Bioengineering. The development of a strong presence in biological chemistry would position our school for center grants and other translational research initiatives. Biologically related chemistry is a large area of chemistry research that is well funded, largely by NIH but also through other agencies. Potential areas for future Biological Chemistry hires include:

- *Nucleic acid replication, damage and repair*
- *Novel modes for drug delivery*
- *Development of ultrasensitive bioanalytical techniques, particularly for single molecule/single assembly measurements and/or high throughput screening*
- *Single molecule studies of molecular motors, DNA/RNA dynamics, transcription factor binding/functioning, viral genome packaging, ion channel transport etc.*
- *Organized chemical systems that imitate the functioning of biological cells*
- *DNA and/or other biological macromolecules as scaffolds for fabrication of organized structures*
- *Protein folding*
- *Molecular recognition*
- *Novel uses of combinatorial techniques at the interface of chemistry and biology: aptamers, phage display, novel approaches to screening and combinatorial synthesis*
- *Atomistic modeling of biological systems (channels, membranes, receptors)*
- *Membranes and associated phenomena including fusion, exo/endocytosis, pore formation and functioning, lipid rafts*

Five-year growth plan

The smallest Ph.D.-granting chemistry departments in the U.S. have at least ten full-time faculty. This is a minimum number needed to provide a full set of graduate and undergraduate courses as well as to provide sufficiently broad range of research opportunities for students. The current faculty (primary affiliation) plus the three currently open positions give us a total of nine, bringing us close to the absolute minimum required. We request two new positions for AY 10-11: one in analytical chemistry, a broad area that is popular with students and overlaps the research interests of several of our existing faculty, and a second in theoretical chemistry to strengthen our programs in this important, growing, and non-space-intensive area. Thereafter, approximately one new faculty member per year for the next four years will allow us to diversify our research programs and graduate course offerings. The new hires should be distributed among the four subdisciplines (organic, inorganic, physical, and analytical) and between the two application areas (biological and materials) as summarized below:

<u>Additions for AY 09-10 (this request)</u>

- Analytical chemist, applied to either materials or biology
- Theoretical/computational chemist, application area complementary to current search

Additions for AY 11-12 through 14-15

- Biophysical chemist
- One additional organic chemist, application area complementary to current faculty
- One additional theoretical/computational chemist, application area open
- Inorganic or organometallic chemist, applied to either biology or materials

Whenever possible, all positions should be searched at open rank; however, recruiting top-notch tenured faculty will be very challenging, particularly in experimental fields that are highly resource-intensive. We feel that the most profitable strategy is to attempt to recruit tenured faculty but accept that many of our new hires will have to be made at the Assistant Professor level.

Facilities and space

Laboratory research space poses a huge challenge. Competitive offers will require allocation of significant amounts of laboratory space. This is particularly true for senior-level candidates. SE I will be full with (or before) the current year's faculty hires. Following this year, further space will be needed. There are several options for acquiring this further space. These include acceleration of the timetable for SE II, use of space at Castle, and the use of temporary buildings on campus. The exact mix of these alternatives involves decisions by the UC Merced administration, and is therefore beyond the scope this strategic plan. Theoretical/computational chemists who do not need lab space could be accommodated in temporary office buildings; for experimental chemists, Castle seems the most likely source for the needed lab space.

Physics

Physics is the study of the properties of nature at their most fundamental. It ranges from the study of the very tiniest pieces of matter and energy, including molecules, atoms, photons, and subatomic particles, to the study of the entire universe. Insights in physics have revolutionized our society. It is hard to imagine an area of science or engineering that has not been profoundly affected by fundamental developments in physics. One need only think of the harnessing of electricity, the invention of the transistor, and the discovery of the laser. The present strength in physics at Merced is centered on three broad areas of research, detailed below.

Current composition of the physics subgroup

- Ray Chiao, Professor
- Sayantani Ghosh, Assistant Professor
- Ajay Gopinathan, Assistant Professor
- Linda Hirst, Assistant Professor
- Kevin Mitchell, Assistant Professor
- Jay Sharping, Assistant Professor
- Lin Tian, Assistant Professor
- Roland Winston, Professor

Searches are currently underway in biophysics (open rank), nanoscale physics (tenured), and condensed matter physics (untenured).

Atomic, Molecular, and Optical Physics research

UC Merced is building a strong research emphasis in atomic, molecular, and optical (AMO) physics. Interest and developments in this field have surged in the last ten to fifteen years, primarily due to advanced experimental techniques. These developments have been recognized by several recent Nobel prizes: for ion trapping and atomic clocks (1989; Ramsey, Dehmelt, Paul), for atomic cooling and trapping techniques (1997; Chu, Cohen-Tannoudji, Phillips), for the creation of Bose-Einstein condensates (2001; Cornell, Ketterle, Wieman), and most recently for advances in quantum optics (2005; Glauber, Hall, Haensch).

The modern trend in AMO science is toward greater control over quantum systems such that quantum coherence is maintained and quantum processes can be resolved. This includes working at very low temperatures, at ultrashort time scales, and with very high spectroscopic precision. Modern techniques can now routinely address single atoms, single photons, and single qubits (the quantum analog of a bit).The technological implications for such precise control over the fundamental building blocks of ordinary matter are as yet unimagined, but the promise is great. By analogy, the laser, which in some sense is a "Bose-Einstein" condensate of photons, has impacted almost every area of technology and medicine. The program in AMO physics complements the research programs in condensed matter physics and chemistry.

At present UC Merced has hired five faculty whose research supports the general AMO theme: Roland Winston and Ray Chiao (both split between Natural Science and Engineering), Kevin Mitchell, Jay Sharping, and Lin Tian. . Potential areas for subsequent AMO hires include, but are not limited to:

- *ultrafast optics*: pico-, femto-, and attosecond pulses, time-domain studies, wavepacket dynamics, high harmonic generation, photonic crystals and nanostructures for plasmonics and terahertz dynamics
- *attosecond physics*: fourth generation synchrotron sources, attosecond pulse generation, characterization, and applications
- *fundamental quantum processes and engineering*: quantum control, quantum computing and information theory
- *atomic cooling and trapping*: ultracold gases and plasmas, Bose-Einstein condensates, degenerate Fermi gases, superfluidity
- *precision measurement*: atomic clocks, ultrasensitive detectors, high precision spectroscopy, multi-photon microscopy
- *novel imaging techniques*: sub-diffraction fluorescence imaging, near-field imaging, etc.

Funding potential: Various government funding agencies support physics research, and AMO research in particular, with NSF being the largest sponsor of table-top AMO research. Furthermore, DOE funds several large national user facilities, including three that are strategically located with respect to UC Merced: Lawrence Livermore National Lab, Lawrence Berkeley National Lab, and the Stanford Linear Accelerator Center. Research is supported to a significant extent by the DOE and defense organizations (DARPA, ONR, AFOSR, ARO). In addition, optics research has historically benefited financially from its close connection to industry and industrial applications.

Cross-disciplinary and cross-school linkages

Expertise in AMO science has a natural connection to other present and potential University research programs. This is reflected in the fact that two of the AMO faculty have joint appointments between natural science and engineering. Specific connections include, but are not limited to:

a) The energy sciences program: Optics is of fundamental importance to solar energy collection.
b) Chemical physics/physical chemistry: Current faculty rely heavily on lasers and other optical techniques. They could be well supported by additional expertise in optics and atomic physics.
c) The materials or nanoscience programs would benefit from advanced optical techniques. Also, many of the issues of quantum control, manipulation, computing, etc. are relevant to nanoscience just as they are to AMO science.
d) Computer science: Quantum computation and information processing synergizes naturally with computer science.
e) Biology and Earth systems science: Synergy could potentially arise in the areas of microscopy, advanced detector design, and optics.

Condensed Matter Physics research

The Condensed Matter Physics program in Natural Science is a broad, interdisciplinary program focusing on "condensed" phases of matter. These phases range from simple solids and liquids to metallic and semiconductor nanomaterials to exotic condensed phases such as the superconducting phase exhibited by conduction electrons in certain materials, and the ferromagnetic and antiferromagnetic phases of spins on atomic lattices. The intellectual scope of this program is vast, and includes an understanding of the optical, electrical, mechanical, and transport properties of materials, encompassing the nano- to the macro-scale. Research in condensed matter can be

harnessed to design new materials such as magnets, semiconductors, ferroelectrics, superconductors, polymers, colloidal systems and liquid crystals, used for applications in a wide variety of disciplines including efficient energy conversion, ultra-fast optics, quantum information processing, information display and structural materials, to name a few.

The faculty participating in this program span the disciplines of solid state physics, nanoscale physics, soft matter physics, physical chemistry, surface science and materials characterization. Several specific areas that are at the forefront of modern condensed matter science are targeted. These include photonic materials, nano-scale electronics, quantum information and "smart" materials.

Photonic materials. "Photonics" may be broadly defined as the technology of generating and harnessing light and other forms of radiant energy. All photonic technologies rely on appropriate materials, which may be organic, inorganic, or composites. Materials that respond nonlinearly to light are used in frequency conversion of lasers, as optical limiting materials to protect eyes or optical sensors from laser pulses, and as contrast agents in nonlinear optical imaging technologies. Materials that change their optical properties in response to applied electric fields can be used to fabricate electro-optic modulators for electrical to optical conversion in fiber-optic communications. Photonic band-gap crystals, periodic dielectric structures that forbid propagation of a certain frequency range of light, have potential applications in ultra-low-threshold lasers, optical filters, polarizers, and waveguides. Metamaterials are those that exhibit novel optical properties leading to compact imaging systems and even "cloaking" devices. Research in this area is highly interdisciplinary and spans solid-state physics, surface science, optical physics, physical chemistry and applied mathematics.

Nanoscale electronics. " Nano-electronics" is poised to provide the next technological revolution in computer design. Moore's prediction of rapid miniaturization has already pushed commercial transistors well below 100 nm in size. Developing an in-depth understanding of the fundamental properties of nanoelectronic devices is of crucial importance because Nature behaves quite differently at the nanoscale, and an extrapolation of our knowledge at larger dimensions is not possible. It is not prudent to invest a vast amount of time and effort to try to compete with the immense silicon industry. Instead, it is more attractive to look into nanoelectronic devices that could play a role complementary to the silicon technology, with a strong focus on exploring the possibilities of organic materials, for example in the form of single molecules or self-assembled molecular monolayers. Investigating the use of complex transition-metal oxides in nanoelectronic devices is another field worth exploring since these materials show a wide range of interesting characteristics, including strongly insulating behavior, high-temperature magnetism and superconductivity. Nanoelectronics is the field where physics, material science, chemistry and electrical engineering inevitably meet.

Quantum information science. The tremendous miniaturization of electronic devices has led to the point where the spatial scale has hit the atomic limit. In this regime, the quantum properties of matter dominate, which, at first glance, seems to compromise information processing and storage, since quantum states are unstable and are destroyed by the very act of making a measurement. However, this very fragility of quantum phenomena has the capability of revolutionizing the fields communication and computation. A quantum channel of information transfer is very secure, since any effort to eavesdrop leaves an imprint on the quantum state. Computation power is exponentially enhanced when using quantum bits instead of classical ones due to the property of entanglement, which adds immense parallel processing capabilities. Recently, quantum information processing has started influencing the agenda of condensed matter, and some of the implementable

quantum bits which this field has contributed include superconducting structures (Josephson junctions), single-electron quantum dots and semiconductor photonic devices.

Photovoltaics. As the worldwide demand for energy increases, the need for renewable energy sources will become more and more urgent. Solar energy is the obvious answer, providing an unlimited, pollution-free energy source. Through the use of efficient photovoltaics, a relatively small amount of land area can in principle be used to meet the energy needs of the entire United States. For these reasons, research into more efficient and lower cost ways of turning the energy of sunlight directly into electrical energy is now, and will continue to be, an important field in the physical sciences. Photovoltaic devices can be grouped into two broad categories, each type having its advantages and disadvantages: solid state (semiconductor) devices, which may be organic, inorganic, or hybrid, and electrochemical cells.

The areas described above are particularly attractive because they offer the possibility of many different types of collaborations, both within UC Merced and at other nearby institutions. Potential industrial collaborators include Hewlett-Packard's basic research labs in Palo Alto. There are also collaborative opportunities with LLNL through LLNL/UCM adjunct faculty. We also anticipate that collaborations and funding through NASA/Ames will be available in the near future.

Current faculty in this research area are:

- Sayantani Ghosh (experimental condensed matter physics)
- Raymond Chiao (experimental condensed matter physics)
- Lin Tian (theoretical condensed matter physics and quantum information)
- Ajay Gopinathan (theoretical soft condensed matter physics)
- Linda Hirst (Experimental soft condensed matter physics)

Other faculty across disciplines who could contribute include

- Roland Winston (solar energy, optics)
- David Kelley (experimental chemical physics)
- Anne Kelley (experimental physical/analytical chemistry)
- Tao Ye (nanotechnology)
- Jennifer Lu (materials engineering)
- Valerie Leppert (materials engineering)

Given the necessarily diverse and fundamentally interdisciplinary nature of this group, and the desirability of building on and extending current strengths, we would like to see recruitment of new faculty in fields that encompass and bridge condensed matter physics, physical chemistry, and materials engineering. We need to recruit faculty with related but complementary research interests in order to build a program that can attract graduate students, offer modern and compelling programs for both undergraduate and graduate students, successfully compete for funding, and achieve national and international prominence in research. The condensed matter physics and nanoscale physics searches underway during the current academic year will result in new faculty who would contribute to this research area. It is assumed that these positions will be carried forward if we are unsuccessful at filling them this year.

Funding potential: The level of support available is a primary concern when considering programmatic initiatives. This type of research is very well funded and we suspect will continue to be well funded in the foreseeable future.

Single-investigator or small collaborative group funding in this field is available from a number of different agencies and programs within these agencies. Examples include:

- NSF: programs in Physics and Materials Research divisions.
- AFOSR Broad Area Announcement (BAA): programs in Metallic Materials, Ceramic and Nonmetallic Materials, Quantum Electronic Solids, Semiconductor Materials, Surface and Interfacial Science.
- ARO BAA: programs in Condensed Matter Physics, Quantum Information Science, Surfaces and Catalysis, Electrochemistry and Advanced Energy Conversion, Materials Synthesis and Processing.
- ONR BAA: programs in Electronic Materials, Semiconductor Materials.
- DARPA: solicitation in Nano-Composite Optical Ceramics.
- DOE: Several programs in Basic Energy Sciences: Condensed Matter Physics, Materials and Engineering Physics.

Biological Physics research

Experimental, computational and theoretical methods and techniques from Physics have played a major part in recent advances in our understanding of biological systems. Examples include cutting-edge imaging techniques that have provided snapshots of biological molecules and their complex assemblies in action and have also led to dramatic improvements in medical imaging. The ability to control matter at the smallest scales, using for example optical and magnetic tweezers, has allowed us to study and manipulate biological processes at the single molecule level. Theoretical and computational modeling are leading the way in our efforts to understand protein folding/misfolding, the functioning of molecular motors and enzymes, ion channels, membrane structure and dynamics as well as the dynamics of complex biochemical and neural networks. The result of advances in biological physics will be a better understanding of normal and pathological processes at both the molecular and systems level. Equally important, from a physics perspective, is that studies of biological systems that serve as paradigms of complex, self-assembling, non-equilibrium systems has led to new and interesting physics including emergent properties in dynamical networks, self-assembled, self-replicating systems, the thermodynamics of "active" systems and an atomistic understanding of complex macromolecules. Biophysics is the most rapidly growing area in physics research attracting both seasoned physicists from several different subfields and large numbers of entering students.

To develop a state of the art research program in biophysics requires individuals who have had extensive training in doing biophysical research, hailing from either traditional physics subfields such as condensed matter, polymer or statistical physics or from more interdisciplinary backgrounds including specifically biophysics, materials or bioengineering.

Current faculty in this research area are:

- Ajay Gopinathan (theoretical soft condensed matter physics)
- Linda Hirst (Experimental soft condensed matter physics)
- Jay Sharping (experimental biophotonics)

Other faculty across disciplines who could contribute include

- Mike Colvin (computational biology)
- Tao Ye (nanotechnology)
- Michelle Khine (bioengineering)
- Andy LiWang (biochemistry)
- Patti LiWang (biochemistry)

A core group of at least 6 biophysicists is needed to establish a strong competitive program. Broad areas of interest include biomaterials and biopolymers, membranes and associated phenomena, single cell studies of biomechanics including motility and mitosis, microfluidics with biological applications and protein folding. Several specific research fields are listed below that would allow us to attract the best available candidates with interests in these broad areas.

- Biocompatible organic materials as organ replacements and/or as scaffolds for cell growth (links to Materials program and to Bioengineering)
- Development of ultrasensitive bioanalytical techniques, particularly for single molecule/single assembly measurements and/or high throughput screening
- Single molecule studies of molecular motors, DNA/RNA dynamics, transcription factor binding/functioning, viral genome packaging, ion channel transport etc.
- DNA and/or other biological macromolecules as scaffolds for fabrication of organized structures (links to Materials program)
- Protein folding, experimental and computational methods that quantitatively determine protein structure and folding pathways
- Atomistic modeling of biological systems: channels, membranes, receptors, proteins, enzymes (links to CCB)
- System level studies of mitosis, morphogenesis, cellular motility, cytoskeletal dynamics, viral self-assembly, cellular hydrodynamics, chemotaxis and pattern formation. (links to Systems Biology)
- Membranes and associated phenomena including fusion, exo/endocytosis, pore formation and functioning, lipid rafts. Also biomedical applications of engineered membranes. (links to Materials and Bioengineering).

It is to be noted that many of these areas will have a considerable overlap with research interests in Biochemistry and Molecular Biology. There is also a considerable overlap with the field of soft condensed matter physics in both expertise and methodology. We will seek to hire individuals to enhance this natural synergy and anticipate hiring both theorists and experimentalists in these fields.

Funding potential: Funding for biophysics is growing at an extremely rapid pace. The NSF provides substantial funding for fundamental research in physics including its interfacial areas with biology. Research more directed toward specific problems in the life sciences is supported by the NIH, and also to a significant extent by the DOE and defense organizations (ONR, AFOSR, ARO). Funding for research in biological physics is also available from private foundations (*e.g*. Packard, Hughes, Burroughs-Wellcome) and for-profit companies. Faculty with research interests in this area should have a variety of funding opportunities available to them, although all of these sources are highly competitive.

Cross-disciplinary and cross-school linkages

The fundamental principles of Physics form the foundation for all of modern science and engineering. While there remain exciting unsolved problems in pure physics there is increasing interest in the frontiers that lie at the intersection with other disciplines including the life sciences, earth and environmental sciences, and engineering. The Biological Physics program is explicitly interdisciplinary between the physical and life sciences, and there should be extensive opportunities for collaboration across these groups. In particular, Biological Physics faculty are expected to have research interests that overlap Biochemistry, Molecular Biology, Materials Engineering and Bioengineering. Finally, this research area offers a natural interface with the proposed medical school. Interdisciplinary collaborative science is one of the strengths that UC Merced can leverage as a research institution, and this strength should be fostered as a means of bolstering the resources and potential of both biological and physical science at UC Merced.

Space and Facilities Needs

We expect about a three to one ratio between experimental physicists and theoretical physicists. Thus, most physics hires will be experimentalists. Although the nature and configuration of the space required by different types of physicists are quite different, all of the experimentalists are likely to require an average of at least 1000 sq. ft. of lab space each, plus office space for the PI, postdocs, and graduate students. Established senior faculty will require more space than this. Start-up costs for experimentalists depend on specific research needs but typically fall in the $400,000-$750,000 range.

Experimental condensed matter and AMO physicists sometimes need bench and fume hood space but typically have large pieces of specialized equipment such as cryostats, vacuum chambers, and laser-based setups on large optical tables. They often also have specialized requirements for the space in which these instruments are housed, such as high temperature stability, low vibration, isolation from sources of electrical noise, and light-tightness. Because of the specialized nature of the instrumentation it is often not possible for a single room to be shared by multiple investigators.

Experimental biophysicists tend to have research groups that require a mixture of wet lab space, with fume hoods, and dry space for specialized instruments and depending on the specific field they may require access to core facilities for confocal microscopy, in-house x-ray diffraction, or lithography facilities.

Theoretical and computational hires will require office space and computational facilities for the PI, postdocs, and graduate students.

Five-year hiring plan

At a bare minimum twelve FTEs will be needed to teach the core of the undergraduate and graduate physics curriculum, with more faculty needed to provide depth in our course offerings and to provide a critical mass for an effective research environment. This implies a hiring rate of at least two faculty per year. We currently have seven FTEs dedicated to teaching physics (Profs. Chiao and Winston at 0.5 FTE each and Profs. Mitchell, Ghosh, Gopinathan, Sharping, Hirst and Tian at 1 FTE each.)

Summary of proposed physics faculty hires for the next five years

	2007-2008	2008-2009	2010-2011	2011-2012	2012-2013	2013-2014
FTEs already hired	5	7	11	13	15	17
Active searches	4	3	2	2	2	2
Cumulative	9	11	13	15	17	19