Annual Report
2009-2010
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Mission Statement

The mission of ITST is to

advance science and technology at the heart of the electromagnetic spectrum* while training and inspiring new generations of scientists, engineers, and the public at large and supporting research with outstanding service in a warm, welcoming and fun workplace.

Figure 1: Chart showing ITST’s research emphasis at the heart of the electromagnetic spectrum.

*roughly 0.1-10 terahertz (1 terahertz= $10^{12}$ cycles/s). For reference, cell phones transmit near 1 GHz ($10^9$ cycles/s) and the spectrum of visible light stretches from about 400-800 terahertz.
Director’s Statement

In July 2008, consistent with recommendations of the 2007 extramural review board and a 3-year strategic plan developed by the advisory committee in 2007-2008, this Organized Research Unit changed its name from the “Institute for Quantum and Complex Dynamics” (IQCD) to the “Institute for Terahertz Science and Technology” (ITST). The name change reflects a sharpened intellectual focus which is embodied in the first phrase of our mission statement, which is “to advance science and technology at the heart of the electromagnetic spectrum,” at frequencies between 0.1 and 10 terahertz (1 terahertz is one trillion cycles/s).

In 2009-2010, exciting new instrumentation has been commissioned at ITST, solidifying UC Santa Barbara as one of the world’s leading institutions for research at terahertz frequencies. In particular, two new spectrometers enable the measurement of absorption and refraction of electromagnetic waves with frequencies between 0.07 and 3 THz. These spectrometers are powering unprecedented studies of the terahertz response of liquids and solids. A third spectrometer, which is based on UC Santa Barbara’s unique and powerful Free-Electron Lasers, is pushing the powerful methodologies of magnetic resonance—normally performed at radio or microwave frequencies—into the terahertz frequency range. The development and acquisition of this suite of instruments is enabled by a transformative grant from the W. M. Keck Foundation, with additional support from the NSF.

This was also an excellent year for building a community of terahertz researchers. For example, in July 2009, ITST held an afternoon of terahertz “magic”—a demonstration of one of the instruments described above for about 45 people—followed by a real magic show by a visitor from Germany. A well-attended series of 19 seminars featured speakers from Cornell, University of St. Andrews (Scotland), UCLA, USC, the University of Utah, Ecole Normale Supérieure (Paris) and the National High Magnetic Field Laboratory in Tallahassee, as well as students, post-docs and faculty from many departments at UC Santa Barbara in

ORU’s at UCSB have dual functions—to serve as centers for interdisciplinary research, and to excel in the pre- and post-award administration of contracts and grants. A core mission of ITST is “supporting research with outstanding service in a warm, welcoming and fun workplace.” ITST is UC Santa Barbara’s only ORU focused in the physical sciences. As you will see if you glance through the summaries of the exciting research projects we administer, we proudly continue to welcome and serve principal investigators from a wide range of departments in the sciences and engineering, regardless of the intellectual focus of their research. Notable in 2009-2010 are five awards funded under the American Recovery and Reinvestment Act of 2009.

We are looking forward to continuing to grow the community of terahertz researchers at UC Santa Barbara and elsewhere, while providing outstanding administrative support for contract and grant administration for researchers in all areas of science and engineering.
Advisory Committee

David Stuart  Physics, Committee Chair
S. James Allen  Former iQuest Director, Physics
Elliot Brown  Electrical and Computer Engineering, Materials
Rick Dahlquist  Chemistry & Biochemistry
Songi Han  Chemistry and Biochemistry
Ben Mazin  Physics
Christopher Palmstrom  Electrical and Computer Engineering
Kevin Plaxco  Chemistry and Biochemistry
Joan-Emma Shea  Chemistry and Biochemistry
Win Van Dam  Computer Science
Chris Van de Walle  Materials Department

Ex Officio Members

Marlene Rifkin  Business Officer, ITST
Mark Sherwin  Director, ITST, Physics
Mark Srednicki  Chair, Physics

Personnel

Administrative Staff-ITST

Marlene Rifkin, Business Officer
Kate Ferriane Personnel Analyst
Rita Makogon Contract and Grant Manager
Rob Marquez Contract and Grant Analyst
Elizabeth Strait Computer and Network Administrator

Technical Staff-ITST

Pankaj Dhaubhadel, Assistant Development Engineer
David Enyeart Senior Development Engineer
Gerald Ramian Research Specialist
Other Project and Activities

ITST Summer Magic

07/17/09: ITST held an afternoon of terahertz magic followed by ice cream and a magic show performed by Steffan Glaser. Participants were invited to bring either a (benign) liquid or “solid” sample to be measured in ITST’s new vector network analyzer (VNA). Prizes were awarded to the owners of the liquid and powder with the highest transmission for a fixed path length in the 280-480Ghz frequency range, and the solid sample which resulted in the largest phase change in the 280-480 GHz frequency range. A great time was had by all.

Seminars and Workshops

ITST continued its very successful lunchtime Seminar Series. Refreshments (usually pizza) were provided. The following seminars took place throughout the year:

07/27/09: Glassy Equilibration and Dynamics of 'Supersolid' Helium: Ethan Pratt, Cornell University

10/08/09: Quasi-Optical Instrumentation: Richard Wylde – University of St Andrews and Thomas Keating Ltd
10/15/09:
Report on the International Conference on Inter-subband Transitions in Quantum Wells, Montreal, 2009: Mark Sherwin, Director ITST – UCSB, Gernot Fasching, PhD. Materials, UCSB

10/22/09:
Pulsed Electron Paramagnetic Resonance at 240 GHz for Biological Studies: Devin Edwards, Physics, UCSB

10/29/09:
Terahertz Detection by a Resonant 2D Plasmon Cavity in a Multi-Gate High Electron Mobility Transistor: Greg Dyer, Physics, UCSB

11/5/09:

11/12/09:
MBE Growth of InGaAs Quantum Posts for THz Absorption and Emission: Tuan Anh Truong, ITST, UCSB

11/19/09:
Site-Directed Spin Labeling Studies of Nucleic Acid Structure and Dynamics: Peter Z. Qin, Department of Chemistry, University of Southern California

12/03/09:
What We Have Learned from LIGO: Distance Measurement and EPR: Karoly Holczer, Department of Physics and Astronomy, UCLA

01/14/10:
Spin Decoherence at High Magnetic Fields: Susumu Takahashi, ITST/Physics, UCSB

01/28/10:
1.55 μm InGaAs THz Synchronized Photoconductive Switch Array: Kimani Williams, ECE Department, Dr. Elliott Brown Research Group, UCSB

02/04/10:
Coherent Control of Rydberg States in Silicon: Vinh Nguyen, ITST, UCSB

02/11/10:
Death by THz – The Fate of the Universe: Philip Lubin, Physics, UCSB
02/18/10:
**Active Terahertz Metamaterials and Quantum Cascade Metamaterial Lasers:** Ben Williams, UCLA

02/25/10:
**A 200 GHz Dynamic Nuclear Polarization and Electron Paramagnetic Resonance Spectrometer:** Brandon Armstrong, Physics, UCSB

05/13/10:
**Coherent Spin Control in Organic Electronics:** Dane R. McCamey, Department of Physics and Astronomy, University of Utah

05/20/10:
**Planck: Looking Back Towards the Dawn of Time:** Jatila van der Veen Education and Public Outreach Coordinator for the US Planck Collaborators co-authors: Philip Lubin, Peter Meinhold, Andrea Zonca (US Planck science team); Charles Lawrence (US Planck Chief Scientist); Basak Alper, Wesley Smith, Ryan McGhee (Allosphere group), UCSB

05/27/10:
**Time-Domain Spectroscopy of Quantum Cascade Lasers:** Nathan Jukam, Laboratoire Pierre Aigrain, Ecole Normale Supérieure, Paris

06/03/10:
**Pulsed EPR at the National High Magnetic Field Laboratory:** Applications from biology to solid state magnetism: Hans van Tol, NHMFL Tallahassee
Awards Administered
(July 2009 – June 2010)

NOTE: Dates in green are the projected end dates and dollar value in green is the projected total award value.

Guenter Ahlers
National Science Foundation, DMR-0702111
Turbulent Convection in a Fluid Heater from Below
05/01/07-04/30/11 (04/30/12)
$465,000 ($620,000)

Turbulent convection in a fluid heated from below occurs naturally in Earth's atmosphere and oceans where it influences climate and weather, in Earth's mantle where it contributes to the motion of continental plates, in Earth's outer core where it determines the magnetic field, in the Sun where it influences the temperature on Earth, and in many industrial processes where it may have significant economic consequences. This grant supports experiments under highly controlled laboratory conditions and in samples of idealized shapes where some of the central physical components of this process can be studied quantitatively. These components include relatively quiet fluid layers just above the bottom and below the top plate (the "boundary layers"), and a turbulent interior with highly fluctuating temperature and fluid-flow. A large convection cell, known as the "wind of turbulence", is superimposed on these interior fluctuations. Quantitative measurements will be made of the turbulent enhancement of the heat transport, of the temperature distribution in the interior, and of the wind dynamics. The highly quantitative experiments are of modest complexity and thus afford an exceptional diverse learning experience for both graduate and undergraduate students who participate in the work.

S. James Allen
Sandia National Laboratories, 979057
Terahertz Resonant Plasmonic Detectors
12/01/09-05/31/10
$15,000

The objective of this award is to test, model and document plasmonic resonant detectors with integrated, voltage controlled barrier detectors, log periodic antennas and back side gates.
Bjorn Birnir  
Marine Research Institute (Iceland) SB080063  
Simulations of Complex Schools of Fish  
11/01/07-01/15/10  
$48,259  

This is an agreement to conduct research and simulations on capelin migration in Icelandic and adjacent waters, based on data collected and provided by the Marine Research Institute with the aim to further understanding underlying dynamics of changes in the migration pattern of capelin in these waters.

Jeffrey Bode  
National Science Foundation, CHE-0449587  
CAREER: Development and Applications of Catalytic Generated Activated Carboxylates  
01/15/05-12/31/10  
$437,525  

Intramolecular redox reactions of a-functionalized aldehydes mediated by N-heterocyclic carbenes (or heterocyclic ylides) lead to the catalytic generation of activated carboxylates, suitable for the synthesis of esters, amides, and other carboxylic acid derivatives under economical and environmentally friendly reaction conditions. The discovery of this novel reactivity, mediated by an organic catalyst, of a-heteroatomic and a,b-unsaturated aldehydes opens a broad range of mechanistically unique pathways for the synthesis of chiral carboxylic acid derivatives, including anti-b-hydroxyesters and b-amino peptides. The design and application of chiral heterocyclic salts for catalyzing this novel process will provide an enantioselective method for directly controlling the absolute stereochemistry concomitant with esterifications and peptide couplings, and has the potential to supplant traditional multi-step chiral auxiliary based methodologies. By developing means of effecting the direct, enantioselective synthesis of amides from a,b-didehydroamino aldehydes, a waste-free, atom-economical approach to the synthesis of poly-a-amino-peptides from achiral precursors will emerge. The unique reactivities of unsaturated aldehydes under these catalytic conditions will enable novel carbon-carbon bond forming processes, including new annulation reactions affording lactones, lactams, and cyclopentanones, thereby providing a long-sought method for the direct, intermolecular synthesis of hetero- and carbocycles from stable, readily available starting materials. Applications of these new reactions include the synthesis of (1) short, biologically active a- and b-peptides, (2) the kalafungin class of naturally occurring antibiotics, and (3) the antibiotic moiramide B, which is active against drug resistant bacterial strains. With the support of this CAREER award from the Organic and Macromolecular Chemistry Program, Professor Jeffrey W. Bode, of the Department of Chemistry and Biochemistry at the University of California, Santa Barbara, is developing new reactions catalyzed by simple organic molecules rather than by metals. This reaction chemistry not only offers promise of great chemical selectivity, but also represents an economical, environmentally friendly ("green") approach to organic synthesis, eliminating the use of potentially hazardous metals and greatly reducing waste generation. Professor Bode will exploit the newly discovered reaction chemistry for the synthesis of a variety of products, including biologically active polypeptides and antibiotics, demonstrating the potentially broad applicability of this chemistry in
the synthesis of important products. He will also engage undergraduate students, both at UCSB and from local community colleges, in an alternative sophomore level organic laboratory course aimed at exposing them to hands-on training in the realities of inquiry and research based organic chemistry.

Jeffrey Bode  
Research Corporation, CS1392  
New Ligation Reactions for the Synthesis of Biomolecules and Biomaterials  
07/01/06-06/30/11  
$100,000

The next generation of therapeutics, functional materials, and designed nanostructures are inaccessible with existing methods of molecular synthesis. To address this, we are developing new organic reactions that enable both stepwise and fragment condensation approaches to large, functionalized structures under aqueous conditions and without reagents, catalysts, or by-products. These processes, and others under development in our laboratories, will provide the foundation for a new approach to the synthesis of complex molecules including glycopeptides, tailored biomaterials, and nanoscale assemblies. As a specific example, we detail new approaches to the synthesis of poly-?-peptides by a novel ligation reaction that forms amide bonds under aqueous conditions, without reagents, and produces only carbon dioxide as a by-product.

Dirk Bouwmeester  
National Science Foundation, PHY-0804177  
Quantum States of OptoMechanical Structures  
08/01/08-07/31/10 (07/31/11)  
$440,000 ($600,000)

Quantum theory has been extremely successful in explaining many aspects of the world around us. Despite this achievement, fundamental aspects of the quantum theory are as mysterious as they were to the founders of the theory. Especially remarkable is the feature that a particle somehow obtains information about different "paths" it could have taken. This observation leads to the question of what would happen if such quantum effects could be observed in macroscopic objects. If the laws of quantum mechanics remain valid for large objects, one seems to be forced to accept that cats can be alive and dead at the same time (following Schroedinger's famous thought experiment). However, others question whether such a drastic conclusion is justified based on the current support for the theory. The fact is that all experiments to date that directly tested the quantum superposition of individual objects are restricted to photons, atoms, molecules and ensemble of electrons. Furthermore the quantum theory is faced with problems when trying to unify it with the theory of relativity. It is not possible either on theoretical or experimental grounds, therefore, to rule out the possibility that quantum mechanics does not apply to large objects. Optical technology has progressed to the level that it is conceivable to put a small mirror into a superposition of two quantum states. The experiment will be done with a particularly tiny mirror, smaller in diameter than a human hair but still about ten billion times more massive than any object previously brought into a quantum superposition. This award provides support for the mirror and
cantilever fabrication as well as for designing a liquid-helium cooled apparatus and performing supporting theoretical work. Furthermore it provides travel support for establishing a close collaboration with international experts on sub-millikelvin systems. Testing quantum mechanics in this unexplored regime is first of all of fundamental importance. The optical control of micro-mechanical systems, in particular the application of optical cooling techniques, is however also expected to be of broad interest in metrology and could also be used for several different experiments such as generating squeezed light and resonance enhanced Casimir forces. This research program involves significant educational component, and the research is excellent for teaching fundamental properties of quantum mechanics and micro-mechanical systems and for training young researchers in state-of-the-art technologies in a multi-disciplinary and international environment.

Dirk Bouwmeester
Pierre Petroff
National Science Foundation, ECCS-0901886
Solid State Cavity Electrodynamics
06/03/09-08/31/12
$399,914

This award is funded under the American Recovery and Reinvestment Act of 2009 (Public Law 111-5).

The objective is to develop solid-state devices for achieving controlled and efficient coupling between single photons and single electrons confined in microstructures.

Dirk Bouwmeester
Elisabeth Gwinn
Deborah Fygenson
Everett Lipman
Michael Liebling
National Science Foundation, DMR-0960331
MRI-R2 Nano Photonic Imaging System
03/15/10-2/28/13
$464,703

This award is funded under the American Recovery and Reinvestment Act of 2009 (Public Law 111-5).

A rapidly expanding field of research concerns the development of new techniques for optical imaging of nanometer to micron scale structures, such as biological molecules with integrated functional elements, semiconductor optoelectronic devices and cells. The investigator team proposes to develop an unconventional optical instrument capable of resolving structures on the scale of a few tens of nanometers, by using special correlated states of light (such as entangled two-photon states) in combination with an ultra stable optical platform with nanometer resolution scanning capabilities and

Note: Dates in green are the projected end dates and dollar value in green is the projected total award value.
recently-developed signal processing algorithms. In order to probe the special light-matter interactions that occur when phonon-induced dephasing is minimal, the system is designed to operate at cryogenic as well as ambient temperatures. The wide wavelength range of this nano-photonics imaging system would enable investigation of structures ranging from semiconductor nanodevices to DNA scaffolds to living cells. The research team consists of experts in the key technological aspects: quantum optics, high resolution optical imaging and high speed image processing, ultra-low vibration and low-temperature operation, and biological system design.

Michael Bowers  
Air Force, FA9550-06-1-0069  
POSS and Metal Clusters: Structures and Energetics  
01/01/06-11/30/10  
$936,000  

There are several objectives for this proposal:  
1. Structure and Characterization of Polyhedral Oligomeric Silsesquioxane (POSS) attached to Polymer Backbones: The POSS family of molecules has recently generated great interest due to their inherent thermal and chemical stability and their ability to improve the thermal, physical and chemical properties of host polymer systems. We have developed ion-mobility-based mass spectrometric methods suitable for characterizing a wide variety of POSS cages. In the coming three years, these methods, coupled with extensive molecular modeling will be applied to POSS cages covalently bound to oligomers of a variety of organic polymers. We will collaborate with a number of synthetic research groups in the development of rational synthetic strategies to produce these materials.

2. Size-Selected Structures and Ligand Binding Energies of Metal Clusters: In recent years there has been a major renaissance in the study of small metal clusters as catalytic agents for select, important industrial processes. Of special importance are the clusters of coinage metals: gold, silver and (possibly) copper. At UCSB we have constructed a unique instrument for the deposition and characterization of size-selected coinage metal clusters on metal oxide surfaces, funded by a multi-investigator DURINT grant. There are several aspects of this work that are strongly complemented by gas phase studies. Careful STM measurements have established that clusters of four or more gold atoms have specific structures on the surface and that the onset of the transition from 2-dimensional to 3-dimensional surface clusters occurs below n=8. It will be very important to know the actual structures of the species that are deposited at low energies onto the surfaces to see if they correlate with observed surface structures. Theory also plays a large role in interpreting the structure and reactivity of surface-deposited systems. Careful measurement of structures and ligand binding energies of size- and charge-selected gas-phase clusters is crucial for providing experimental benchmarks for testing theoretical models. Finally, shape and ligand binding energy studies over large cluster size ranges allows direct observation of atomic to bulk transitions, an area where much is speculated but little is known.
The objective of this research is to understand, on a molecular level, the folding and assembly of Aβ-protein alloforms. Recent results indicate small soluble oligomers of Aβ are responsible for initiating a pathological cascade resulting in Alzheimer’s disease (AD). Aβ42 has been shown to be the primary neurotoxic agent even though Aβ40 is nearly 10 times more abundant. Single-point amino-acid substitutions at positions 22 and 23 in Aβ42 account for a variety of familial forms of AD. It is our hypothesis that Aβ monomers and small oligomers are important therapeutic targets and characterization of their structure and mechanisms of folding and assembly are critical research objectives. Here we propose to apply, for the first time, the powerful methods of ion mobility spectrometry coupled with mass spectrometry (IMS-MS) to the problem of Aβ folding and assembly. These methods provide accurate measures of monomer and oligomer cross sections and oligomer size distributions. When coupled with high-level molecular dynamics modeling, monomeric structure with atomic detail is obtained. The method is ultrasensitive, routinely working with picomoles of sample or less. These methods can be readily extended to other neurological diseases like ALS and Parkinson’s disease that share the misfolding/aggregation motif with AD.

The specific aims of this research are (1) to structurally characterize Aβ monomers and to determine how these structures change with single-amino-acid substitution, oxidation or other simple sequence modification, (2) to structurally characterize Aβ monomer fragments and determine how these structures change with sequence length, single-amino-acid substitutions or other modifications, and (3) to measure oligomer-size distributions and oligomer structures for the early stages of assembly if Aβ and modified forms of Aβ40 and Aβ42.

In this award funded by the Experimental Physical Chemistry Program of the Division of Chemistry, Professor Michael Bowers of University of California, Santa Barbara, explores the question of why peptides and proteins in living systems are solely composed of L-amino acids - one of the deepest mysteries in biology. Professor Bowers and his students will start with several simple model systems of peptides that are available in a wide range of chirally mixed forms. These peptides are small enough (5 or 6 amino acids long) that good theory can be done on them to help understand observed changes in their folding and aggregation tendencies as a function of their chiral purity. These peptide families will also provide an entrée into a second major thrust of the proposal - amyloid formation mechanisms. Amyloids are ubiquitous in complex living systems and are implicated in many serious diseases.
(Alzheimer's, type 2 diabetes, etc.). The goal is to understand the aggregation process and how initially coiled or alpha-helical oligomeric systems end up as large beta-sheet assemblies. As part of this effort Professor Bower's team will initiate a collaboration with Gerhard Meijer and Gert Von Helden at the Fritz Haber Institute in Berlin. This group is building a state of the art instrument to Professor Bower's specifications for this work to couple with a new free electron laser under construction at that facility. Finally the researchers have initiated studies on a related biologically important amyloid system, the 37 residue IAPP or amylin peptide, involved in type 2 diabetes. The human wild type peptide rapidly forms large oligomers but a number of very similar peptides do not. Preliminary data implicate compact assemblies as leading to fibril formation (and hence disease) while elongated assemblies of the same oligomer number do not aggregate further. Modeling and further experiments are planned to fully understand these initial results.

Science education in the United States is in a sustained downturn that threatens our world leadership in both innovation and technology development. The problems start early. The 5th grade has been targeted as the first "go" or "no go" indicator in a child's scientific development. At UCSB there is a strong outreach program at the 5th grade level initiated and sustained by a former group member with continuing help from current research group members. Professor Bowers decided to tackle the second "go" or "no go" decision time in young adults - their high school years. His group is developing an outreach program using all group members to present their research projects to high school classes and to relate their personal scientific stories and how they ended up in graduate school at UCSB. A preliminary trial with one of the group members has been run with encouraging results. Additional UCSB faculty and research groups will be incorporated as the program grows.

Steven Buratto
Michael Bowers
Department of Energy/Miscellaneous Offices and Programs, DE-FG02-06ER15835
Chemical Imaging with 100nm Spatial Resolution
09/01/06-08/31/10
$596,299

Over the past decade high resolution optical microscopy methods have been utilized with great success to image the absorbance, luminescence, photoconductivity and Raman scattering of thin films and surfaces with spatial resolution of the order of 100nm. Using conventional far-field optics (i.e. microscope objectives), laser scanning confocal microscopy (LSCM) is capable of probing materials with spatial resolution approaching 200 nm and single molecule sensitivity in fluorescence and surface-enhanced Raman contrast. In addition, a new scanned probe microscopy, near-field scanning optical microscopy (NSOM) method has been developed with the same capabilities and array of applications as LSCM but with spatial resolution enhanced by nearly an order-of-magnitude. Despite such wide applicability, these imaging methods still lack chemical specificity and often produce images where it is difficult to determine the chemical origin of the image contrast. In order to address this deficiency we propose to combine, in a single instrument, the high spatial resolution microscopy techniques of LCSM and NSOM with the chemical specificity and conformational selectivity of ion mobility mass spectrometry. We will adapt the source chamber of an ion mobility apparatus to include a combination
scanning confocal/near-field microscope. The optical microscopy will be performed in vacuum and an image with luminescence, transmission (absorption) or Raman contrast will be recorded using either the microscope objective or the NSOM optics. In order to determine the chemical contrast from selected domains in the optical image, we will position the sample to the desired spot with the scanning electronics and vaporize molecules from the selected region via laser desorption ionization using the imaging optics. A mass spectrum and/or an arrival time distribution (ATD) will then be recorded from the gas-phase molecules. This data will provide a chemical signature (i.e. mass measurement) and a shape distribution for a given species (ATD) within the localized region of the sample.

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Steven Buratto  
Michael Bowers  
Horia Metiu  
National Science Foundation, CHE-0749489  
Model Nanocluster Catalysts: The Role of Size, Shape and Composition on the Catalytic Activity on Monometallic, Bimetallic and Metal Oxide Clusters on Oxide Surfaces  
04/01/08-03/31/11  
$536,000

In this research supported by the Analytical and Surface Chemistry Program, Professors Buratto, Bowers, and Metiu and their groups will prepare, characterize, and test three new types of nanoscale catalysts, having one feature in common: very small, isolated, well-defined, catalytically active sites. They will prepare and study (a) very small Aun and Agn mass-selected clusters supported on oxide, (b) very small mass-selected, binary clusters such as PdmAun supported on oxides, and (c) very small, mass-selected oxide clusters supported on oxides. A variety of techniques will be used, in a concerted manner, to study these important catalytic processes: model catalytic systems will be prepared by depositing mass-selected clusters on oxide surfaces to ensure atom-by-atom control of catalyst size; all samples will be prepared and studied in ultra-high vacuum by surface science techniques (AES, XPS) as well as by STM/AFM before, during and after the catalytic chemistry; and density functional theory (DFT) will be used to calculate the structure of the clusters, their XPS spectrum and their chemical activity. Through the work proposed here they will develop a detailed understanding of the catalytic chemistry of these materials and find out how this chemistry depends on size, composition and the nature of the substrate. While the focus of the research is on the catalytic activity of specific nanoscale catalysts, there is a high probability that the results will be applicable to other systems. In addition, it is hoped that the concepts developed through this research will help optimize important industrial processes using these nanoscale catalysts and provide insight into the discovery of new nanoscale catalytic materials. The research funded by this grant will be interdisciplinary. Graduate students will interact continuously with three different research groups, will have daily contact with other outstanding scientists, and will acquire hands-on experience in a large number of techniques of surface science, gas-phase chemistry, scanned probe microscopy, and high level theory. The research will provide a valuable opportunity for graduate education, found in very few places in the world. Researchers supported by this grant (including PIs) will also be active in outreach to K-12 schools in the Santa Barbara area to present a tutorial on an atomistic view of heterogeneous catalysis and to show an atomically-resolved picture of our model catalyst systems. This will be included in the currently active outreach program in the
chemistry department at UCSB. A series of lectures on catalysis by nanostructures will be developed and included as part of a course in nanoscience currently taught in the materials chemistry curriculum.

David Cannell  
**National Aeronautics and Space Administration, NNX08AE53G**  
**Gradient Driven Fluctuations**  
03/01/08-02/28/11  
$190,000

This research continues the work done previously. Although we do not yet have the data in hand, our experiment was flown aboard the Foton-M3 mission on September 14-26, 2007. Hopefully, our results will provide insight into the behavior of single-component fluids and mixtures, including protein solutions, when placed in the microgravity environment, and subjected to temperature and/or concentration gradients. This might be of considerable interest to anyone attempting crystal growth in the microgravity environment, for example, because the growth process of necessity generates concentration gradients, and thus enhanced fluctuations.

Andrew Cleland  
**National Science Foundation, DMR-0605818**  
**Mechanical Quantum Resonators: Quantum Optics with Phonons**  
07/01/06-06/30/11  
$355,000

Quantum mechanics controls the behavior of very small, atomic-scale systems like the hydrogen atom and the electron. Demonstrations of the applicability of quantum mechanics to larger scale systems, especially ones with millions or more independent atoms, are challenging due to the need to isolate the system of interest from the environment that surrounds them, an environment that demolishes the quantum effects so peculiar to our classical experience. To date, no clear demonstration of quantum effects in large systems has been performed, certainly not in large mechanical systems. This project will focus on the construction of small mechanical resonators, similar to quartz crystals used to time computer circuits, sufficiently disconnected from the rest of the world to allow quantum effects to be displayed in an unambiguous fashion. In particular, the quantum nature of vibrational energy, which is predicted to change in steps rather than in a continuous fashion, will be explored in detail. The multidisciplinary project integrates research and education in order to train students and postdoctoral researchers in modern methods required to address this key problem in physics, which will be integrated with engineering and nanotechnology to achieve the goals set forward here. The acquired interdisciplinary skills, which include state-of-the-art nanofabrication and radiofrequency and microwave technology, prepare the trainees for careers in academe, national laboratories, and industry.
The original goal of this research was to define the molecular mechanisms that underlie bacterial chemotaxis. It has become clear that bacterial chemotaxis employs “two component” regulation in its basic biochemistry. This mechanism is common to many bacterial signaling pathways (at least 30 in *Escherichia coli*). These feature a specific histidine auto-kinase that phosphorylates a specific response regulator domain on an aspartate residue that is conserved in the family of response regulators. The phosphorylation event modulates the interaction of the response regulator domain, resulting in enhanced or diminished interactions with other domains or proteins. Thus our long-term has expanded to include a more general understanding of the consequences of phosphorylation of response regulator domains while we continue our focus on bacterial chemotaxis.

Purchase of an 800 MHz NMR Spectrometer.
DNA Patterned Pairs of Colloidal Quantum Dots: A Scalable Approach to Computing Without Wires

To reduce the size of computer architecture and test a revolutionary new approach to computation, we will investigate fully self-assembled arrays of classical and quantum bits that are addressed by optical signals only. As bits we propose to use single electron spins in colloidal quantum dots (cqdots). Every cqdot has a specific resonance frequency at which the absorption of a photon can lead to the formation of a trion state (two electrons and one hole confined within a quantum dot). Trion states have large electric dipole moments and can therefore interact over distances of the order of 10 nm. We will leverage the polarization of the illuminating light and the Pauli exclusion principle to control trion formation and subsequently detect the spectral effect of dipole-dipole interactions between cqdots spaced 5 to 10 nm apart. In this manner, we have as a long-term goal the physical realization of theoretical schemes for quantum computing. On the way to this goal, we will explore simplified approaches that are also very interesting from the perspective of classical computation and data storage. For the three-year period of the proposed research, our primary contribution to the quest for all-optical classical and quantum computation will be to address the challenge of nanometer positioning of colloidal quantum dots and to study their optical interactions. Our approach will be to combine self-assembled DNA scaffolds with site-specific binding elements to produce an array of optically active colloidal quantum dots. Self-assembled DNA scaffolds leverage the intrinsic specificity of Watson-Crick base-pairing to organize millions of atoms into close-packed arrays of the familiar double-helical structure with nanoscopic precision. Modern synthesis methods allow decoration of specific atoms in the DNA structure with chemically reactive groups. These reactive groups can be chosen to form covalent links to molecules that stabilize the surface of colloidal quantum dots. By placing the reactive groups at specific sites on the DNA scaffold, pairs of dots and linear or two-dimensional arrays of dots will be patterned, with a spacing that favors quantum mechanical interactions between dots. The resulting structures will be characterized by scanning probe microscopy and the interactions probed by optical pump-probe measurements.

The research will be carried out by a cross-disciplinary research team at the University of California Santa Barbara that is anchored by expertise in self assembly of DNA, the synthesis of colloidal quantum dots and their attachment to functionalized elements at specific locations (Fygenson), and expertise in quantum-optics and solid-state experiments analyzing coupled quantum dots embedded in bulk semiconductor material (Bouwmeester). We will collaborate strongly with Paul W. K. Rothemund, in the Department of Computer Science at Caltech, who recently invented an powerful new class of self-assembling DNA scaffolds that can template arbitrary complex patterns with 6 nm resolution.
Songi Han  
Frederick Dahlquist  
Mark Sherwin  
Louis-Claude Brunel  
Johan van Tol  
National Science Foundation CHE-0821589  
MRI: Development of a 240 Hhz Pulsed Electron Paramagnetic Spectrometer with Nanosecond Time Resolution  
08/01/08-07/31/11  
$1,254,623

The Department of Chemistry and Biochemistry at the University of California-Santa Barbara will develop a 240 GHz pulsed electron paramagnetic resonance spectrometer (EPR) with this award from the Major Research Instrumentation (MRI) program. This high frequency EPR spectrometer will capitalize on the tunable terahertz excitation pulses generated at UC Santa Barbara's Free Electron Laser (FEL) facility. The instrument will push the frontier of EPR spectroscopy to more than twice the current frequency/field limitation. It will open up new areas of investigation of the structure and dynamics in biological, chemical and electronic systems.

EPR spectroscopy detects changes in electron spin in materials that contain an unpaired electron. This provides information on the structure and motions of the material at an atomic level. The resultant data provides insight on the properties of materials such as proteins, enzymes and defects in solid materials. This new instrument will allow the study of proteins in biologically relevant environments that were heretofore impossible in many cases. After development, the new spectrometer is intended to become a multi-user facility because of its unique capabilities. Graduate and undergraduate students will be involved in this project learning skills in the design and construction of state-of-the-art instrumentation.

Bruce Lipshutz  
National Science Foundation, CHE-0550232  
Asymmetric Catalysis with Ligated Copper Hydride  
02/01/06-01/31/10  
$592,000

This project is focused on the theme of catalysis, specifically involving copper(I) hydrido complexes that are mainly ligated by nonracemic bis-phosphines ((L*)CuH). The action of catalytic (L*)CuH on aryl ketone intermediates will form products useful for the synthesis of known pharmaceuticals. Catalytic (L*)CuH will be used in new contexts that will afford valued nonracemic intermediates for synthesis, extending the limits of this CuH chemistry. A newly designed ligand will be synthesized to test the factors that may control both reaction rates and enantioselectivities. Experiments aimed at investigating the nature of the species (L*)CuH are planned, supporting the goal of providing a practical source of (L*)CuH; i.e., effectively CuH in a Bottle. Using boranes as the stoichiometric source of hydride, new inroads to boron enolates will be developed and used to synthetic advantage based on transmetalations. Finally, copper-in-charcoal (Cu/C) will be explored as a potential new approach to
asymmetric (heterogeneous) organocopper chemistry. Catalysis represents a powerful tool in the development of more economical and environmentally friendly technologies. Professor Lipshutz and his students are exploring new ways to catalyze organic chemical transformations using copper compounds. These copper compounds are significantly less expensive than the more commonly used precious metal catalysts and offer unique chemical reactivity as well. By developing these new catalysts, Professor Lipshutz is developing methodologies that may be generally and broadly applicable in the synthesis of complex organic molecules and pharmaceuticals.

Bruce Lipshutz
UCSB
The Green Initiative Fund (TGIF)
Getting Organic Solvents Out of Organic Reactions
06/01/09-06/30/10
$45,000

Our plan is to devise up to three new experiments that will teach high school and college level students about green chemistry. These will focus on eliminating the major source (i.e. 75+%) of chemical waste: organic solvents. The nanotechnology (“micellar catalysis”) in hand and upon which these new experiments are to be based will allow for them to be run in water (actually seawater!) at room temperature; no additional energy consumption/cost should be needed. If realized as envisioned, lab hoods may not even be required. This pilot study may, therefore, be a model that further encourages those who oversee teaching labs in Chemistry to design elements of sustainability (i.e. “benign by design”) into their curricula so as to focus on minimizing use of organic solvents.

Bruce Lipshutz
National Institutes of Health, 1R01 GM086485-01A1
New Technologies for Catalysis in Water
08/15/09-07/31/10 (07/31/11)
$304,904 ($600,810)

This award is funded under the American Recovery and Reinvestment Act of 2009 (Public Law 111-5).

A nanomicelle-forming amphiphile "PTS" has been identified that allows for several Pd- and Ru-catalyzed cross-couplings to take place in water as the only solvent, and at room temperature, in high isolated yields. The new processes include Heck, Suzuki, Sonogashira, and olefin cross-metathesis reactions, where product isolation is especially facile. Several additional studies are planned based on the "micellar effect." The notion of "designer" surfactants applied to organometallic catalysis is advanced in this proposal, and represents a variable essentially overlooked by the synthetic community. This technology also is to be applied to other important cross-couplings, such as aminations and asymmetric additions of hydride to Michael acceptors, all in water at room temperature.

Note: Dates in green are the projected end dates and dollar value in green is the projected total award value.
Bruce Lipshutz  
National Science Foundation, CHE-0937658  
EAGER: Chemistry of Water-Intolerant Intermediates….in Water  
09/01/09-08/31/11  
$200,000

This award is funded under the American Recovery and Reinvestment Act of 2009 (Public Law 111-5).

This project will initiate work on the development of methods for two unprecedented reactions: (1) in situ Grignard formation and use in cross-coupling reactions in water, and (2) formation of unstabilized ylides for Wittig-like olefinations, also in water. These will take advantage of micellar catalysis, where the reactive species to be generated either on the surface of the metal, or within a micelle, are protected from their aqueous surroundings by the hydrophobic interior of these nanoparticles. For these studies, many variables will need to be screened, including the nature of the amphiphile that is to supply a dry reaction medium, in water.

With this award, the Organic and Macromolecular Chemistry Program is supporting the research of Professor Bruce H. Lipshutz of the Department of Chemistry at the University of California, Santa Barbara. Professor Bruce Lipshutz's research efforts revolve around the development of new synthetic methods for the formation of C-C, C-H, C-O, and C-N bonds. Such chemistry will contribute to environmentally benign methods for chemical synthesis, as these new processes will be developed in the absence of organic solvents. Successful development of the methodology will have an impact on synthesis in the pharmaceutical, fine chemicals, and agricultural industries.

Bruce Lipshutz  
National Science Foundation, CHE-094879  
New Technologies Based on Organocopper Catalysis  
06/01/10-05/31/13  
$489,000

This project will explore several synthetic methods that rely on copper as the metal that effects catalysis. A number of the transformations are on copper hydride chemistry, which includes new uses of nonracemically ligated CuH for syntheses. The potential to realize unprecedented ligand-accelerated catalysis with CuH in pure water at room temperature will be pursued, along with the potential to deliver water-sensitive carbon-based residues via conjugate addition chemistry, with both approaches based on micellar catalysis in water. Heterogeneous processes that take advantage of both readily accessed valence states of copper [Cu(I) and Cu(II)] impregnated into the pores of inexpensive charcoal matrices will also be developed. A high substrate-to-ligand ratio and tandem processes that can be carried out in a single reaction vessel will be studied.

With this award, the Chemical Synthesis Program is supporting the research of Professor Bruce H. Lipshutz of the Department of Chemistry at the University of California, Santa Barbara. Professor Lipshutz's research efforts revolve around the development of organocopper-based asymmetric catalysis...
leading to new methods for the formation of C-C and C-H bonds. Such chemistry will contribute to environmentally benign methods for chemical synthesis as most of these new technologies will be developed in the absence of organic solvents, where water serves as the macroscopic medium. Successful applications of the methodology will have an impact on synthesis in the pharmaceutical, fine chemical, and agricultural industries.

**R. Daniel Little**  
Robert Jacobs  
**Army, W81XWH-06-1-0089**  
**The Role of the Pseudopterosins and their Analogs in Wound Healing**  
**11/20/06-10/19/09**  
$991,582

Severe injury from chemical or physical sources continues to be a serious and challenging medical problem from the perspective of successful treatment, survival, and recovery. A physical surface injury to the skin of most animals initiates a complex series of immune and physiological responses involving pain, inflammation, wound repair and scar formation. The total process of wound repair or wound healing is not homogenous among species but many components of the response are phylogenetically conserved and are observed in very primitive unicellular algae and ciliates. In vertebrates including man certain forms of injury are followed by a major initial infiltration and concentration of neutrophils at the sight of injury. During the early stages of phagocytosis, these cells degranulate and release stored enzymes such as myeloperoxidase, proteases, lipases, and pro-inflammatory eicosanoids and chemotactic factors that attract additional immune cells. They also produce reactive oxygen species, alter vascular permeability, and induce swelling. Most cells also contribute to this early stage by releasing histamine and other autocoids.

We hypothesize that donor sites in patients undergoing repeated reconstructive surgery may represent a clinical condition that can be simulated experimentally by topical treatment of mouse ears with the irritant phorbol myristate acetate (PMA). We base our hypothesis on the fact that Pseudopterosin A and its analogs block infiltration of neutrophils in the PMA treated mouse ear aln also block phagocytosis and degranulation in cell culture models. Recent phase 2 clinical trials have shown that topical application of pseudopterosin A methyl ether significantly increased healing rate of donor sites in burn patients. We believe this may be in part the result of diminished pro-inflammatory mediators at the wound site. We wish to exploit these results and propose to optimize the potency and efficacy of the pseudopterosin pharmacophore, increase its bioavailability and provide a new molecule that can be readily synthesized.

**Philip Lubin**  
Jet Propulsion Laboratory, JPL1367008  
**Planck Educational and Public Outreach Effort at UCSB**  
**02/10/09-09/30/13**  
$30,000 ($62,000)

Note: Dates in green are the projected end dates and dollar value in green is the projected total award value.
This award will fund a cosmology summer session that brings in students from a local high school (Dos Pueblos High and perhaps others) and a local community college (Santa Barbara City College). Graduate students, post doc (Rodrigo) Peter Meinhold and Dr. Lubin will orient the students on the Planck mission and relevant science and technology issues, and then the students will work during the summer as a team on various CMB technology programs for a hands-on summer program. We hope to run this program over a six week period each summer.

Douglas Scalapino
Oak Ridge National Laboratory, 4000068439
Exploration of Routes to Higher Superconduction Transition Temperatures
04/14/08-01/31/12
$330,666 ($446,886)

Using recently developed algorithms and new state of the art computer hardware and architecture, we are seeking to understand the properties of strongly correlated electronic materials. Our work is particularly focused on the challenges posed by the high temperature cuprate superconductors. We believe that an understanding of these materials will open an important area of material science and applications.

Mark Sherwin
Pierre Petroff
Craig Pryor
Jelena Vuckovic
National Science Foundation, CCF-0507295
NIRT: Semiconductor Nanostructures and Photonic Crystal Microcavities for Quantum Information Processing at Terahertz Frequencies
08/01/05-07/31/09
$1,500,000

This grant will explore the fundamental physics of elements in a proposed semiconducting quantum information processor (QIP) which is potentially scalable to ~1000 quantum bits (qubits). The qubits in the envisioned QIP are the two lowest orbital states of electrons bound to shallow donors (D0) in GaAs or bound in elongated self-assembled quantum dots called quantum dashes (QDAs). QDAs will be grown by molecular beam epitaxy on patterned substrates. The resonance frequency of D0 and QDA-based qubits will be between 1 and 4 Terahertz (THz). The energy relaxation and decoherence rates of these qubits will be measured, and are predicted to be slow because the resonant frequencies are well below that of an optical phonon. GaAs and Si Photonic crystal resonators for THz frequencies will also be fabricated and characterized. Finally, qubits will be incorporated into resonators and reversible coupling of energy between the resonator and qubits will be investigated. This research program works at two scientific and technological frontiers: harnessing quantum mechanics for information processing, and developing the portion of the electromagnetic spectrum between 1 and 10 THz (THz-1 THz=one trillion cycles/s). The research will explore a new approach to quantum information processing in...
semiconductors, enhance our fundamental understanding of the transfer of information and energy between simple quantum systems and their semiconducting hosts, and create new materials and structures in which to store THz light and control its interaction with matter.

Mark Sherwin  
DN Naval Research Laboratory, N00173-06-P-1198  
Practical Terahertz Detectors  
07/11/06-07/10/09  
$89,943

A practical THz detector for most earth-based applications would be one that is sufficiently sensitive to detect thermal THz emission with high signal to noise ratio in reasonable integration times, has modest cryogenic requirements, and is sufficiently fast for use as a heterodyne detector with wide intermediate frequency bandwidth, and for applications requiring high speed such as radar and communications. We propose to design, fabricate and test tunable antenna-coupled intersubband terahertz (TACIT) detectors and recently-conceived, closely-related plasmonic antenna-coupled Terahertz (PACT) detectors which operate at frequencies between 1 and 2 THz. These detectors are suitable for eventual incorporation into focal plane arrays.

Mark Sherwin  
National Science Foundation, DMR-0703925  
Terahertz Electro-Optics and Intersubband Micro-Plasmonics in Semiconductor Quantum Well Devices  
07/01/07-06/30/10  
$390,000

This research program explores the response of semiconductor devices (designed and fabricated at UC Santa Barbara) in the "terahertz (THz) gap" of the electromagnetic spectrum between 0.1 and 10 THz. A frequency of 1 THz corresponds to 1 trillion (1012) cycles per second, 1000 times faster than the frequency at which cell phones broadcast, and 500 times lower than the frequency of green light. A new kind of detector for terahertz radiation will be explored, potentially useful for applications including security, medicine, and non-destructive materials testing. At the heart of this detector is a "gas" of electrons confined in a thin layer. The electrons will be forced perpendicular to the layer to search for the simultaneous existence of two stable operating states ("optical bistability," potentially useful as a terahertz-activated switch), spontaneous oscillation (a potential terahertz source) and a "chaotic" current induced by periodic driving (chaos is not normally observed in quantum mechanical systems). Strong terahertz radiation will also be used to enhance the functionalities of semiconductor optical devices, such as optical modulators used to transmit information over fiber-optic cables. Undergraduates, graduate students and post-doctoral researchers will receive broad experimental training. Along with the PI, they will bring novel outreach materials to local K-12 schools.

Note: Dates in green are the projected end dates and dollar value in green is the projected total award value.
Mark Sherwin  
S. James Allen  
Eliott Brown  
Song-I Han  
Philip Lubin  
Kevin Plaxco  
Mark Rodwell  
William M. Keck Foundation, SB080017  
“Filming” Proteins in Action with UC Santa Barbara’s Free Electron Lasers  
07/01/07-06/30/11  
$1,750,000

The movement and dynamics of proteins is of enormous importance in almost all of the biological processes and reactions that occur in living organisms. Unfortunately, however, our ability to characterize these motions is limited by the fact that proteins perform their biological roles in aqueous solution, a milieu that poses nearly intractable problems for established experimental methodologies to study molecular dynamics. Here we propose a research program dedicated to the hitherto difficult task of monitoring the collective, functional motions of proteins and other biomolecules in aqueous solution. The program will receive significant leveraging from UC Santa Barbara’s unique existing suite of high power terahertz free electron lasers. We will pioneer the development and application of two complementary techniques by which protein motions in aqueous solution can be “filmed:”

1. terahertz absorption spectroscopy of proteins and  
2. terahertz pulsed electron paramagnetic resonance.

Taken together the two approaches will provide revolutionary insights into the dynamics of proteins as they function in their biologically relevant environments.

Mark Sherwin  
National Science Foundation, DMR-0901970  
Education and Outreach through Optical Terahertz Science and Technology Workshop: Santa Barbara, California: March 2009  
03/01/09-02/28/10  
$17,000

The recent development of terahertz (THz) technology based on optical light has resulted in rapid growth and real world applications. Prototype terahertz imaging systems have been installed in airports and post offices for security inspections. Industries from ship building to forestry are applying THz light for process monitoring. Biomolecular and biomedical research now experiment with terahertz technology. To ensure U.S. leadership in this rapidly moving field, it is essential that current science and engineering students become fluent in the technology. The Optical Terahertz Science and Technology Workshop 2009 will achieve this through: a day of tutorials by specialists; three days of research presentations by world renowned investigators; and student poster presentations to be critiqued by leaders in the field. Undergraduate education will be impacted through a workshop on incorporating
THz research into undergraduate teaching. The resulting modules will inspire undergraduates to participate in research that will give them the hands-on skills to pursue high tech careers and contribute to innovation in the U.S. economy. Three NSF divisions have contributed to supporting the attendance by graduate students and post docs at this workshop: the Division of Materials Research, the Division of Chemistry, and the Division of Electrical, Communications and Cyber Systems.

Mark Sherwin
Tanner Research Inc., UCSB FA9550-09-C-0161
A Room Temperature Tunable Antenna Coupled Intersubband Terahertz (TACIT) Detector for Man-Portable Spectroscopy
06/15/09-12/15/09
$20,000

The Sherwin group at UC Santa Barbara will fabricate TACIT detectors and test their responsivity, noise and noise-equivalent power at temperatures between 4K and 300K. We will also perform a Phase I demonstration of the TACIT device, at an Air Force facility designated by the AFOSR POC (at an AFOSR customer site, for instance), whereby we will demonstrate the room temperature responsivity of the TACIT device to 1 THz radiation.

Mark Sherwin
Pierre Petroff
DAF Air Force Research Laboratory, FA8650-10-1-7011
Efficient Current Injection into 3-D Confined Nanostructures for Room-Temperature Terahertz Lasers
10/07/09-07/06/10
$396,065

Compact, room-temperature sources for 1-5 terahertz are required for straightforward integration into imaging, communications, sensing and other terahertz systems. Such lasers do not exist at present. Quantum cascade lasers (QCLs) are compact semiconductor sources that currently operate across the 1-5 THz frequency band. However, they operate only at deep cryogenic temperatures. The active regions of today’s QCLs are quantum wells, which are confined in one dimension. The most promising strategy for raising the operating temperature of terahertz QCLs is to replace quantum wells with nanostructures in which electrons are confined in all three dimensions.

The most important barrier to the implementation of a QCL with an active region containing three-dimensionally-confined nanostructures is that it is extremely difficult to inject carriers into the lasing states of said nanostructures.
The objectives of this seedling are
  1) to reliably measure the injection efficiency from an injector into the upper lasing state of an active region consisting of three-dimensionally-confined nanostructures which are designed to lase between 1 and 5 THz and
  2) to boost the state of the art for said injection efficiency from the current upper bound of 3% to a lower bound of 30%

Dominik Stehr
Mark Sherwin
Pierre Petroff
DOE Los Alamos Area Office, RA2008A196
Time Resolved THz Spectroscopy in Semiconductor Quantum Posts
06/01/08-09/01/09
$0

This project will investigate the electronic transitions in a new type of semiconductor nanostructure called quantum posts (QPs) which are closely related to quantum dots (QDs) but form a nanowire-like structure in the growth direction. Unlike in QDs, where the ground state transition in the semiconductor band is fixed around 50-60 meV, the transition energy related to the confinement in the z-direction is expected in the THz region in sufficiently “tall” QPs. Additionally, the transition energy is variable by changing the height of the QPs, allowing to address a large spectral range. This unique structure is currently successfully grown by MBE at UCSB and up to now, QPs with heights between 23 and 60 nm have been demonstrated with expected resonances between 16 meV (3.6 THz) and 2 meV (0.5 THz). In order to observe the THz resonances and part of their dynamics, we propose an all-optical approach including an ultrafast interband excitation at the QP resonance followed by probing of the THz with single-cycle THz pulses with an adjustable delay. The approximately 15 nm broad interband resonance lies around 980 nm ((1.26 eV), requiring the use of a suitable ultrafast laser system at CINT.

Jatila van der Veen
Phillip Lubin
Jet Propulsion Laboratory, JPL 1388406
The Planck Visualization Project: Education and Public Outreach Effort of the U.S. Planck Mission
10/01/09-09/30/13
$58,400 ($187,900)

Planck is a mission to measure the anisotropy of the cosmic microwave background (CMB), sponsored by the European Space Agency (ESA) with significant input from NASA. Launched on May 14, 2009, Planck will measure the sky across nine frequency channels, with temperature sensitivity of $10^{-6}$ K, and spatial resolution up to 5 arc minutes.
NASA participation in Planck is approved and funded, and is managed by the Planck Project at the Jet Propulsion Laboratory in Pasadena, California. The US Planck project is required by NASA to perform Education and Public Outreach (E/PO) as an integral part of the science development. This award serves as the focal point for the E/PO activities of the US Planck team.

Note: Dates in green are the projected end dates and dollar value in green is the projected total award value.
Contracts/Grants Awarded 2009-2010

Department of Air Force
Office of Scientific Research
Michael Bowers
FA9550-06-1-0069  12/01/08-11/30/10  $ 189,000
POSS and Metal Clusters: Structures and Energetics

Air Force Research Laboratory
Mark Sherwin, Pierre Petrof
FA8650-10-1-7011  10/07/09-07/06/10  $ 396,065
Efficient Current Injection into 3-D Confined Nanostructures for Room-Temperature Terahertz Lasers

Department of Air Force  $ 585,065

Jet Propulsion Laboratory
Philip Lubin
1367008  02/10/09-09/30/13  $ 10,000
Planck Educational and Public Outreach Effort at UCSB

Jatila van der Veen, Philip Lubin
1388406  10/01/09-09/30/2013  $ 15,000
The Planck Visualization Project: Education and Public Outreach Effort of the U.S. Plank Mission

Jatila van der Veen, Philip Lubin
1388406  10/01/09-09/30/2013  $ 14,200
The Planck Visualization Project: Education and Public Outreach Effort of the U.S. Plank Mission

Jatila van der Veen, Philip Lubin
1388406  10/01/09-09/30/2013  $ 29,200
The Planck Visualization Project: Education and Public Outreach Effort of the U.S. Plank Mission

Jet Propulsion Laboratory Subtotal  $ 68,400

National Aeronautics & Space Administration
David Cannell
NNX08AE53G  03/01/08-02/28/2011  $ 65,000
Supplement to Gradient Driven Fluctuations
**National Science Foundation**

Guenter Ahlers  
DMR-0702111  
05/01/07-04/30/11  
$155,000  
Turbulent Convection in a Fluid Heater from Below

Dirk Bouwmeester  
PHY-0804177  
08/01/08-07/31/10  
$160,000  
Quantum States of OptoMechanical Structures

Dirk Bouwmeester, Pierre Petroff  
ECCS-090188  
09/01/09-08/31/12  
$399,914  
Solid-State Cavity Electrodynamics

Dirk Bouwmeester, Michael Liebling, Deborah Fygenson, Elisabeth Gwinn, Everett Lipman  
DMR-0960331  
03/15/10-02/28/13  
$464,703  
MRI-R2 Nano Photonic Imaging System

Michael Bowers  
CHE-0909743  
08/01/09-07/31/13  
$730,000  
Non-Covalent Complexes

Steven Buratto, Michael Bowers, Horia Metiu  
CHE-0749489  
04/01/08-03/31/10  
$167,000  
Model Nanocluster Catalysts: The Role of Size, Shape and Composition on the Catalytic Activity of Monometallic, Bimetallic and Metal Oxide Clusters on Oxide Surfaces

Bruce Lipshutz  
CHE-37658  
09/01/09-08/31/11  
$200,000  
EAGER: Chemistry of Water-Intolerant Intermediates…..in Water

Bruce Lipshutz  
CHE-0948479  
06/01/10-05/31/13  
$489,000  
New Technologies Based on Organocopper Catalysis

**National Science Foundation Subtotal**  
$2,765,617

**National Institutes for Health**

**NIH Center for Scientific Review**

Bruce Lipshutz  
1R01 GM086485-01A1  
08/15/09-07/31/10  
$304,904  
New Technologies for Catalysis in Water
**Oak Ridge National Laboratory (Department of Energy GOCO Operated by UT Batelle, LIC.)**

Douglas Scalapino  
400068439  
04/14/08-03/31/12  
$120,000  
Study of the Properties of Strongly Correlated Materials

**Sandia National Laboratories**

James Allen  
979057  
12/01/09-05/31/10  
$15,000  
Terahertz Resonant Plasmonic Detectors

**Tanner Research, Inc**

Mark Sherwin  
UCSB FA9550-09-C-0161  
06/15/09-12/15/09  
$20,000  
A Room Temperature Tunable Antenna Coupled Intersubband Terahertz (TACIT) Detector for Man-Portable Spectroscopy Instruments

**UC Los Angeles**

Michael Bowers  
SB070075  
09/01/06-07/31/10  
$258,244  
Pathogenic Protein Folding and Human Disease
## Research Support Summary
### (2009-2010)

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</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>$4,202,230</strong></td>
<td><strong>100.00%</strong></td>
<td></td>
</tr>
</tbody>
</table>
Charts and Graphs

Research Support Summary Chart 2009-2010

Chart 1: Research Support Summary Chart 2009-2010

Chart 2: Federal Research Support Summary Chart
Chart 3: State Research Support Summary Chart

State

University of California, Los Angeles
100%

Chart 4: Private Research Support Summary Chart

Private

Tanner Research, Inc
100%
Chart 5: Base Budget and Overhead Generated

Number of Proposals Submitted and Funded

Chart 6: Number of Proposals Submitted and Funded
Chart 7: Value of Proposals Submitted and Funded
Chart 8: Number of Awards Administered

Number of Awards Administered

<table>
<thead>
<tr>
<th>Year</th>
<th># of Awards Administered</th>
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<tbody>
<tr>
<td>2002-03</td>
<td>38</td>
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<tr>
<td>2003-04</td>
<td>32</td>
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<tr>
<td>2004-05</td>
<td>93</td>
</tr>
<tr>
<td>2005-06</td>
<td>97</td>
</tr>
<tr>
<td>2006-07</td>
<td>57</td>
</tr>
<tr>
<td>2007-08</td>
<td>55</td>
</tr>
<tr>
<td>2008-09</td>
<td>46</td>
</tr>
<tr>
<td>2009-2010</td>
<td>36</td>
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</table>

Chart 9: Value of Contracts and Grants Administered

Value of Contracts and Grants Administered (millions of dollars)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Funding</th>
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<tbody>
<tr>
<td>2002-03</td>
<td>$16.4</td>
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<tr>
<td>2003-04</td>
<td>$15.1</td>
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<td>2004-05</td>
<td>$40.3</td>
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<td>2006-07</td>
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<td>2007-08</td>
<td>$20.0</td>
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<tr>
<td>2008-09</td>
<td>$20.8</td>
</tr>
<tr>
<td>2009-2010</td>
<td>$19.1</td>
</tr>
</tbody>
</table>
# Statistical Summary for ITST 2009-2010

1. Academic personnel engaged in research:
   a. Faculty 35
   b. Professional Researchers (including Visiting) 5
   c. Project Scientists 8
   d. Specialists 12
   e. Postdoctoral Scholars 16
   f. Postgraduate Researchers 0
   **TOTAL** 76

2. Graduate Students:
   a. Employed on contracts and grants 30
   b. Employed on other sources of funds 0
   c. Participating through assistantships 0
   d. Participating through traineeships 0
   e. Other (specify) 0
   **TOTAL** 30

3. Undergraduate Students:
   a. Employed on contracts and grants 5
   b. Employed on other funds 0
   c. Number of volunteers, & unpaid interns 0
   **TOTAL** 5

4. Participation from outside UCSB: (optional)
   a. Academics (without Salary Academic Visitors) 0
   b. Other (2 high school students + 1 chief scientist, industry) 2

5. Staff (Univ. & Non-Univ. Funds):
   a. Technical 10
   b. Administrative/Clerical 4

6. Seminars, symposia, workshops sponsored 20

7. Proposals submitted 35

8. Number of different awarding agencies dealt with* 25

9. Number of extramural awards administered 36

10. Dollar value of extramural awards administered during year** $20,116,852

11. Number of Principal Investigators*** 44

12. Dollar value of other project awards **** $522,310

13. Number of other projects administered 10

14. Total base budget for the year (as of June 30, 2009) $151,272

15. Dollar value of intramural support $584,163

16. Total assigned square footage in ORU 10,582

17. Dollar value of awards for year (08 Total) $4,202,230

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* Count each agency only once (include agencies to which proposals have been submitted).
** If the award was open during the year, even if for only one month, please include in total.
*** Number of PIs, Co-PIs and Proposed PIs (count each person only once.)
**** Other projects - such as donation, presidential awards, fellowships, anything that isn't core budget, extramural, or intramural.
## Principal Investigators

<table>
<thead>
<tr>
<th>Name</th>
<th>Title/Position</th>
<th>Department/Institute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maria Ofelia Aguirre</td>
<td>Director (CSEP)</td>
<td>California Nanosystems Guenter Institute</td>
</tr>
<tr>
<td>Guenter Ahlers</td>
<td>Research Professor</td>
<td>Physics</td>
</tr>
<tr>
<td>S. James Allen</td>
<td>Research Professor</td>
<td>Physics</td>
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<tr>
<td>Bjorn Birnir</td>
<td>Professor</td>
<td>Mathematics</td>
</tr>
<tr>
<td>Jeffrey Bode</td>
<td>Assistant Professor</td>
<td>Chemistry and Biochemistry</td>
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<tr>
<td>Dirk Bouwmeester</td>
<td>Professor</td>
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<tr>
<td>Michael Bowers</td>
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<tr>
<td>Elliot Brown</td>
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<td>Electrical and Computer Engineering</td>
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<tr>
<td>Louis Brunel</td>
<td>Project Scientist</td>
<td>Institute for Terahertz Science and Technology</td>
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<tr>
<td>Steven Buratto</td>
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<tr>
<td>David Cannell</td>
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<tr>
<td>Bradley Chmelka</td>
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<tr>
<td>Andrew Cleland</td>
<td>Professor</td>
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<tr>
<td>Patrick Daughtery</td>
<td>Assistant Professor</td>
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<tr>
<td>Frederick Dahlquist</td>
<td>Professor</td>
<td>Chemistry and Biochemistry</td>
</tr>
<tr>
<td>Deborah Fygenson</td>
<td>Associate Professor</td>
<td>Physics</td>
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<tr>
<td>Elisabeth Gwinn</td>
<td>Professor</td>
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<tr>
<td>Song-I Han</td>
<td>Assistant Professor</td>
<td>Chemistry and Biochemistry</td>
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<tr>
<td>Luc Jaegar</td>
<td>Assistant Professor</td>
<td>Chemistry and Biochemistry</td>
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<tr>
<td>Robert Jacobs</td>
<td>Professor</td>
<td>Pharmacology, Ecology, Evolution &amp; Marine Biology</td>
</tr>
<tr>
<td>John Lew</td>
<td>Associate Professor</td>
<td>Molecular, Cellular, and Development Biology</td>
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<tr>
<td>Michael Liebling</td>
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<td>Everett Lipman</td>
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<td>Bruce Lipshutz</td>
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<td>David Low</td>
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<tr>
<td>Peter Meinhold</td>
<td>Researcher</td>
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<tr>
<td>Horia Metiu</td>
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<td>Chris Palmstrom</td>
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<tr>
<td>Pierre Petroff</td>
<td>Professor</td>
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<td>John Perona</td>
<td>Professor</td>
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<tr>
<td>Kevin Plaxco</td>
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<tr>
<td>Craig Pryor</td>
<td>Chief Scientist</td>
<td>Terahertz Device Corporation</td>
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<tr>
<td>Gerald Ramian</td>
<td>Specialist</td>
<td>Institute for Terahertz Science and Technology</td>
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<tr>
<td>Norbert Reich</td>
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<td>Chemistry and Biochemistry</td>
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<td>Mark Rodwell</td>
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</tr>
<tr>
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<tr>
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<tr>
<td>Douglas Scalapino</td>
<td>Research Professor</td>
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<tr>
<td>Joan-Emma Shea</td>
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<td>Mark Sherwin</td>
<td>Professor</td>
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<tr>
<td>Dominik Stehr</td>
<td>Postdoctoral Scholar</td>
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<td>Susanne Stemmer</td>
<td>Professor</td>
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<tr>
<td>Jatila Van Der Veen</td>
<td>Asst Project Scientist</td>
<td>Institute for Terahertz Science and Technology</td>
</tr>
<tr>
<td>Jelena Vuckovic</td>
<td>Assistant Professor</td>
<td>Stanford University</td>
</tr>
</tbody>
</table>
Map

Our offices are located on the 3rd floor of Broida Hall

Take a left at the elevator then down the hall to room 3410