

## **SPECIAL EXPERIENCES FOR GRADUATE STUDENTS**

Graduate students work on almost all the research projects at iQCD. The projects make it possible for them to work towards their PhD theses. They have written numerous research papers, and have had the opportunity to present their work at domestic and international conferences. They are also involved in mentoring undergraduate students and they participate in summer programs for both undergraduates and high school students.

Here are just a few examples:

### **SHERWIN GROUP:**

**Dan Allen, Chris Morris, Nathan Jukam** and **Cristo Yee** are all participating in a unique, interdisciplinary research program funded by the NSF to investigate quantum information processing with semiconductor nanotstructures and microcavities. They have had the opportunity to interact closely with Pierre Petroff from UCSB's materials Department, as well as theorist Craig Pryor from University of Iowa and photonic crystal expert Jelena Vuckovic from Stanford. In October 2005, the program was kicked off with a joint meeting at which all of the PIs and co-PIs were present. Collaboration is sustained via frequent teleconferences to include our collaborators from other institutions. Nathan Jukam also spent one week at Stanford working with the Vuckovic group, which led to insights that enabled him to break through an intellectual log jam, write a very nice paper that has appeared in Applied Physics Letters, and complete his Ph. D. thesis.

### **DAHLQUIST GROUP:**

**Collin Dyer** was the recipient of a fellowship award by UCSB for outstanding research

### **STUCKY GROUP:**

#### **Arnold Forman**

Project:

Conversion of solar energy into electricity

Research Experience:

In a collaboration between the McFarland, Stucky and Gossard labs a high efficiency AlGaAs/GaAs tandem solar cell was successfully produced and tested.

Current work involves use of colloidal silicon particles to photocatalytically produce H<sub>2</sub> in a low cost, medium efficiency system.

## RESEARCH EXPERIENCES FOR UNDERGRADUATES

### Jeffrey Bode

All of the grants managed by iQCD involve undergraduate researchers.

- a. The Dreyfus New Faculty Award is awarded for both Research and Teaching and the involvement of undergraduate researcher is an important component of this funding. This grant supported a student for his involvement in the synthesis of dynamic organic molecules during the period July 1–September 30, 2005.
- b. A major component of the NSF Career Award is the development of a new model for encouraging undergraduates into the study of organic chemistry at the earliest possible stage in their careers. This unique program, which we have termed the MOLE (Motivated Organic Laboratory Experience) allows the most motivated and talented undergraduates to begin undergraduate research projects in their sophomore year by getting hands on training in modern organic research in lieu of the usual sophomore organic laboratory class. This program exposes these students to the success and failures of scientific research instead of the cookbook, everything works environment of the traditional lab course that belies the challenges and opportunities of organic chemistry. Numerous students have participated in this program. A previous undergraduate participant in this program, continued her research on the catalytic generation of activated carboxylates from July 1, 2005–June 15, 2006.

The NSF also provided support for graduate students Justin Struble and Stephanie Sohn while they acted as mentors to two undergraduate students as part of the MOLE program.

An undergraduate minority supplement to this NSF grant also contributed to the support of an undergraduate student on the development of new methods for amide bond formation.
- c. An undergraduate student was further supported by Pfizer Academic Industrial Relations Minority Research Experience for Undergraduate (AIR-REU) fellowship during Summer 2005. As part of this program, he played a key role in the development of new methods for amide bond formation. He presented his work at Pfizer during a poster session in August 2005.
- d. An ACS Petroleum Research Fund Type G also provided support for the MOLE program. It supported Nancy Carrillo, who mentored an undergraduate student in Winter 2006.
- e. The subcontract from the Japanese Ministry of Health Sciences is executed largely by undergraduate researchers under the direction of our collaborator, Dr. Yoko Yamakoshi. This project is currently the topic of Michael Drew's projected doctoral thesis; he began this project as an undergraduate researcher. This year, it has provided support for two outstanding undergraduates. Both of these students are currently continuing their work on this project and we have recently received word that funding will be continued for an additional year.

## **Michael Bowers**

This year we worked with three undergrads, including one from Gonzaga University and one from UCLA.

## **David Cannel**

An undergraduate from Engineering, works with me and has made himself extremely valuable to the project, so much so that I felt it was essential to include him in the week-long visit to the prime contractor in Zurich for testing and calibration. My faith in him was not misplaced.

## **Rick Dahlquist**

An undergraduate worked on using nuclear magnetic resonance to study proteins involved in bacterial chemotaxis, and another one cloned and expressed proteins involved in the expression of pili in pathogenic bacteria

## **Peter Ford**

Three undergraduates participated in my research this year: one did research on the photochemistry of nitrate metal complexes, one did research on nitric oxide sensors, and one did research on conversions of biofeedstocks to biofuels.

## **Tom Gerig**

An undergraduate worked on the project as part of summer research and a senior honors thesis 2005-6.

## **Eric McFarland**

### **Design and building of batch-type microreactors for studying samples with low catalytic activity**

A senior Chemical Engineering student participated in the project heavily during the entire year. For his exceptional performance he was awarded by the PI by a trip to Atlanta, Ga, for participation in the ACS Meeting.

## **Conversion of solar energy into electricity**

A senior Chemical Engineering student, worked with the McFarland lab on photocatalysis.

## **Mark Sherwin**

Two undergraduates have worked with my post-doctoral researcher, Susumu Takahashi, helping to build and test the world's highest-frequency, high-power pulsed electron spin resonance spectrometer.

Another undergraduate was mentored by Dan Allen as part of MRL's UK intern exchange program beginning June 2006. She was finishing her Junior year at Trinity College in Dublin as an experimental physics major. She assisted Dan with construction of a unique optical delay for his experiments related to quantum information processing. Dan Allen is an outstandingly talented and enthusiastic teacher and mentor, and the student had a terrific time.

## **Petra van Koppen**

We have four faculty members from the Chemistry/Biochemistry and Materials Departments, an education programs assistant, two graduate students, seven undergraduate student coordinator and approximately **forty undergraduate volunteers** contributing to the program.

## PUBLIC SERVICE ACTIVITIES

IQCD manages a K-12 outreach program called QUESTBoards. The QUESTboards project provides hands-on activity materials for students in grades 4 - 12 to investigate principles of electricity, magnetism, electromagnetism, electronic circuits, optics, light, and lasers. Teachers are provided with accompanying curriculum materials, which are aligned with state educational standards. QUESTBoards are available to any unit on campus which wishes to use them associated with one of their outreach activities, which range from campus visits by teachers and/or students to family science nights at schools to sessions in school classrooms.

### Guenter Ahlers

1996-present	Proposal reviewer for National Science Foundation, US-Israel Binational Science Foundation and Department of Energy
1996-present	Reviewer for Phys. Rev. A, Phys. Rev. B, Phys. Rev. E, Phys. Rev. Lett., and J. Fluid Mech., J. Low Temp. Phys., Phys. Fluids

Member, External Advisory Committee for the Center for Nonlinear Studies, LANL (1988 – present)

Member, NASA Fundamental Physics Discipline Working Group (2000 – present)

Member, Editorial Board for Series on Partially Ordered Systems, Springer (2002 – present).

### Jim Allen

Advisory Committee, International Conference on Hot Carriers in Semiconductors, 2005

Chair – External Advisory Board for Sandia National Labs

Laboratory-Directed Research and Development project “Terahertz Microelectronic Transceiver” program November 2005 - present

Advisory Committee, International Conference on Hot Carriers in Semiconductors, 2007

2000 – 2005	Chair	Department of Physics
2005 - present	Member	UCSB Corporate Relations Program

2005	Outreach	INSET, Brian Goss
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### David Awschalom

International Advisory Committee, Worldwide Universities Network Spintronics Consortium, University of York (2006)

Advisory Committee, International Conference on Magnetism (ICM), Kyoto, Japan (2006)

International Advisory Board, International Conferences on Materials and Technologies (CIMTEC), Acireale, Sicily, Italy, June 4-9, 2006

Session Chair, Focused Session on Semiconductor Spintronics, March Meeting of the American Physical Society, Baltimore, MD, March 13-17, 2006

Moderator, Gordon Conference on Ultrafast Phenomena in Cooperative Systems, Buellton, CA, February 5-10, 2006

Member, Advisory Board, Fourth International Conference on the Physics and Applications of Spins in Semiconductors, Sendai, Japan (2006)

DCMP Executive Committee Meeting, Chicago, IL, October 10-11, 2005

Member, Molecular Foundry Proposal Study Panel, Lawrence Berkeley National Laboratory (2005-2008)

National Academy of Science Solid State Sciences Committee Meeting, Irvine, CA, October 20-21, 2005

Chair, International Scientific Advisory Board, Center for Research on Nanostructures and Nanodevices (CRANN), Dublin, Ireland (2005)

Session Chair, Symposium on Spin Dynamics and Relaxation, Conference on Magnetism and Magnetic Materials, San Jose, CA (2005)

International Advisory Committee, Third International Conference and School on Spintronics and Quantum Information Technology (SPINTECH III), Hyogo, Japan (2005)

National Advisory Committee, 24<sup>th</sup> International Conference on Low Temperature Physics, Orlando, FL, August 2005

Program Committee, SPIE Conference on Photonics, Brisbane, Australia, December 11-14, 2005

Advisory Board, International Conference on Nanoscale Devices and System Integration (NDSI), Houston, TX, April 4-6, 2005

Member, Swiss Review Panel for National Center for Nanoscience Research, University of Basel, Switzerland (2005)

Member, Scientific Advisory Board for CRANN Institute, Trinity College, Dublin, Ireland (2005-2008)

Session Chair, "Recent Developments in Semiconductor Heterostructure Spin Physics," March Meeting of the American Physical Society, Los Angeles, CA, March 21-25, 2005

Advisory Board, Handbook of Magnetism and Magnetic Materials, John Wiley & Sons, NY (2005-2006)

Prize Committee Member, MRS Outstanding Young Investigator Award (2004-2006)

Member, International Scientific Advisory Board, Center for Quantum Information and Quantum Control (CQ/QC), University of Toronto (2004-2007)

Elected Member, National Academies Solid State Science Committees (2003-2006)

Advisory Board, Munich Center for Nanoscience (CeNS), Wildbad Kreuth, Germany (2002 – 2007)

Advisory Editorial Board, Journal of Magnetism and Materials (2002 – 2005)

Review Panel Member, Swiss National Science Foundation NCCR Center for Nanoscale Science, Basel, Switzerland (2002 – 2005)

## Jeffrey Bode

In order to provide a forum for the education activities funded by the NSF CAREER Award, Dr. Bode has become closely associated with the College of Creative Studies. He is currently a faculty member there and serves on the committee to improve the environment of the chemistry department for CCS students and to provide them with unique research opportunities

## Dirk Bouwmeester

Sept. 2005		NSF Review
2004-06	Member	Physics Web committee

## David Cannell

05/06	Member	Graduate Student Mentor Committee / Physics Department
05/06	Chair	Curriculum Committee / Physics Department

## Andrew Cleland

2005		Referee for <i>American Petroleum Fund</i> (proposal review)
2005		Referee for <i>Physical Review Letters</i> (two manuscripts)
2005		Referee for <i>Nature</i> (six manuscripts)
2005		Referee for <i>Measurement Science and Technology</i> (one manuscript)
2005		Referee for <i>New Journal of Physics</i> (one manuscript)
2005		Referee for <i>Nanotechnology</i> (three manuscripts)
2005		Referee for <i>Netherlands Organization for Scientific Research (NWO)</i> , 2005 Vici individual investigator proposal
2005		Referee for <i>Sensors and Actuators</i> (two manuscripts)
2005		Referee for <i>Nature Physics</i> (one manuscript)
2006		Referee for <i>Applied Physics Letters</i> (three manuscripts)
2006		Referee for <i>Physical Review Letters</i> (three manuscripts)
2006		Referee for <i>Science</i> (one manuscript)
2006		Referee for <i>US Department of Energy SBIR program</i>
2006		Referee for <i>Austrian Science Foundation</i>
2006		Referee for <i>Nature</i> (one manuscript)
2006		Referee for <i>Sensors and Actuators</i> (one manuscript)
2006		Referee for <i>Physical Review B</i> (one manuscript)

June 2002-present	Consultant for Infratab Inc. (Oxnard CA)
2005-present	Program Committee, Intl. Workshop on Electronics of Nanoscale Materials (Austria)
2004-present	Program Committee, Intl. Conf. on Topology of Ordered Phases (Japan)

2004-06	Physics Building Committee	Chair of Building Committee / Physics Department
2004-06	Condensed matter search committee	Search Committee for Condensed Matter Theory / Physics Department
2006	Ad Hoc campus committee for promotion	Chair of Ad Hoc Committee / Physics Department

## Peter Ford

Chair: Scientific Committee: International Symposium on the Photochemistry and Photophysics of Coordination Chemistry (ISPPCC)--Asilomar CA 7/05  
 Elected member (12 year term) International Organizing Committee ISPPCC  
 Member, Scientific Advisory Committee--NIH SCORE program --Cal State U. Long Beach  
 Vice-Chair of the Department of Chemistry and Biochemistry

## Deborah Fygenon

1996 - present	Referee, Physical Review Letters, Physical Review E, Journal of Molecular Biology, Journal of Theoretical Biology, Nanoletters, Interface
1999 - present	Grant Reviewer, National Science Foundation DMR, BIO, PHY

## Eric McFarland

This past March, two high school students from Ventura spent a full day in the McFarland lab with Arnold Forman and Alan Kleiman, learning about and performing quantitative tests on photovoltaic devices.

Manuel Casillas, a teacher at Santa Maria High School worked in our lab on the nanocluster catalysis projects for building his future class curriculum.

## **Kevin Plaxco**

Completed a popular science book "Astrobiology: A Brief Introduction" that was motivated by earlier IQUEST-administered research (NASA-Astrobiology funds he shared with Jim Allen). The book is in press at Johns Hopkins University press for publication in the Spring.

Chair of the iQCD Advisory Committee

## **Joan-Emma Shea**

Chemistry outreach program for grade 5 students (organized by Petra van Koppen)

## **Mark Sherwin**

Director, Institute for Quantum and Complex Dynamics (IQCD) [formerly iQUEST], UCSB, 7/1/05 - present

Director, Center for Terahertz Science and Technology, iQUEST, UCSB

2005, Interim President of the Terahertz Science and Technology Network (a new professional society)

## **Petra van Koppen**

### **UCSB OUTREACH PROGRAM**

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This year we had over **1200 fifth grade students, parents and teachers** participate in our outreach program.

**Summer 2005** we offered a physical science workshop for K-12 science teachers in collaboration with the South Coast Science Project directed by Tom Ostwald. Teachers are provided standards-based content experiences, lesson plans and activities. A follow up workshop was held at the Cliff House, Friday Dec. 3, 2005. We offer these workshops every summer.

**Oct. 2005 through June 2006** we had one training workshop for new undergraduate volunteers and 40 workshops were offered for fifth graders in the lab at UCSB. Each workshop included a class of ~30 students, parents and teachers. Undergraduates in the chemistry club and in chemistry lecture classes are provided with the opportunity to teach in the chemistry outreach program by leading various hands-on activities. This year we had over 1200 fifth grade students, teachers and parents participate. Schools from Canejo Valley, Oxnard, Ventura, Goleta, Santa Barbara, Carpinteria, Lompoc and Ojai participated in our program.

We have four faculty members from the Chemistry/Biochemistry and Materials Departments, an education programs assistant, two graduate students, seven undergraduate student coordinator and approximately **forty undergraduate volunteers** contributing to the program.



**All of the fifth grade students want to come to the UCSB again to participate in more activities.**

## AWARDS AND OTHER ACTIVITIES

### David Awschalom

Elected Fellow, American Academy of Arts and Sciences (2006)  
Cantor Nanoscience Lecturer, University of York (2006)  
AAAS Newcomb-Cleveland Prize, American Association of the Advancement of Science (2006)  
Whitfield Lecturer, Pennsylvania State University (2005)  
Australian Research Council Nanotechnology Network (ARCNN) Distinguished Lecturer (2005)  
Voted Best Lecturer, Third International School and Conference on Semiconductor Spintronics and Quantum Information Technology, Awaji, Japan (2005)  
Agilent Technologies Europhysics Prize, European Physics Society (2005)  
Oliver E. Buckley Prize in Condensed Matter Physics, American Physical Society (2005)  
Australian Research Council Nanotechnology Network Distinguished Lecturer (2005)

### Patents

“Teleportation System for Many-Qubit States Using Individual Photons,” M. Leuenberger, M. Flatté, and D. D. Awschalom, patent pending (filed February 17, 2006).

### Research Reported in the Public Press

“UCSB Takes Step Toward Spin Processing,” *Computerworld*, November 14, 2005, p. 38.  
“The New Spin on Circuitry,” *Frontiers of Science: Microelectronics*, Curt Suplee, *Discover Magazine*, Special 25<sup>th</sup> Anniversary Issue, October 2005, Vol. 26, No. 10, p. 38-39  
“Taking the Hall Effect for a Spin,” Junichiro Inoue and Hideo Ohno, *Science* **309**, 2004 (2005).  
“Caught on a Jewel,” *Research Highlights*, *Nature* **437**, 1069 (2005).  
“Spin in the Slow Lane,” Bart van Wees, *News & Views*, *Nature* **437**, 1249 (2005)  
“Dark’ Spins Come to Light,” *Research Highlights*, *Nature Physics* **1**, 79 (2005)  
“Researchers Light Up ‘Dark’ Spins in Diamond,” *Science Daily*, November 2005  
“Researchers Light up ‘Dark’ Spins in Diamond,” *Physics Web*, November 2005  
“UC Santa Barbara Researchers Light up “Dark’ Spins in Diamond,” *Innovations Report*, November 2005  
“Towards Room Temperature Quantum Information Processing,” Anne Fischer, *Photonics Spectra*, January 2006, page 142-143  
“UCSB Researchers Who Made Elusive Discovery Win Prestigious AAAS Newcomb Cleveland Prize,” *News from UC Santa Barbara, Office of Public Affairs*, February 15, 2006  
“UCSB Physicists Win Prize,” *Santa Barbara News Press*, February 16, 2006  
“Science Magazine Honors Researchers for 2004 Contribution to Spintronics,” *93106*, UCSB, Vol. 16, No. 11, February 21, 2006

“UCSB Heads Project to Develop New Chip,” *Santa Barbara News Press*, March 9, 2006

“UCSB, UCLA, UCB and Stanford Join to Establish Western Institute of Nanoelectronics,” Office of Public Affairs, News from UC Santa Barbara, Office of Public Affairs, March 9, 2006

“UCSB Plays Big Role in Forming of New Institute,” *Santa Barbara News Press*, March 10, 2006

“UCSB to be Part of Western Institute of Nanoelectronics,” *93106*, UCSB, Vol. 16, No. 13, March 20, 2006

“American Academy of Arts and Sciences Elects 3 Affiliated with UC Santa Barbara,” News from UC Santa Barbara, Office of Public Affairs, April 24, 2006

“Industry and Academia Join Hands in Search for Post-CMOS Logic,” *Physics Today* **59**, 22 (2006), May issue.

## **Jeffrey Bode**

- a. Our development of a new method for the synthesis of amide and peptide bonds was featured as the lead story in *Chemical and Engineering News*, Jan. 30, 2006, pg 7.
- b. Beckman Young Investigator Award
- c. Research Corporation Cottrell Scholar Award

## **Dirk Bouwmeester**

Dutch Physical Society Huygens-lecturer 2005

### **Research Reported in the Public Press**

“Quantum Trickery: Testing Einstein’s Strangest Theory,” by Dennis Overbye, *New York Times*, December 27, 2005.

News article on *Physorg.com*: “Quantum dots self-tune their color for ultra-efficient nano lasers”, (<http://www.physorg.com/news64253705.html>) 2006.

Report, *Physics Today*, “Minimalist laser in a photonic crystal” June 2006 page 22.

## **David Cannell**

### **Research Reported in the Public Press**

Gradflex merited a cover article in *Applied Optics*, April, 2006

## **Pierre Petroff**

In 2005, awarded the “Quantum Device Award” for “Pioneering work on growth and spectroscopy of self assembling quantum wires, quantum dots and quantum devices”

## **Petra van Koppen**

Featured as a “Terrific Teacher” in the 2006-2008 edition of the *Kiosk*  
Honorary Service Award, San Marcos High School Chemistry and Physics Teachers,  
May 17, 2006  
ACS Certificate for Outstanding Contributions towards Public Understanding of  
Chemistry, May 19, 2006  
Outstanding Faculty Member, Residence Halls Association/Office of Residential Life,  
May 24, 2006  
Promoting Success of Living-Learning Communities, Housing and Residential Services,  
June 1, 2006

## **Report of the Center for Nonlinear Science for the Academic Year 2005-2006**

The main event organized by the Center was a conference on “Probability, Geometry and Integrable Systems” at MSRI the NSF's Mathematical Sciences Research Institute in Berkeley. The conference was funded by a grant from NSA ( \$ 15,000 PI Birnir) and grants from NSF and the Courant Institute at NYU. The conference was organized by MSRI and the grant was submitted through MSRI. It took place in Berkeley Des. 05-09, 2005, a schedule of the conference is attached.

One purpose of this conference was to explore the emerging mathematics of complex systems and its applications in many fields. The conference was a great success and the participants concluded that the theory of Stochastic Differential Equations (SDEs), and in particular the theory of nonlinear SPDEs (Stochastic Partial Differential Equation), was now ripe for applications in fields ranging from Geomorphology and Seismology to Ecology and Cellular Biology. In particular a fusion of techniques from nonlinear SPDEs and statistical mechanics is giving physicists, mathematicians, geologists and biologists the tools to solve important problems. Some old problems that have resisted resolution for a long time and many new ones are now being solved using these techniques.

Back at UCSB the Center's Director consulted with researchers in complex systems at UCSB and everyone enthusiastically endorsed the idea that the Center for Nonlinear Science should be turned into a Center for Complex and Nonlinear Science. The Director and Mark Sherwin the Director of IQCD met with Vice Chancellor for Research Michael Witherell and he gave his permission and support to this evolution of the center. Michael Witherell requested that that Center for Complex and Nonlinear Science be organized around focus groups and preliminary meeting of interested researchers was held to discuss how to organize these groups. These researchers suggested that a kick off day for the Complex and Nonlinear Science Center be held Oct. 4<sup>th</sup> where researchers would give short talks and show each other their expertise. It was concluded that this was the best way of initiating cross-fertilization between fields.

Three focus groups on Turbulence and Biological Applications, Seismology and Migrations in Biology have already been formed but more are expected to follow after the Oct. 4<sup>th</sup> meeting.

**Visitors:** The Center had several visitors, James Glazier from Univ. of Indiana, Thordur Jonsson from the Univ. of Iceland, Luis Bonilla from the University of Carlos III, Madrid, etc.

**Meetings:** The Center participated in two meetings in addition to organizing the Berkeley meeting: “Applications of Methods of Stochastic Systems and Statistical Physics in Biology”, Nov. 28-30, at Notre Dame and “Swarming by Nature and Design” Feb. 27-March 3, IPAM, UCLA. A group of researchers the Center attended this meeting and the

Center's Director advised the organizers. In addition the Center's members attended several other meetings.

**Grants:** One grant was obtained from NSA (\$15,000) submitted through MSRI. An application for Collaborations in Mathematical Geology was submitted but not funded. A white paper for DTRA was approved and a full proposal will be submitted August 31<sup>st</sup>.

**Graduate Courses:** A major part of the Center's function is to train graduate students in techniques that they can use to investigate complex systems. The Director along with members of the Department of Applied Probability and Statistics, Jean-Pierre Fouque and Guillaume Bonnet has designed a two course sequence in SDEs and Nonlinear SPDEs and applications. These courses will be taught during the academic year 2006-2007. The latter course will be taught by Bjorn Birnir, Jean-Pierre Fouque and Guillaume Bonnet. The center hopes to eventually develop courses in complex systems using methods from Physics, the Sciences and Biology.

## Center for Terahertz Science and Technology Annual report for July 1, 2005 to June 30, 2006

The Center for Terahertz Science and Technology is growing and broadening its activities. Historically, the Center for Terahertz Science and Technology (CTST) has had activities tightly focused around UC Santa Barbara's unique Free-Electron Lasers, which are tunable from 0.1 to 5 THz with narrow linewidths and peak powers of the order of 1 kW. Terahertz science and technology are experiencing explosive growth worldwide, and UC Santa Barbara is fortunate to have roughly a dozen outstanding faculty members spread across six departments whose research heavily involves terahertz frequencies. Table 1 lists the faculty who are involved in Center activities and their associated departments. The CTST is actively promoting greater synergy among these faculty members, a larger group than has been historically involved in the Center. This group includes many individuals who do not need the special characteristics of the UC Santa Barbara FELs but share many technical challenges and scientific or technical interests.

<i>Faculty member</i>	<i>Department</i>
Jim Allen	Physics
Bjorn Birnir	Mathematics
Elliott Brown	Electrical and Computer Engineering (ECE)
Larry Coldren	Materials and ECE
Art Gossard	Materials and ECE
Song-I Han	Department of Chemistry and Biochemistry (DCB)
Philip Lubin	Physics
Pierre Petroff	Materials, ECE
Kevin Plaxco	DCB and Biomolecular Science and Engineering
Mark Rodwell	ECE
Mark Sherwin (director)	Physics

*Table 1: Faculty members involved in terahertz research at UC Santa Barbara and members of the CTST.*

One of the long-term goals of the Center is to equip a shared facility which will house turnkey, state-of-the-art tools for terahertz spectroscopy that complement the FELs, are not currently available on campus, and are too costly in aggregate to be afforded by a single investigator. Many of the faculty listed above have joined together to submit a large proposal which is intended, in large part, to equip such a laboratory.

A scientific highlight for 2005-2006 has been the publication of the first terahertz spectroscopic studies of proteins *in aqueous solution* by graduate student Jing Xu, under the guidance of Professors Kevin Plaxco and Jim Allen and with technical assistance from Prof. Rodwell's group (support: Army Research Office). Decades of numerical simulation indicate that proteins have biologically-important collective vibrations throughout the terahertz spectrum. Since proteins are charged, the most direct way to probe such vibrations is by terahertz absorption spectroscopy. Many investigators have performed terahertz spectroscopic studies of dry or moist samples of protein. However, the measurement of the absorption of proteins dissolved in water, which is the biologically-relevant condition, was previously prevented by the fact that water itself is a tremendously effective absorber of terahertz frequencies: just 1 mm of water will attenuate 2 THz radiation by  $10^{18}$ ! Xu and co-workers overcame this obstacle by designing a clever

apparatus that used the UC Santa Barbara FELs as a powerful source, and an ultra-sensitive cryogenic bolometer as a detector. Several papers were published as a result of this collaboration, including one in Proceedings of the National Academy of Sciences. Computer simulations of protein dynamics can now be constrained by experiments performed under biologically-relevant conditions.

An NSF-funded collaboration to develop the world's highest-frequency, high-power pulsed electron paramagnetic resonance (EPR) spectrometer was begun 2004-2005 and sped up in 2005-2006. This collaboration has involved post-doctoral researcher Susumu Takahashi, graduate student researchers Sangwoo Kim and Hieu Nguyen, undergraduate researchers Melissa Anholm and Kiyotaka Akabori, under the supervision of Profs. Mark Sherwin and Song-I Han from UC Santa Barbara, as well as Drs. Hans van Tol and Louis-Claude Brunel from the National High Magnetic Field Laboratory in Tallahassee. The source for these experiments will be the UC Santa Barbara FELs. The successful development of this 0.24 THz EPR spectrometer will enable, among other things, the study of structure and dynamics of spin-labeled proteins in aqueous solution at room temperature. Such studies are currently impossible because existing EPR spectrometers have time resolution limited to 50 ns or longer, while the spins of electrons attached to proteins decay on shorter time scales.

Molecular biology is actually a very new direction at the CTST. Our "bread and butter" remains the terahertz dynamics of electrons in semiconductor heterostructures, including the following active research programs:

1. Terahertz electro-optics in semiconductor nanostructures. (NSF, Sherwin (Physics), Gossard and Coldren (Materials and ECE) groups at UCSB. Highlight: publication in Science magazine of "Quantum coherence in an optical modulator.")
2. Semiconductor nanostructures microcavities for quantum information processing at terahertz frequencies. (NSF, Sherwin (Physics, UCSB), Petroff (Physics, UCSB), Pryor (Physics, University of Iowa), and Vuckovic (ECE, Stanford)).
3. Development of a source of terahertz radiation based on Bloch oscillation in semiconductor superlattices. (Agilent, Allen (Physics, UCSB) with Agilent Labs)
4. Development of terahertz detectors based on intersubband transitions in quantum wells. (DOD, Sherwin and Gossard with Dong-Ho Wu at Naval Research Lab)
5. Development of terahertz detectors based on 2-D plasmons in quantum wells. (DOD and NSF, Allen with researchers from Sandia National Labs).

Other scientific research activity at CTST includes a NSF-funded collaboration initiated by Prof. Jing Wu at the New Jersey Institute of Technology to study terahertz dynamics of polymer crystallization. Staff physicist Jerry Ramian constructed the apparatus for this experiment.

We also implemented a major NSF-funded upgrade of the UCSB FELs, which was completed in October 2006. The electrostatic accelerator and roughly 120 items around the UCSB FELs' beam line (e.g. electron gun, pulser, CCD cameras, current monitors) are under computer control. Bulky, late 1980s vintage hardware based on the obsolete "CAMAC" system, distributed through more than a dozen full-sized equipment racks, has been replaced by three racks of, state-of-the-art PXI-based and home-built control electronics. A 15-year-old computer control system operating under IBM's (no-longer supported) OS/2 has been replaced by a highly-flexible

computer program based on industry-standard LabView software. **The FEL control room that formerly contained equipment racks connected by miles of cables now just has a computer, connected by a single optical fiber to the control electronics in the FEL vault, and the FEL can now be operated from any computer in the lab.** The FEL is back in operation, and the beam is much more stable than before. It will only continue to improve as final tweaks are made.

Other users of the CTST facilities in 2005-2006 include a company called Passport Systems, researchers from the Pacific Northwest National Laboratories, and researchers from Lawrence Livermore National Laboratories. These entities are working on security-related applications. We also had the pleasure of a six-month sabbatical visit from Dr. Matthew Halsall of the ECE Department at the University of Manchester (U.K.).