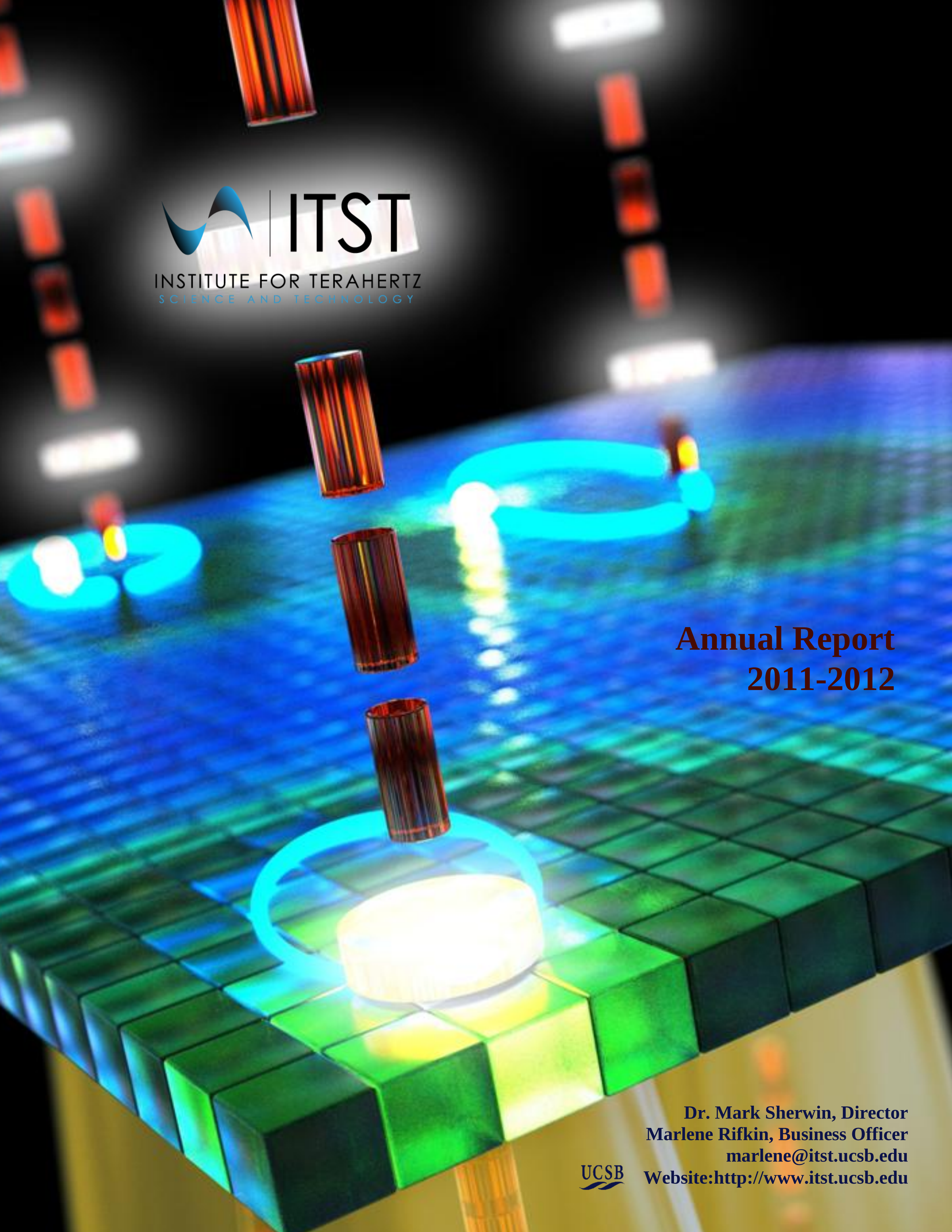

ITST

INSTITUTE FOR TERAHERTZ SCIENCE AND TECHNOLOGY

Annual Report 2011-2012

Dr. Mark Sherwin, Director
Marlene Rifkin, Business Officer
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UCSB **Website:http://www.itst.ucsb.edu**

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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.

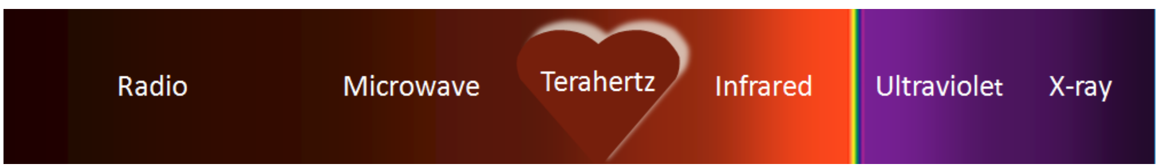

Figure 1: Chart showing ITST's research emphasis at the heart of the electromagnetic spectrum.

*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

The heart of the electromagnetic spectrum—between 0.1 and 10 terahertz—is becoming more exciting each year. The number of publications in terahertz science and technology has grown by 15-20% each year over the last ten years. Continued rapid growth is nearly certain, both because terahertz technology is at the nexus of frontiers in electronics and photonics, and because methodologies involving terahertz radiation are being adopted in an increasing number of fields of science and engineering. The Institute for Terahertz Science and Technology (ITST) at UC Santa Barbara is internationally known as a leading center for terahertz research.

The 2011-2012 year has been very exciting at ITST. The image on the cover of the annual report is an artist's representation of a new phenomenon in the interaction of light with matter that was discovered using the UC Santa Barbara Free-Electron Lasers (FELs)—the world's brightest sources of tunable electromagnetic radiation between 0.1 and 5 terahertz. Intense laser fields can rip electrons from an atom and slam them back into it. By using intense terahertz radiation, ITST researchers extended this idea to electrons paired with "holes" in a semiconductor. The experimental manifestation of electrons and holes colliding roughly one trillion times per second under the influence of intense terahertz radiation is the conversion of a beam of monochromatic red light into a beam containing a "comb" of up to 11 additional frequencies of light, separated from each other by roughly 1 terahertz.[1]

The workhorses of the UCSB FEL facility are two free-electron lasers driven by a single electrostatic accelerator. These were completed in the early 1990s. In October 2011, work began on constructing the first new FEL in over 20 years at the UC Santa Barbara FEL facility, funded by a Major Reseach Instrument Development grant from the NSF, with participants and co-Investigators from the Departments of Physics, Chemistry and Biochemistry, and Materials at UCSB, in addition to researchers at the University of Utah, the National High Magnetic Field Lab, the Weizmann Institute for Science in Israel, and the University of Sidney. The new FEL will be optimized for pulsed electron paramagnetic resonance (EPR). EPR is analogous to nuclear magnetic resonance (NMR), which is the basis for magnetic resonance imaging (MRI). However, whereas NMR uses static and dynamic magnetic fields to interrogate the magnetic states of nuclei, EPR interrogates the magnetic states of electrons. Because electrons couple nearly 1000 times more strongly to magnetic fields than nuclei, the frequencies required for EPR at a given static magnetic field are nearly 1000 times higher. The new FEL will be optimized for pulsed EPR at frequencies between 0.24 and 0.5 THz, enabling unprecedented studies of systems ranging from proteins to organic solar cells.

We are very proud that UC Santa Barbara chemistry professor and ITST PI Bruce Lipshutz has been awarded the 2012 Encyclopedia of Reagents for Organic Synthesis (EROS) Best Reagent Award. The annual award is sponsored by Sigma-Aldrich and John Wiley.

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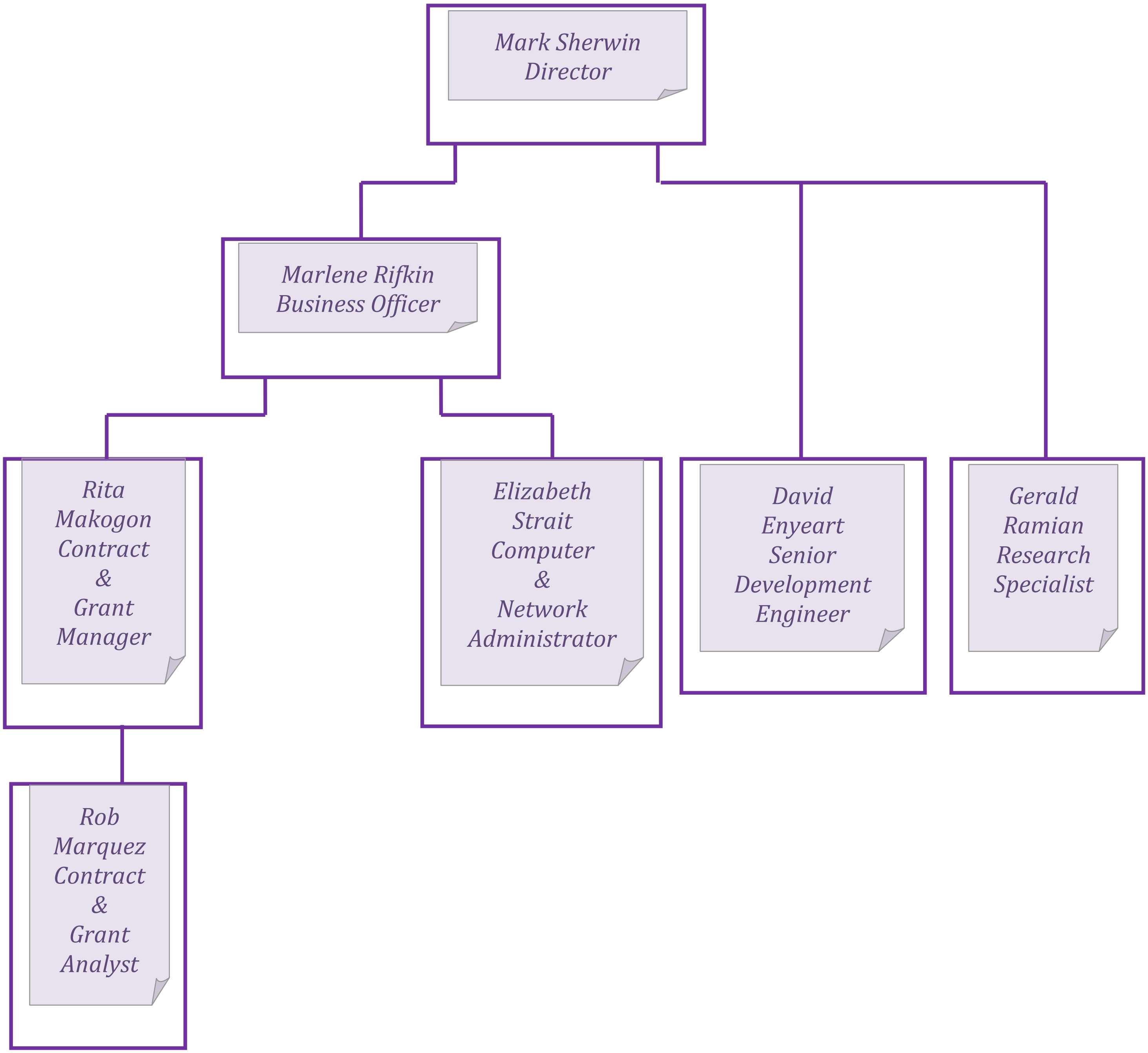
[1] Benjamin Zaks, Ren-Bao Liu and Mark S. Sherwin, "Experimental Observation of Electron-Hole Recollisions," Nature **483**, 580 (2012). See also R. Huber, "Terahertz Collisions," Nature **483**, 545 (2012) (News and Views).

We are also pleased that, despite a difficult federal funding climate, the value of proposals funded was $2.7M for 2011-2012, up significantly from 2010-2011 and comparable to the previous few years. The ITST staff, with tremendous assistance from the Office of Research, put in an enormous effort to submit a proposal for the Center for Infrared Science and Technology (CFIRST), led by Prof. Phil Lubin. This was one of two NSF Science and Technology Center proposals that the campus was invited to submit this year at an advanced stage of the NSF's fierce, roughly quadrennial competition. We wish the other UCSB team, led by Prof. Susanne Stemmer, the best of luck going forward.

We look 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.

Organizational Chart



Advisory Committee

Songi Han	**Chemistry and Biochemistry, Committee Chair**
S. James Allen	Former iQuest Director, Physics
Andrew Cleland	Physics
Ben Mazin	Physics
Christopher Palmstrom	Electrical and Computer Engineering
Kevin Plaxco	Chemistry and Biochemistry
Susanne Stemmer	Materials Department
Win Van Dam	Computer Science

Ex Officio Members

Omer Blaes	Chair, Physics
Rick Dahlquist	Chair, Chemistry and Biochemistry
Marlene Rifkin	Business Officer, ITST
Mark Sherwin	Director, ITST, Physics

Personnel

Administrative Staff-ITST

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

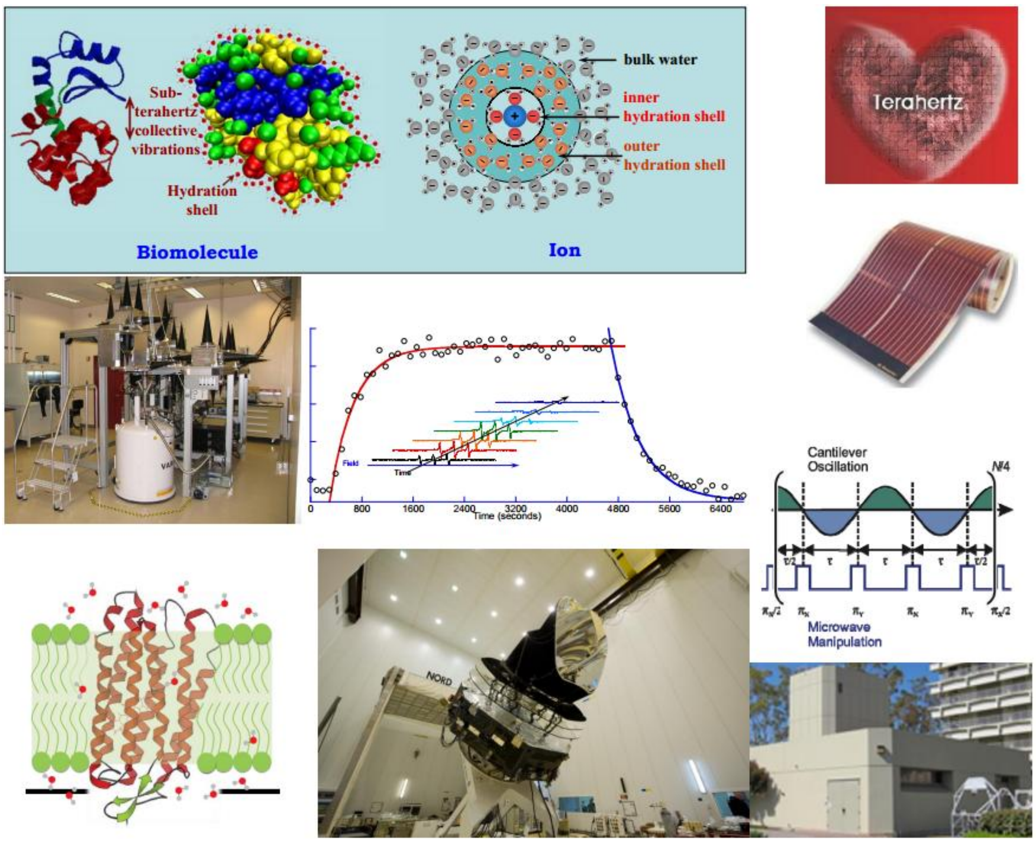
Technical Staff-ITST

David Enyeart Senior Development Engineer
Gerald Ramian Research Specialist

Other Project and Activities

Seminars and Workshops

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



07/11/11:
A New Terahertz Source Concept: Dr. Adam Bushmaker, The Aerospace Corporation

10/21/11:
Field Effect Transistors for THz Detection At Room Temperature: Dr. Sascha Preu, ITST, Materials and Physics Departments, University of California, Santa Barbara

10/06/11:
Gd3+ Based Spin Probes for High Frequency Electron Paramagnetic Resonance: Devin Edwards, Physics Department, University of California, Santa Barbara

10/13/11:
Spectroscopy of Correlated Electrons in Nickelates and Titanates: Dan Ouellette, Physics Department, University of California, Santa Barbara

10/20/11:
High-Order Sideband Generation from Electron-Hole Recollisions: Ben Zaks, Physics Department, University of California, Santa Barbara

10/27/11:
Probing the Motion of a Mechanical Resonator via Coherent Coupling to a Single Spin Qubit : Ania Bleszynski Jayich, Physics Department, University of California, Santa Barbara

11/03/11:
Measuring Sub-Nanometer Variations in Water Diffusivity with oDNP: John Franck, Department of Chemistry and Biochemistry, University of California, Santa Barbara

11/10/11:
Free Electron Lasers: Gerald Ramian, ITST, University of California, Santa Barbara

11/17/11:
The Affinity and Stability of Immobilized Biomolecules: Time-Resolved EPR Detection During Mobile Phase Gradients: Eric Walter, Environmental Molecular Sciences Laboratory, Pacific Northwest National Laboratory

01/19/12:
Terahertz Spectroscopy Identifies the Picosecond Dynamics of Water and Biomolecules in Aqueous Solutions: Dr. Vinh Q. Nguyen, ITST, University of California, Santa Barbara

1/26/12:
The Planck Satellite: Dr. Peter Meinhold & Dr. Jatilla van der Veen, Physics Department, University of California, Santa Barbara

02/02/12:
Filming Hydration and Conformational Dynamics of a Light-Activated membrane Protein: Sunyia Hussain, Department of Chemical Engineering, University of California, Santa Barbara

02/09/12:
Experimental Observation and Relevance of the Hydrophobic Effect in Biological Systems: Dr. Songi Han, Department of Chemistry and Biochemistry, University of California, Santa Barbara

02/13/12:
Toward Miniaturization of NMR and MRI: Dr. Alexander Pines, Glenn T. Seaborg Professor of Chemistry, University of California, Berkeley

02/16/12:

The Prion Protein—More Structure Than You Think: Dr. Glenn Milhauser, Chemistry Department, University of California, Santa Cruz

02/23/12:
Ultrafast Laser Pulses for Materials Diagnostics, Microfabrication and Tomography: Dr. Tresa M. Pollock, Materials Department, University of California, Santa Barbara

03/01/12:
Elucidating Mechanisms of Drug Resistance in HIV1 Potease by Pulsed EPR Spectroscopy: Dr. Gail Fanucci, Department of Biochemistry and Molecular Biology, University of Florida
Partitioning and Structure of Amphipathic Helices in Lipid Bilayers by Solid State NMR and EPR: Dr. Joanna Long, Department of Biochemistry and Molecular Biology, University of Florida

03/08/12:
Probing Macromolecular Interactions at Lipid Membrane Interface by Overhauser Dynamic Nuclear Polarization: Dr. Chi-Yuan Cheng, Department of Chemistry and Biochemistry, University of California, Santa Barbara

04/12/12:
Solid-State NMR Investigations on Protein-Solvent Interactions and Functional Amyloid Proteins: Dr. Ansgar B. Siemer, Zilkha Neurogenetic Institute, Keck School of Medicine of USC , Los Angeles

05/14/12:
Novel Semiconductor-Based THz Sources and Detectors: Dr. Sascha Preu, Chair for Applied Physics, University of Erlangen-Nuremberg, Germany

05/14/12:
Type-II InAs/GaSb Superlattices: Physical Understanding and Barrier Engineering: Dr. Nutan Gautam, Krishna's Infrared Detector Laboratory, Center for High Technology Materials, The University of New Mexico

Awards Administered

(July 2011 – June 2012)

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

Guenter Ahlers
National Science Foundation, DMR-0702111
Turbulent Convection in a Fluid Heater from Below
05/01/07-04/30/13
$775,000

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.

Guenter Ahlers
National Science Foundation, DMR-1158514
Turbulent Convection in a Fluid Heated from Below
06/01/12-05/31/12 (05/31/16)
$160,000 (640,000)

Turbulent convection in a fluid heated from below is of utmost importance in many natural phenomena and in industry. It occurs in Earth's mantle where it contributes to the motion of continental plates and influences vulcanism. In the outer core of the Earth it determines the magnetic field in which we live. It is the important heat-transport mechanism in the outer layer of the Sun and thus impacts the temperature of our environment. It plays a significant role in many industrial processes, where its enhancement or inhibition may have significant economic consequences. These applications range from miniature heat-transport devices in computer applications to the giant cooling systems of power plants. And yet much remains unknown to the scientist and engineer about these processes. The proposed work will extend our understanding of turbulent convection to fluids with properties similar to the Earth's atmosphere; this property range has remained relatively unexplored in the laboratory. The work will also be extended to samples that are rotated about their vertical axis. The rotation will exert a force on the fluid known as the Coriolis force and thus will change the behavior of the system in a manner related to how Earth's rotation modifies the nature of hurricanes and ocean currents. These experiments require the construction of complex apparatus and the automatic computer-control of numerous intricate processes. Thus they are an exceptionally good training ground for our young coworkers, many of whom will evolve into the leaders of the next generation of scientists and engineers.

Dirk Bouwmeester
National Science Foundation, PHY-0804177
Quantum States of OptoMechanical Structures
08/01/08-07/31/12
$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.

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

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 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.

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

Michael Bowers
UC Los Angeles, SB070075
Pathogenic Protein Folding and Human Disease
09/01/06-07/31/12
$1,292,132

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 cacadw 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.

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

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

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.

Michael Bowers
Air Force FA9550-11-1-0113
Litigated Metal Clusters: Structures, Energetics and Reactivity
06/15/11-06/14/14
$380,000 ($570,000)

The field of metal clusters, their reactivity and ligand binding energies has undergone a renaissance in recent years. There are two principle drivers: The importance of metal clusters in catalysis and their fundamental importance as bridging agents between the atomic and the solid phases of matter. The Bowers group is uniquely positioned to contribute to this important area of research. They have developed two tools that allow structural determination for size-selected clusters: ion mobility methods that yield accurate cross sections and sequential ligand binding energies that identify equivalent binding sites. These have been applied primarily to coinage metals but here the group will extend these studies to transition metal clusters.

Steven Buratto
Michael Bowers
Horia Metiu
National Science Foundation NSF CHE-1152229
Model Nanocluster Catalysts: The Role of Size, Shape and Composition on the Catalytic Activity of Small Metal Oxide and Bimetallic Clusters on Oxide Surfaces
04/01/12-03/31/15
$450,000

A large number of industrial processes use nanometer-size clusters (both metal and metal oxide) supported on oxide surfaces to perform reactions that would not take place, or would be commercially unsuccessful if performed on the bulk material. In research supported by this grant the investigators will utilize state-of-the-art experimental and theoretical methods to probe the catalytic activity of well-defined nanocluster catalysts in great detail and develop a fundamental understanding of the catalytic chemistry at the atomic level. The concepts developed through this research will help optimize important industrial processes using these nanoscale catalysts and provide valuable insight into the discovery of new nanoscale catalytic materials. Researchers supported by this grant will also be active in outreach to K-12 schools in the Santa Barbara area. They plan to develop a tutorial presentation on an atomistic view of heterogeneous catalysis that will be included in the currently active outreach program in the department at UCSB. In addition, researchers working on this project will visit high schools in the Santa Barbara and Ventura Counties three times per year to discuss their research and its impact as well as to promote science education.

David Cannell
National Aeronautics and Space Administration, NNX08AE53G
Gradient Driven Fluctuations
03/01/08-08/31/12
$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.

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
08/01/08-07/31/12
$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
UCSB
The Green Initiative Fund (TGIF)
Getting Organic Solvents Out of Organic Reactions
06/01/09-06/30/12
$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.

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

Bruce Lipshutz
National Institutes of Health, 1R01 GM086485-02
New Technologies for Catalysis in Water
08/15/09-08/31/11
$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.

Bruce Lipshutz
National Science Foundation, CHE-0937658
EAGER: Chemistry of Water-Intolerant Intermediates….in Water
09/01/09-08/31/12
$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.

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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.

Bruce Lipshutz
National Institutes of Health, R01 GM086485-04
Transition Metal-Catalyzed Chemistry in Water at Room Temperature
09/01/11-05/31/13 (05/31/15)
$594,822 (1,110,318)

New technologies are to be developed that “get organic solvents out of organic reactions”; that replace traditional processes that use strictly organic media with a “green” alternative: water. These studies are driven by the potential for decreasing the amount of solvent waste, to be carried out by investigating several reactions in water that are important to the pharmaceutical and fine chemical areas. All are to be done at room temperature, and thus, without any investment of energy for either heating or cooling purposes.

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Philip Lubin
Jet Propulsion Laboratory, JPL1367008
Planck Educational and Public Outreach Effort at UCSB
02/10/09-09/30/13
$55,700 ($67,000)

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
Studies of the Properties of Strongly Correlated Materials
04/14/08-03/31/14
$477,724 ($693,430)

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
National Science Foundation, DMR-1006603
Quantum Coherence and Dynamical Instability in Quantum Wells Driven by Intense Terahertz Fields
08/15/10-07/31/14
$425,000 ($560,000)

Beginning when early humans harnessed fire for heat and light, the control of electromagnetic radiation has been central to the development of our species. The notion of electromagnetic radiation is nearly 150 years old, proposed by Maxwell in 1865 and demonstrated with the discovery of radio waves in 1866. Radio waves remained largely a laboratory curiosity for nearly 50 years. It is difficult to imagine modern life without radio waves, microwaves, heat, light, and X-rays, which are now all understood to be manifestations of electromagnetic radiation, listed in order of increasing frequency. However, lying between the frequencies of microwaves and heat, stretching from 0.1 to 10 trillion cycles per second (0.1-10 terahertz) is the so-called 'terahertz gap.' Electromagnetic waves exist in this frequency range, but they are extremely difficult to generate and control. This individual investigator award supports a project that will use the world's brightest pulses of terahertz waves, generated by accelerator-driven 'free-electron lasers', to search for new quantum-mechanical phenomena predicted to occur in nanometers-thick semiconductor devices. The semiconductor devices under study are similar to those used to modulate light in fiber-optic communications, and as ultrafast transistors in cellular telephones. This project will support the education of two PhD students, as well as undergraduate and high-school interns. The students will learn the most advanced techniques to generate and manipulate electromagnetic radiation across the electromagnetic spectrum, preparing them for leadership in the nation's scientific and technological workforce, and bringing mankind closer to harnessing terahertz radiation for future technologies.

Mark Sherwin
Tanner Research Inc., UCSB FA9550-10-C-0177
Frequency Agile THz Detectors for Multiplicative Mixing
09/30/10-09/30/11
$35,000

Prototypes fabricated by Tanner will be tested at UCSB using the world's best set of terahertz sources, detectors, and spectroscopy systems. The tests will measure metrics defined in the metrics model. We have in the past measured responsivity, noise and noise-equivalent power for self-mixing detectors at 1 THz. Such measurements can be performed on the multiplicative mixer devices, which can also operate as self mixers. Many of the relevant metrics for multiplicative mixers will be similar to those for additive mixers—for example, noise temperature. We have experience measuring the noise temperatures of additive mixers (Schottky diode superheterodyne receivers) at 240 GHz, and can easily extend these measurements, with equipment on hand, to 700 GHz. We will develop techniques to measure other important metrics, such as mixer conversion gain or loss (ratio of power at the intermediate frequency to THz signal power for heterodyne mixing). The Free-Electron-Lasers will be especially useful for measurements at frequencies above 1 THz. Terahertz time-domain spectrometers (broad-band, 0.1-3 THz) or a vector network analyzer with frequency extenders (phase-sensitive measurements 70-700GHz with up to 120 dB dynamic range).

Mark Sherwin
Synaptics SB120039
Developing an Imaging System for ITO Based Touch Screens
08/01/11-08/31/11
$1,567

The aim of this first step is to make a preliminary measurement to gauge the effectiveness of using terahertz in imaging ITO films: a proof of concept for the technology. If the results are agreeable we can then move to developing a more rigorous testing system with the final goal of imaging whole samples and detecting defects.
We are going to do a one dimensional terahertz measurement using terahertz time-domain spectroscopy. We will scan about 20mm across one of the samples we received from Synaptics and observe the frequency response. This will allow us to gauge the transmittance of the samples as well as see if we can clearly detect the edges of different ITO layers.

Mark Sherwin
U.S.-Israel Binational Science Foundation 2010130
Development of Gd^{3+}-Based Spin Labels for Probing Structure, Dynamics and Interfaces by Electron Paramagnetic Resonance Techniques
10/01/11-08/31/12 (09/30/15)
$22,365 (93,805)

EPR and DNP (dynamic nuclear polarization) rely on the introduction of spin probes or labels to intrinsically diamagnetic systems and the standard, widely used spin labels are based on the nitroxide group that has a spin, S=1/2. The recent development of high field EPR opens new opportunities in spin labeling by exploiting the unique spectroscopic properties of half-integer high spin systems at high fields that can offer high sensitivity and resolution. The objective of this proposal is to establish a new family of Gd^{3+} (S=7/2)-based spin labels for probing structure, dynamic and interfaces of molecules and materials using EPR and DNP at high magnetic fields. The basic spin physics and dynamics of Gd^{3+} spin labels at high fields must be explored and understood in order to realize their tremendous promise for EPR and DNP. Using a variety of mono- and bis-Gd^{3+} compounds we will measure spin lattice relaxation, phase memory time and spectral diffusion as a function of field (95 and 240 GHz. 3.5 and 8.5T), temperature and Gd^{3+} concentration. Having established a good understanding of the spin dynamics that is needed for the optimum measurements conditions and the design of appropriate Gd^{3+} chelators we will explore Gd^{3+} spin labels for structure determination through Gd^{3+}-Gd^{3+} distance measurements and their potential to probe protein dynamics and light triggered conformational changes. Finally, we propose to develop a Gd^{3+} spin label based methodology to study polymer interfaces in systems with nanometer scale heterogeneities and phase boundaries using solid state DNP of ^{1}H and natural abundance ^{13}C NMR at 7T

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

Mark Sherwin
S. James Allen
Christopher Palmstrom
Thuc-Quyen Nguyen
Song-I Han
National Science Foundation, DMR-1126894
MRI: Development of a Free-Electron Laser for Ultrafast Pulsed Electron Paramagnetic Resonance
10/01/11-09/30/14
$992,270

The world's brightest source of tunable terahertz radiation will be developed to manipulate electron spins faster than has ever been possible. This ultrafast spin manipulation will enable pathbreaking studies with applications ranging from development of inexpensive solar cells to understanding how protein molecules fit together and move to regulate the flow of energy, information and matter in living organisms.

Electrons and atomic nuclei both have a property called spin, which makes them behave like (very tiny) magnets. In nuclear magnetic resonance (NMR), which is the basis for magnetic resonance imaging (MRI), a strong external magnetic field aligns nuclear spins, while powerful pulses of radio-frequency electromagnetic radiation manipulate nuclei to discover otherwise invisible information about neighboring atoms. Electron paramagnetic resonance (EPR), in a fashion similar to NMR, uses an external magnetic field to align electron spins (rather than nuclear spins). Typically, pulses of microwave-frequency electromagnetic radiation manipulate these electrons to learn about local environments over larger neighborhoods. EPR becomes even more powerful when extremely high-frequency terahertz is used.

The free-electron lasers (FELs) at the University of California at Santa Barbara (UCSB) are famous as the world's brightest sources of tunable terahertz radiation. Recently, researchers at UCSB demonstrated that one of the UCSB FELs could be used to rotate electron spins 50 times faster than ever before at .25 terahertz. This project will fund the construction of an even more powerful FEL. The new FEL, which will be used by scientists from all over the nation and world, will be 100 times more powerful than the existing one, and will pulse ten times faster, enabling at least 1000 times more rapid acquisition of experimental data. The EPR spectrometer powered by this new FEL will create an unprecedented capability to observe the structure and ultrafast dynamics of molecules, materials and devices at nanometer length scales.

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

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
$185,165 ($297,715)

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 manages 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 at the focal point for the E/PO activities of the US Planck team.

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

Contracts/Grants Awarded 2011-2012

Department of Air Force

Office of Scientific Research

Michael Bowers
FA9550-11-1-0113 06/15/2011-06/14/2014 $ 190,000
Litigated Metal Clusters: Structures, Energetics and Reactivity

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
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
1388406 10/01/09-09/30/2013 $ 35,365
The Planck Visualization Project: Education and Public Outreach Effort of the U.S. Plank Mission

Jatila van der Veen
1388406 10/01/09-09/30/2013 $ 12,000
The Planck Visualization Project: Education and Public Outreach Effort of the U.S. Plank Mission

Jatila van der Veen
1388406 10/01/09-09/30/2013 $ 2,000
The Planck Visualization Project: Education and Public Outreach Effort of the U.S. Plank Mission

Jet Propulsion Laboratory Subtotal $ 74,365

National Science Foundation

Guenter Ahlers
DMR-1158514 06/01/12-05/31/16 $ 160,000
Turbulent Convection in a Fluid Heated from Below

Steven Butatto
CHE-1213950 04/01/12-03/31/15 $ 450,000

Model Nanocluster Catalysts: The Role of Size, Shape and Composition on the Catalytic Activity of Small Metal Oxide and Bimetallic Clusters on Oxide Surfaces

Mark Sherwin
DMR-1126894 10/01/11-09/30/14 $ 992,270
MRI: Development of a Free-Electron Laser for Ultrafast Pulsed Electron Paramagnetic Resonance

Mark Sherwin
DMR-1006603 08/15/10-07/31/14 $ 135,000
Quantum Coherence and Dynamical Instability in Quantum Wells Driven by Intense Terahertz Fields

National Science Foundation Subtotal $1,737,270

National Institutes for Health

NIH Center for Scientific Review

Bruce Lipshutz
R01 GM086485 09/01/11-05/31/12 $ 321,349
Transition Metal-Catalyzed Chemistry in Water at Room Temperature

Bruce Lipshutz
R01 GM086485 09/01/11-05/31/12 $ 273,473
Transition Metal-Catalyzed Chemistry in Water at Room Temperature

National Institutes for Health Subtotal $ 594,822

Oak Ridge National Laboratory (Department of Energy GOCO Operated by UT Batelle, LIC.)

Douglas Scalapino
4000068439 04/14/08-03/31/12 $ 43,585
Study of the Properties of Strongly Correlated Materials

Douglas Scalapino
4000068439 04/14/08-03/31/14 $ 30,838
Study of the Properties of Strongly Correlated Materials

Oak Ridge National Laboratory Subtotal $ 74,423

Synaptics

Mark Sherwin
SB120039 08/01/11-08/31/11 $ 1,567
Developing an image system for ITO based touch screens

U.S.-Israel Binational Science Foundation

Mark Sherwin
2010130 10/01/11-09/30/12 $ 22,365
Development of Gd^{3+}-based spin labels for probing structure, dynamics and interfaces by electron paramagnetic resonance techniques

Research Support Summary
(2011-2012)

			% Total
Federal			
Air Force	190,000	7%	7%
Jet Propulsion Laboratory	74,365	3%	3%
National Science Foundation	1,737,270	65%	64%
National Institites for Health	594,822	22%	22%
Oak Ridge National Laboratory	74,423	3%	3%
Federal Totals	**$2,670,880**	**100%**	**99%**
Private			
Synaptics	1,567	100%	0%
Private Totals	**$1,567**	**100%**	**0%**
International			
U.S.-Israel Binational Science Foundation	22,365	100%	1%
International Totals	**$22,365**	**100%**	**1%**
TOTALS	**$2,694,812**		**100.00%**

Charts and Graphs

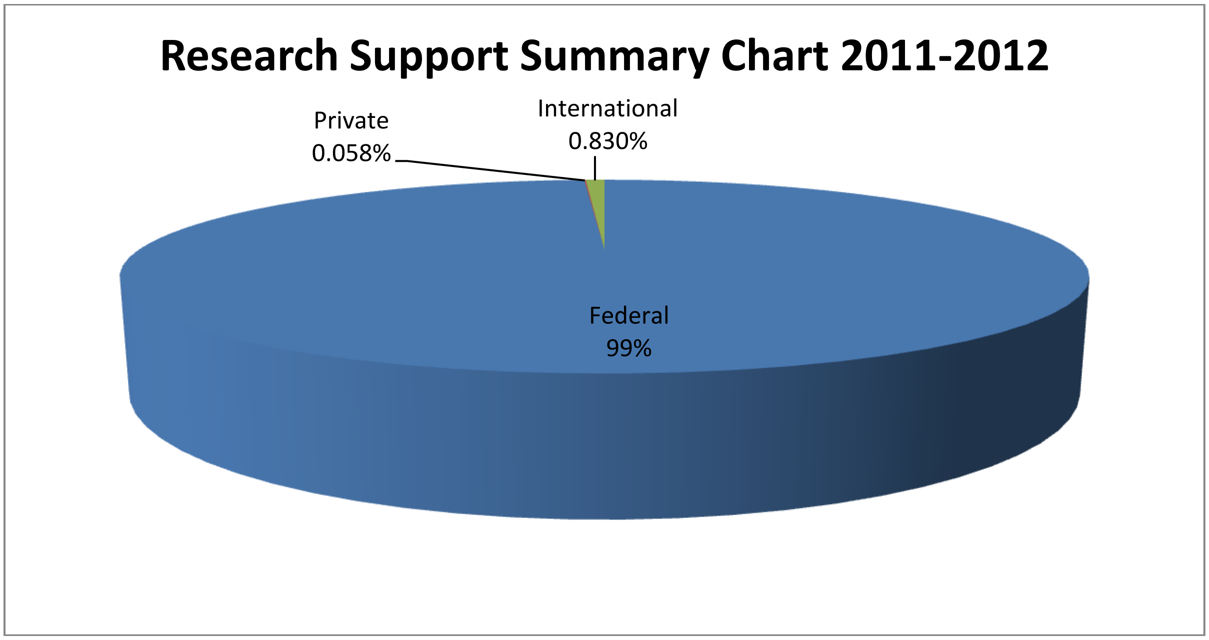

Chart 1: Research Support Summary Chart 2011-2012

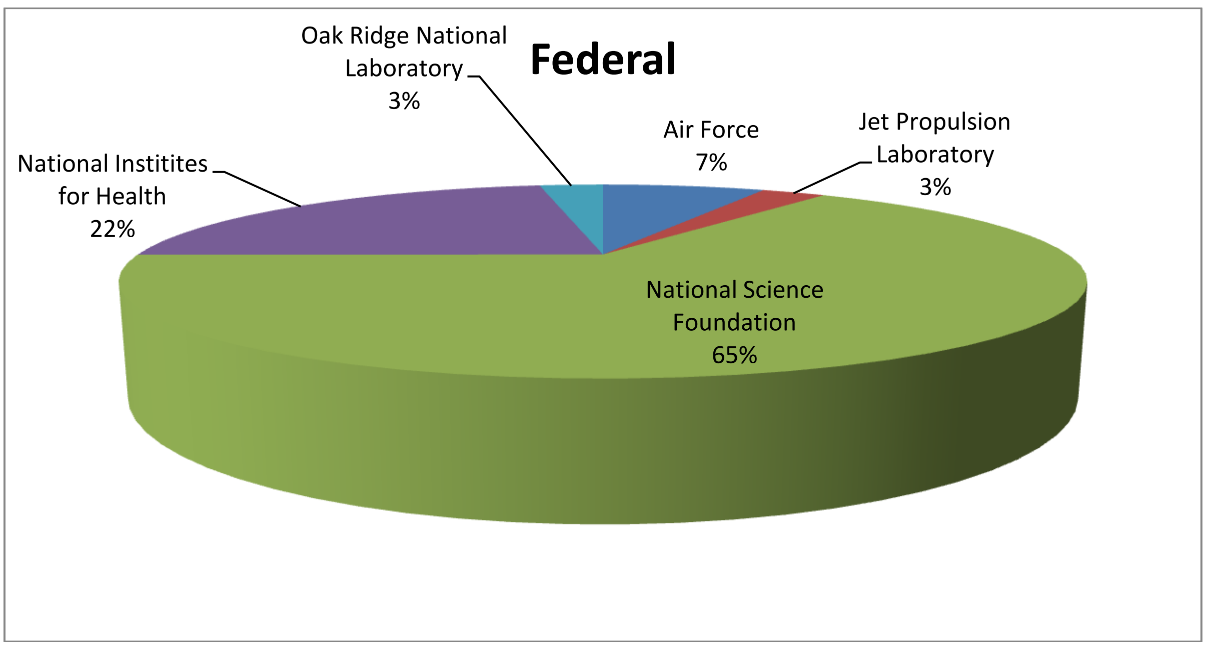

Chart 2: Federal Research Support Summary Chart

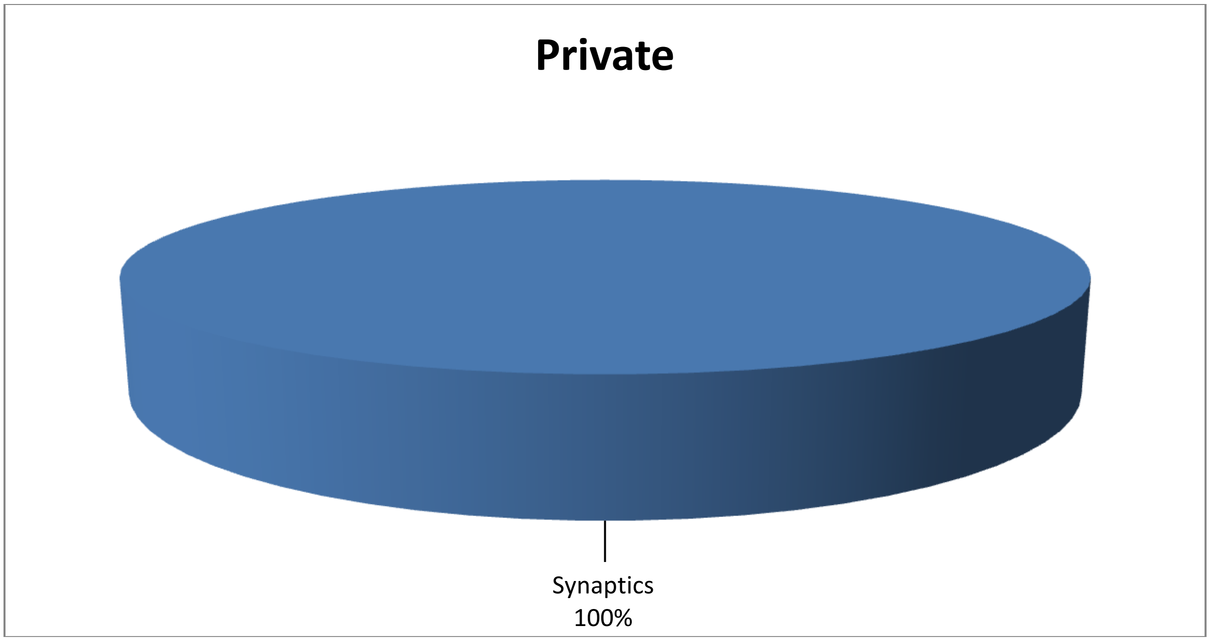

Chart 3: Private Research Support Summary Chart

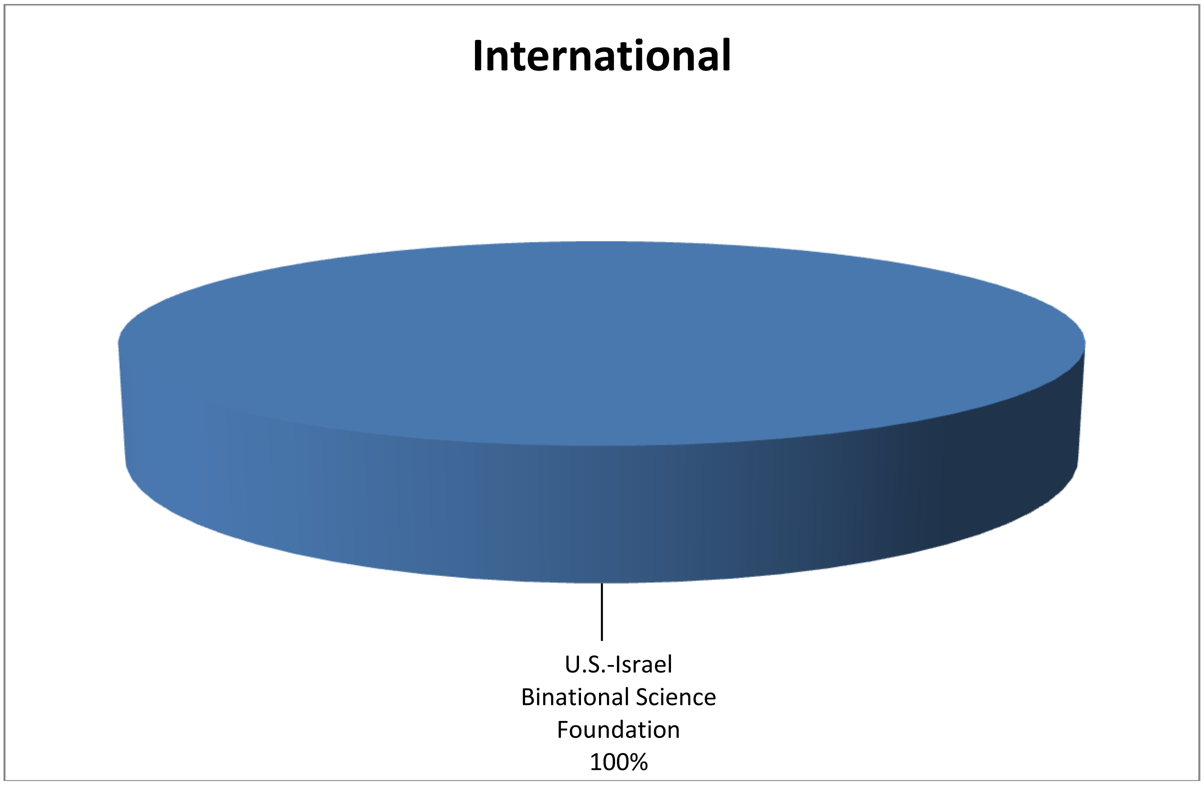

Chart 4: International Research Support Summary Chart

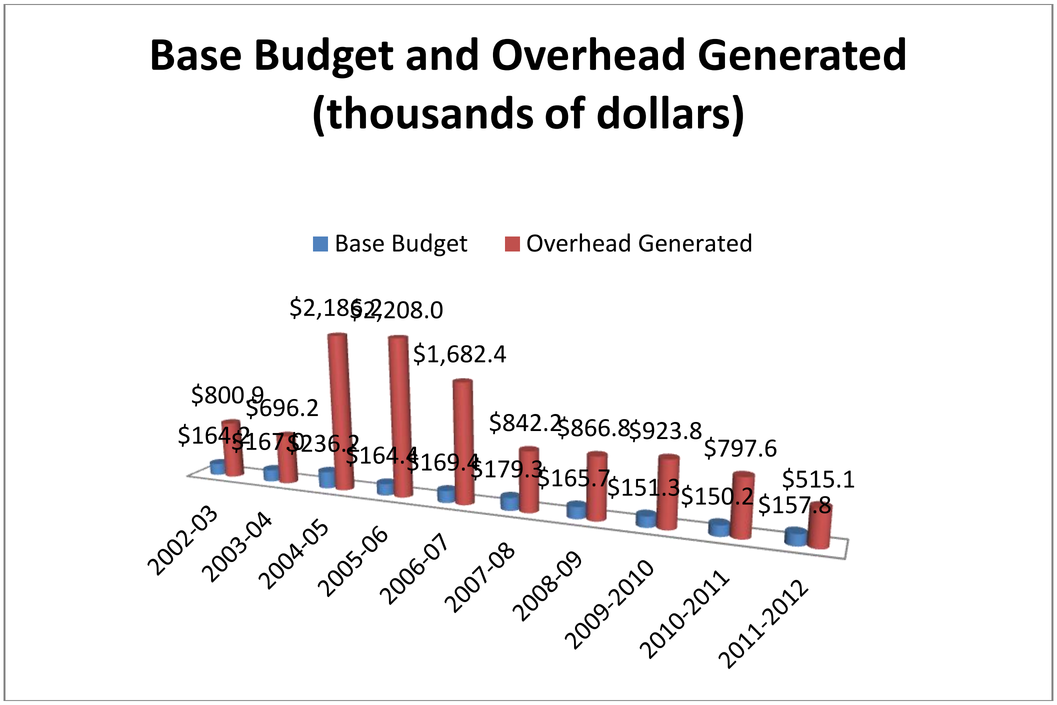

Chart 5: Base Budget and Overhead Generated

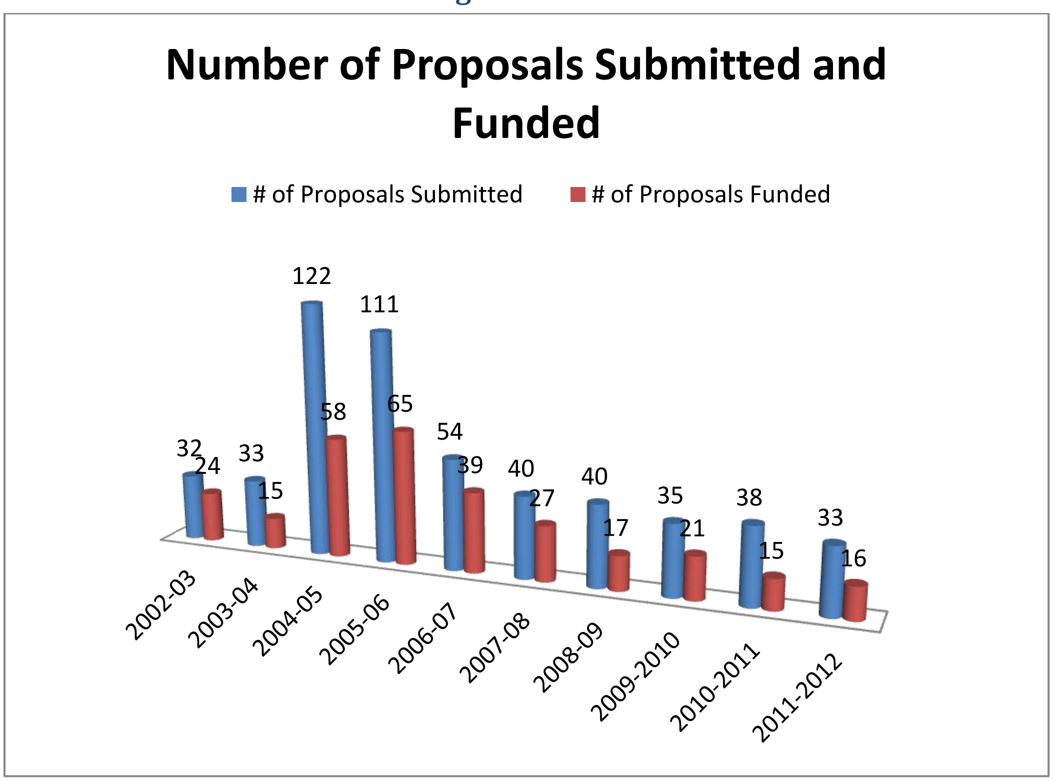

Chart 6: Number of Proposals Submitted and Funded

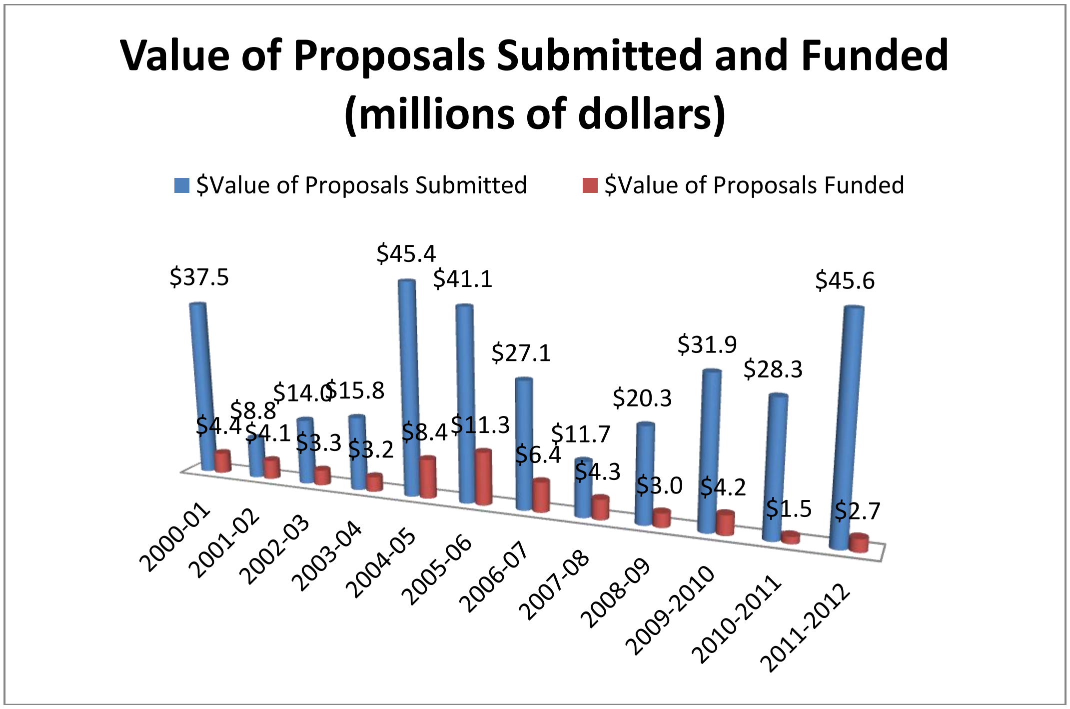

Chart 7: Value of Proposals Submitted and Funded

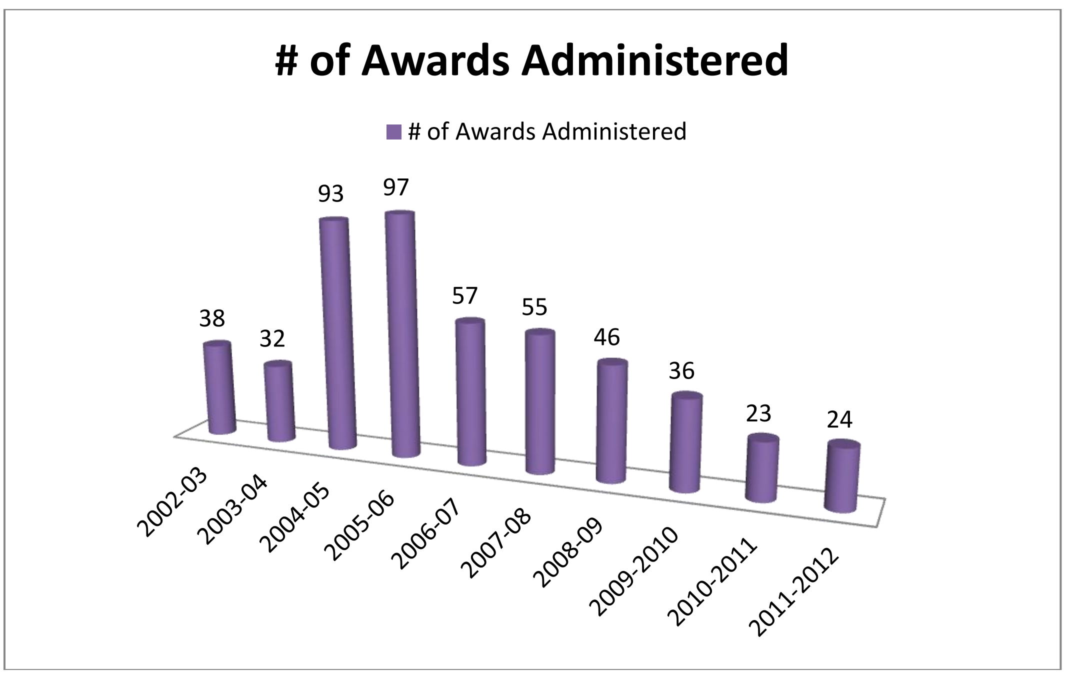

Chart 8: Number of Awards Administered

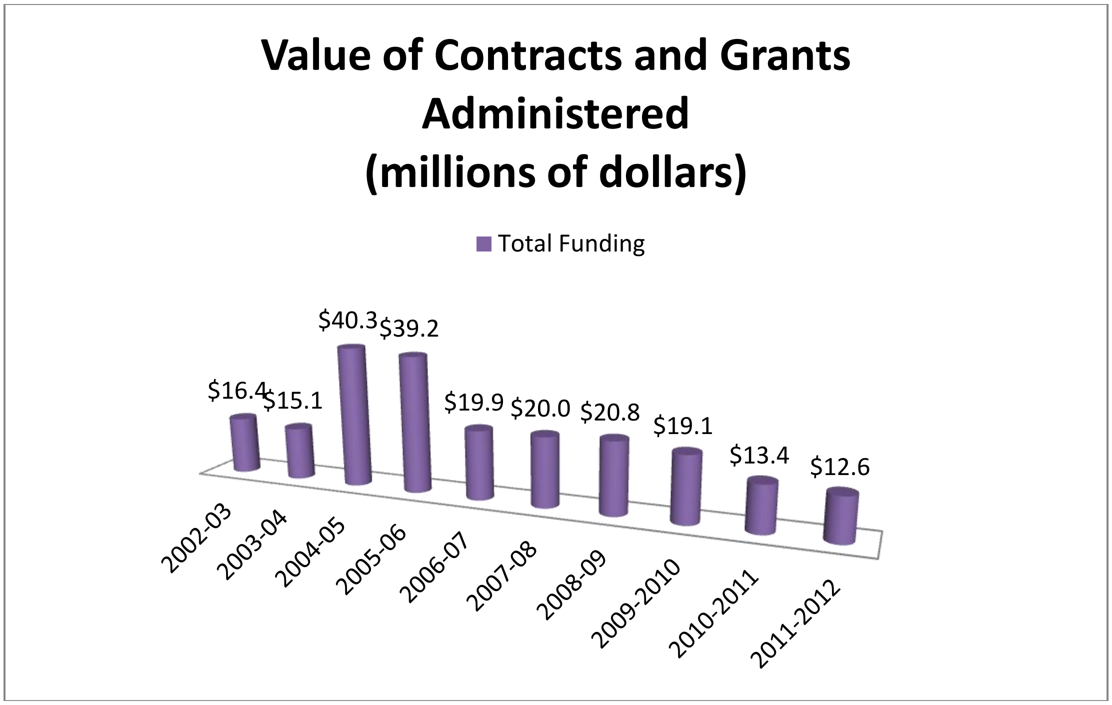

Chart 9: Value of Contracts and Grants Administer

Statistical Summary for ITST

			2011-2012
1. Academic personnel engaged in research:			
	a.	Faculty	24
	b.	Professional Researchers (including Visiting)	7
	c.	Project Scientists	4
	d.	Specialists	12
	e	Postdoctoral Scholars	4
	f	Postgraduate Researchers	0
		TOTAL	**51**
2. Graduate Students:			
	a	Employed on contracts and grants	21
	b.	Employed on other sources of funds	0
	c.	Participating through assistantships	0
	d.	Participating through traineeships	0
	e	Other (specify)	0
		TOTAL	**21**
3. Undergraduate Students:			
	a.	Employed on contracts and grants	11
	b.	Employed on other funds	0
	c.	Number of volunteers, & unpaid interns	0
		TOTAL	**11**
4. Participation from outside UCSB: (optional)			
	a.	Academics (without Salary Academic Visitors)	0
	b.	Other (City College Student)	5
5. Staff (Univ. & Non-Univ. Funds):			
	a.	Technical	8
	b.	Administrative/Clerical	3
6. Seminars, symposia, workshops sponsored			21
7. Proposals submitted			33
8. Number of different awarding agencies dealt with*			14
9. Number of extramural awards administered			24
10. Dollar value of extramural awards administered during year**			$12,552,287
11. Number of Principal Investigators***			29
12. Dollar value of other project awards ****			$331,436
13. Number of other projects administered			9
14. Total base budget for the year (as of June 30, 2012)			$157,774
15. Dollar value of intramural support			$606,887
16. Total assigned square footage in ORU			7,700
17. Dollar value of awards for year (08 Total)			$2,694,812

* 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

Guenter Ahlers	Professor	Physics
S. James Allen	Professor	Physics
Dirk Bouwmeester	Professor	Physics
Michael Bowers	Professor	Chemistry and Biochemistry
Steven Buratto	Professor	Chemistry and Biochemistry
David Cannell	Professor	Physics
Frederick Dahlquist	Professor	Chemistry and Biochemistry
Devin Edwards	Graduate Student Res.	California NanoSystems Institute
Deborah Fygenson	Associate Professor	Physics
Elisabeth Gwinn	Professor	Physics
Song-I Han	Associate Professor	Chemistry and Biochemistry
Alexander Kozhanov	Assistant Researcher	California NanoSystems Institute
Michael Liebling	Assistant Professor	Electrical and Computer Engineering
Everett Lipman	Associate Professor	Physics
Bruce Lipshutz	Professor	Chemistry and Biochemistry
Philip Lubin	Professor	Physics
Peter Meinhold	Associate Researcher	Physics
Horia Metiu	Professor	Chemistry and Biochemistry
Nguyen, Thuc-quyen	Professor	Chemistry and Biochemistry/Center For Polymer & Organic Solids
Nguyen, Vinh Quan	Postdoc Employee	Institute for Terahertz Science and Technology
Chris Palmstrom	Professor	Electrical and Computer Engineering
Pierre Petroff	Professor	Materials/Electrical and Computer Engineering
Kevin Plaxco	Professor	Chemistry and Biochemistry
Dar Roberts	Professor	Geography
Douglas Scalapino	Research Professor	Physics
Joan-Emma Shea	Professor	Chemistry and Biochemistry
Mark Sherwin	Professor	Physics
Kimberly Turner	Professor	Mechanical & Environmental Engineering
Jatila Van Der Veen	Research Associate	Institute for Terahertz Science and Technology/Lecturer College of Creative Studies

Map


Our offices are located at
Bldg 937 west of Broida Hall
937
ITST
Harder Stadium
Caesar Uyesaka Stadium
Storke Field
Future site of San Clemente Housing
Facilities Management
Intercollegiate Athletics
Robertson Gym
Student Health
Student Affairs & Admin. Services
Cheadle Hall
North Hall
Campbell Hall
Phelps Hall
Mosher Alumni House
Ellison Hall
Buchanan Hall
Physical Sciences North
Engineering Science
Kohn Hall
Old Gym
Kerr Hall
South Hall
Davidson Library
Broida Hall
MRL
Harold Frank Hall
Events Center
Humanities and Social Sciences
Counseling & Career Services
Girvetz Hall
Webb Hall
Noble Hall
Life Sciences
Psych
Music
Storke Tower
Arts
Art Museum
Theater and Dance
Faculty Club
Isla Vista Theater
Embarcadero Hall
University Center
San Rafael Hall
Manzanita Village
San Miguel Hall
San Nicolas Hall
Santa Rosa Hall
Anacapa Hall
Santa Cruz Hall
University House
Marine Science Research
Marine Biotechnology Laboratory
REEF/Aquarium
Office of Technology & Industry Alliances
UCSB Lagoon
Ocean Road
El Colegio Road
Mesa Road
Lagoon Road
Cervantes Road
El Greco Road
Picasso Road
Segovia Road
Cordoba Road
Pardall Road
Madrid Road
Seville Road
Trigo Road
Sabado Tarde Road
El Nido Lane
Del Playa Drive
PARKING DESIGN
A Faculty
S Staff
R Reserved
V Vendors
Motorcycles
Bus Stop
Traffic Light
Parking
SPEED LIMIT 25
Emergency
• For fire, police or medical emergency assistance call 9-911 or use emergency phones (in red boxes).
• UCSB Police Department, Public Safety Building, non-emergency 805-893-3446 (24 hours).
• CSO Escort Service is available by calling 805-893-2000.