SRI REU 2010 Student Projects and Program Activities

REU 2010 Students

Student Research Projects and Accomplishments:

Below is a summary of each student's project in their own words with some editing of the text as appropriate.

Aaron Buikema (Haverford College, Haverford, PA)
Mentors: Drs. Gregory Faris and Kanaka Hettiarachchi

Title: Nanoliter-Droplet Generation and Locomotion for RT-PCR Analysis of Rare Cells.

"My primary goal this summer was to develop a way to produce RT-PCR (reverse transcription-polymerase chain reaction) reagent droplets reliably underneath a thin layer of oil. In the process of trying to achieve this goal, I tested a number of different methods, including a piezoelectric drop-on-demand jet ('piezo tip' or just 'piezo' from this point), a microfluidic T-junction, and many other less elaborate techniques using a variety of dispensing tips. Of these, I found the piezo tip to be the most effective and consistent tool for producing droplets. I spent the first part of this summer finding the jetting parameters that would produce droplets approximately 100 µm in diameter reliably while reducing the probability of secondary droplet formation. Additionally, I improved the reliability of, and added functionality to the original LabVIEW software used to control the tip and associated hardware. The ultimate goal of the PCR project is to be able to perform RT-PCR on numerous samples at a time to analyze rare cells, so we want to scale it up at some point in the future. To further this goal, I also modified the software to allow production of an array of reagent droplets quickly.

The second part of my work involved improving the mobility of reagent droplets. This required testing numerous oil phase mixtures and Petri dish coatings, as well as different surfactant additions to the droplet solutions. The most difficult aspect of this task was the requirement that, the droplets containing the sample cell for RT-PCR had to adhere to the surface and remain immobile during the application of heat necessary to enable the PCR, while the other reagent droplets had to have as small a contact area as possible and needed to be moved with little heat for as long as possible. The group centered on using silicone oil, specifically, poly(dimethylsiloxane) (PDMS for short), as the oil phase. Kanaka and I found that using a solid coating of PDMS on the bottom of a Petri dish and a silicone oil mixture with an ideal viscosity resulted in very small droplet contact areas and high mobility for reagent droplets while keeping the cell drop adhered to the surface. The addition of a lipid (DPhPC) to the reagent droplets ensured that they remained mobile for even longer. My final task this summer was attempting to extend the droplet production method to another project in the lab called the droplet bilayer project."

Alejandro Ceballos (Northern Arizona University, Flagstaff, AZ)
<u>Mentors</u>: Drs. Jochen Marschall, Dušan Pejaković and Luning Zhang

Title: Oxidation of Graphite Materials Relevant to the Thermal Protection Systems of Reentering Spacecraft.

"In this project we studied the oxidation behavior of carbon-based materials for use in ablator shield technology for atmospheric re-entry vehicles. The material we studied is called FiberForm. FiberForm is a low density, highly porous material designed to perform in a vacuum and resist chemical and physical attacks. The oxidant was air and the reaction occurred in two ways:

At T≥ 600° C, this was the favored reaction:
$C + O_2 \rightarrow CO_2$

At T≥900° C, this was the favored reaction:
$2C + O_2 \rightarrow 2CO$

We built up a system that would allow us to study the oxidation behavior of FiberForm. The system we constructed consisted of the following:

1) A tube furnace fitted with a quartz tube of diameter = 22mm. FiberForm samples were inserted in the tube and exposed to:
    i) Temperatures of up to 900° C
    ii) Flows of synthetic air at pressures of up to 100 Torr
2) A mass spectrometer to detect and record the levels of the gaseous products of the oxidation reaction
3) A mass flow controller to control the amount of gas being injected in to the system
4) Pressure gauges to measure the absolute and differential pressure across the system
5) Vacuum pump and a temperature controller
6) Computer terminal to record data from the mass spectrometer, the temperature controller, and the pressure gauges

We tested a total of 19 FiberForm samples of different lengths and under different flow regimes and pressures. The experimental process can be broken into 3 stages. Before and after each oxidation, regardless of the experimental stage, all samples were weighed and measurements of their length and diameter were taken to calculate the density of each sample. After having acquired all the data from a particular oxidation, the mass loss and the flow rate of molecular oxygen were used to calculate gamma (γ), a ratio of the carbon atoms that reacted with the oxygen molecules. The value of this ratio indicated how efficient the reaction was in our experiments. The value of this ratio was compared to the ratio of reactants from the chemical equations presented above. Thus, if at 625° C gamma ended being close to 1, then we were having a very efficient reaction that consumed most of the oxygen to produce CO_2.

Stage 1 dealt with rarefied gas flows at 900° C. Gamma values ranged between 1.25 and 1.6, indicating production of CO, as predicted.

Stage 2 dealt with continuum gas flows at 625° C. Gamma values were between 0.923 and 1, indicating a highly efficient reaction.

Stage 3 aimed at studying the effects of the O-atom on the reaction by using a microwave discharge to dissociate the oxygen molecule. Only 1 sample was successfully oxidized due to time limitations. A sample oxidized under the same conditions minus the discharge revealed that no apparent change between the two runs existed. This could be due to a number of reasonable causes such as the upstream pressure being too high for the discharge to work efficiently, but further testing is required to conclude anything.

Ultimately we met several of our goals and were in good shape. We tested a large volume of samples, and though not every one of them yielded good results, we trust that the rest of what we have is a reliable set of data for NASA Ames to employ."

Sage Doshay (University of California, Santa Cruz, CA)
Mentors: Dr. Gregory Faris

Title: Stimulated Scattering Measurements in Supercritical Fluids.

"During my first week at SRI, I attended orientation, was introduced to the experimental setup, and read SOPs and the manuals of several key components of the optical setup. Over the following two weeks I learned how to align the various components of the setup and worked on them. We then realized that many of the components were not well attached to the optical table that the experiment sits on, and as a result were not remaining aligned. We fixed this and went about the major realignment that was then necessary. In addition, we decided to replace some parts and worked out what was needed, ordered it, and installed the pieces. At the end of my third week I took two fiber optic parts to be repaired, and brought them back after the 4th of July vacation. I reinstalled these parts and continued working on the alignment of the setup. I also helped to install a new part of the setup, the acousto-optic modulator, along with its signal generator and power supply.

I was then given several LabVIEW VIs that had been used to control the experiment in the past and tried to understand what they were doing when I had time. While Greg was away, I read a great deal about LabVIEW, working through its tutorials. Once I had a better grasp on the language, I was able to go through the VIs that had been given to me and understand how they worked. After Greg returned we found a laptop that had LabVIEW 6.1 installed on it and hooked it up to the necessary detector and oscilloscope. I then spent several days doing final setup of the experiment and running the VI, trying to use its feedback to get the two relevant laser beams to overlap. At one point I thought they had and I collected and processed some data, only to discover that it was most likely just noise.

We then decided to add some amplifiers to the setup for the signal passing from the signal generators to the acousto-optic and electro-optic modulators. I tested the proposed amplifiers with a signal generator and a temporary power supply to help us determine which we should use. We then needed a permanent power supply for the amplifiers, and one or two broke on us until we were able to borrow one from another setup in the lab. Things seemed to be working well for a few hours, but then all signal disappeared and we realized that the acousto-optic modulator's signal generator was inexplicably no longer working. I contacted the appropriate people at its manufacturer and saw to having it shipped back for examination and repair or replacement. Around this time I prepared and gave my final presentation.

After this, we found another signal generator that could work in the meantime, installed it, and spent time deciding what the best configuration of power from signal generators, amplifiers, and attenuators was appropriate so that no equipment would be damaged but we would get the desired signals. We also tested some amplifiers for the detector that we thought might have been damaged, found them to still be working, and reinstalled them. We tried again to get a signal from the experiment after putting both laser beams through a pinhole to be sure that they were overlapping as necessary and were very confused as to why we weren't getting any signal. We decided to try to reflect the non-detected beam into the detector as well and set their signal generators at slightly different frequencies to try to diagnose the problem, since in this case we should just get the beat frequency between the two beams. We did, but the signal was incredibly noisy, sometimes to the point of making it difficult to discern the data. At this point it was decided that there must be excess noise in the laser beams, so we borrowed a camera system that can look at cross-sections of laser beams and evaluate them. I spent a few days reading its manual while we tried to find a PC that would be compatible with the necessary hardware and software. In this time I also cleaned many of the optical components of the experiment. Once we had a PC, I installed the parts and used the camera to look at the laser beam at various locations in the setup. The beam, which passes through many optical and other components, was providing good power but bad modes, which are not useful for our experiment, so I went about realigning relevant parts of the setup to try to improve the laser beam to the point of usability. This took several days and we decided to add some other parts to the setup to minimize the problems we were seeing.

In my final week I worked on more alignment, got in the new parts and helped in incorporating them, and wrote a detailed description of how to use and align various parts of the setup in the hoped that in the future it will take others less time to learn what I have learned over the course of this summer. In addition, I looked for potential replacements for our fiber optic splitter, which was not working well. I also dealt with the final paperwork associated with the end of the program and terminating my position at SRI."

Michael Glaros (University of California, Davis, CA)
Mentors: Drs. Tom Slanger, Kostas Kalogerakis and Jérôme Thiebaud

Title: Laboratory Studies Relevant to the Sodium Emission in the Terrestrial Atmosphere.

"My project this summer involved mostly laboratory experiments concerned with the sodium nightglow in the mesosphere. The source of the sodium is the ablation of meteors that enter the earth's atmosphere. These sodium atoms interact with ozone and other atmospheric species to yield an excited state of sodium that emits light, an important component of the nightglow spectrum. Two bright lines termed the "sodium D-lines" dominate the sodium emission spectrum. It is well known that the D-line intensity ratio is variable with values ranging from 1.1 to around 1.9 with a semiannual oscillation. Previous studies have shown a dependence on the intensity ratio with varying $[O]/[O_2]$. The main goal for this project was to elucidate the relevant mechanisms producing the variability; specifically the effect $[O]/[O_2]$ has on experiments.

First, it was important to make sure that all of our equipment was set up and working correctly; specifically I was involved with assembling and checking the vacuum system for leaks. I installed the gas flow lines and mass flow controllers, set up the detection optics and electronics (photomultiplier tubes, boxcar averager and gated integrator, etc.) and also learned different techniques for handling and introducing sodium in the experiment. There were some complications with the oxidation of the sodium sample preventing us from seeing any emission. The next step will be to use 193 nm radiation to photodissociate the oxides.

During the last few weeks of the summer I was involved with some data analysis of laboratory data for $O(^1D)$ relaxation by $O(^3P)$ atoms gathered from a previous REU student. I was able to determine the rate constants for collisions of $O(^1D)$ with $O(^3P)$ and $O(^1D)$ at room temperature. These results are relevant to the atomic oxygen red line emission observed in the terrestrial upper atmosphere."

Alexandra Pincus (Scripps College, Claremont, CA)
Mentors: Drs. Sanhita Dixit and Gregory Faris

Title: Using Fluorescein to Assess the Proton Permeability of Droplet Lipid Bilayers.

"Project Goals:

1) Establish the effectiveness of fluorescein dye as a pH indicator in PBS buffer solution. Solidify an easily reproducible procedure for the creation of uncontaminated lipid bilayers in mineral oil.
2) Justify the use of fluorescein as a valid measure of pH in a droplet-droplet bilayer system
3) Use fluorescein to measure the proton permeability of droplet lipid bilayers (DLB).
4) Demonstrate successful integration of α-hemolysin transmembrane protein into such a bilayer based on the change in proton permeability.

Learn new laboratory techniques and familiarize myself with a range of lab equipment and computer programs, such as:

- Spectrophotometer and SpectraSuite
- Light Microscope/ Laser/ Mercury lamp setup with LabView
- Buffers (taking into consideration pH, concentrations, ionic strength)
- pH meter – setup, calibration, cleaning, utilization

Summary of Work Done this Summer:

Two weeks were spent reading articles and background information on the project, the system, the probe, the lipids and permeability in general, and preparing buffer solutions and instrumentation. Phosphate Buffered Saline (PBS) was made acidic or basic by the addition of HCl or NaOH respectively, and was used as the buffer for all the experiments. Fluorescein dye's absorbance at pH values varying from 6 to 8 was estabilished using a spectrophotometer, and found to follow an expected pattern based on prior literature. A picture of the fluorescence intensity of two fluorescein-containing drops at different pH values was taken under a mercury lamp (Figure 1), and analysis revealed a clear difference in intensity between them. Together, these data support the claim that fluorescein is an effective pH indicator in a PBS/Mineral oil DLB system. Fluorescein and DphPC lipid stocks of known concentration were made. Two days were spent practicing the optical manipulation technique necessary for forming bilayers between droplets. Techniques for cleaning the petri dish and moving the drops without causing the water to boil were estabilshed, and a reproducible method for making clean lipid bilayers in a clean petri dish was found. Initial tests for proton permeability were carried out between a drop of pH 6 and one of pH 8. All personal goals were completed. To the list of aquired lab techniques should be added Image J analysis, liposome preparation, and troubleshooting equipement and experiments. I am very happy with the vast amount that I did get to learn and do."

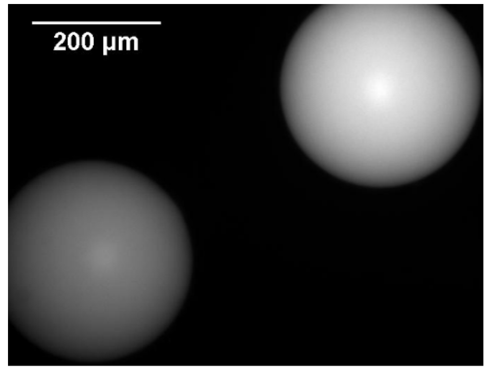

Figure 1: Fluorescein in buffer droplets immersed in mineral oil.

Data from experiments performed during the summer are currently being analyzed and will be part of a future publication.

Eric Schiesser (University of Rochester, Rochester, NY)
Mentors: Drs. Tom Slanger and Riccardo Melchiorri

Title: CESAR: Compact Echelle Spectrograph for Aeronomy Research

"CESAR is a spectrograph which has been designed from the ground up to be portable and powerful. Its intended use is to provide aeronomers with a high resolution, large pass-band, and portable spectrograph for studying nightglow, dayglow, aurora, and other energy emissions in the upper atmosphere. Over the summer, I assisted in the design and construction of certain elements of CESAR. In June and early July, I focused mainly on the digital model of the Fore-Optics (FO), the light collecting telescope-like optics of the system. The goal was to perform a tolerance analysis of the FO in the optical design software ZEMAX. Using this software, I was able to determine that the uncertainties in our construction of the FO did not affect the performance of the optics appreciably, and therefore the current design for each of the FO lens configurations was within spec and was constructible. This allowed us to confidently order the FO lenses and lens tubes.

In late July and early August, I began combining the FO configurations with the rest of the main optics to create an optical model of the whole system in ZEMAX. Once I had a working model, I began to investigate how the system behaved at each of the three different bandwidths (exposures). This essentially involved looking at the projection of the slit on the detector. The purpose of this was to ensure that the spectral orders were not overlapping on the detector, essentially ensuring that we could resolve the orders. By looking at the pattern on the detector, I also determined which spectral lamp would be best to calibrate CESAR by looking at where the emitted wavelengths appear on the detector.

Mid-August was spent assembling the support structure. This included placing the struts, nodes, adaptive plates, linear stages, the Off Axis Parabolic Mirror, and the Echelle diffraction grating and cross disperser casings. Each of these pieces needed to be placed with <0.5 mm precision. During my last week, I was able to place the diffraction gratings into their casings. This involved wearing gloves and hairnets to protect the surfaces, and working inside of the optical facility."

SRI's Molecular Physics Laboratory: REU Program Activities

Regular meetings with the REU students were scheduled to gauge student progress and address any concerns. In addition, several activities were included in the 12 week program to provide a well-rounded REU experience.

1. Seminars

Several opportunities exist for the REU students to attend seminars on the SRI campus. Besides the staff at the Molecular Physics Laboratory (MPL), staff members from across the campus routinely give seminars. In addition, there are invited speakers visiting the campus as well. For example, SRI is the venue for seminars hosted under the Café Scientifique Silicon Valley initiative (http://www.cafescipa.org). Below, is a list of seminars attended by the REU students during the summer of 2010.

Date	Time	Seminar Title and Speaker
6-8-2010	6:00-7:30 pm	*This is your brain on money* Brian Knutson, Ph.D. Associate Professor of Psychology & Neuroscience Stanford University
6-14-2010	1:00-2:00 pm	*BCI for Everyone- Consumer-oriented Brain-Computer Interface Technology* KooHyoung Lee, Ph.D. Chief Technology Officer NeuroSky, Inc.
6-18-2010	12:00-1:00 pm	*Cavity Ring-Down Spectroscopy Coupled to Laser Photolysis: i) Spectroscopy and Kinetics of the Radical HO_2 and ii) Relevance to Aeronomy* Jérôme Thiebaud, Ph.D. Postdoctoral Fellow, MPL, SRI International
6-23-2010	11:00-12:00 am	*Reaction Dynamics of Vibrationally Excited CH3D Molecules with Chlorine* Christopher Annesley University of Wisconsin-Madison
6-25-2010	10:30-11:30 am	*Femtomolar Isothermal Desorption and Reaction Kinetics on Microhotplate Sensor Platforms* Amol Shirke, Ph.D. University of Maine.
6-25-2010	10:00-11:00 am	*Optogenetic Control of Arousal* Luis de Lecea, Ph.D.

		Associate Professor Department of Psychiatry and Behavioral Sciences Stanford University School of Medicine
8-10-2010	6:00-7:30 pm	*Stem Cells & Regenerative Medicine* Jill Helms, Ph.D. Professor - Department of Surgery Stanford University
8-12-2010	11:00-12:00 am	*A Cubic Mile of Oil - Realities and Options for Averting the Looming Global Energy Crisis* Ripudaman Malhotra, Ph.D Associate director of the Chemical Science and Technology Laboratory SRI International

2. Student Presentations

All the students presented their work at the end of the summer. Each presentation lasted 20 minutes with 10 minutes reserved for questions from the audience. Below is the presentation schedule for the summer of 2010.

Date	REU Student	Seminar Title
8-16-2010	Alejandro Ceballos	Oxidation of Graphite Materials Relevant to the Thermal Protection Systems of Re-entering Spacecraft.
8-16-2010	Alexandra Pincus	Using Fluorescein to Assess the Proton Permeability of Droplet Lipid Bilayers.
8-16-2010	Aaron Buikema	Nanoliter-Droplet Generation and Locomotion.
8-17-2010	Eric Schiesser	Compact Echelle Spectrograph for Aeronomy Research: A Digital Model.
8-17-2010	Sage Doshay	Stimulated Rayleigh Scattering in Fluids.
8-17-2010	Michael Glaros	Laboratory Studies Relevant to the Sodium Emission in the Terrestrial Atmosphere.

3. Academic/Industrial Visits in 2010

Each REU student gave a brief oral overview of his or her project to fellow students in an organized lab tour within the MPL. The students got a chance to see how experiments were performed or computational analysis done on data obtained from the lab. The students also visited local Silicon Valley companies to get a unique perspective on research environments in a company setting. This year, the students expressed an interest in visiting labs that were engaged in energy research, hence the choice of Codexis, and the Joint Bioenergy Institute.

a) On June 29th, the REU students visited Codexis (http://www.codexis.com/); a Silicon Valley biofuels company based in Redwood City, CA. Dr. Dayal Saran, a scientist at Codexis, hosted the students. The students got a tour of the entire facility, and were given a presentation by scientists at Codexis, detailing the technology platform of the company. The students also got an opportunity to see various instruments used by the research and development staff.

b) On July 21st, The REU students had a day long visit to the Joint Bioenergy Institute (JBEI), one of three, U.S. Department of Bioenergy Research Centers (BRCs). It is based in Emeryville, CA and is a San Francisco Bay Area scientific partnership led by the Lawrence Berkeley National Laboratory (Berkeley Lab) and includes the Sandia National Laboratories (Sandia), the University of California (UC) campuses of Berkeley and Davis, the Carnegie Institution for Science, and the Lawrence Livermore National Laboratory (LLNL). Dr. Joshua Heazlewood, Director of Systems Biology at JBEI and postdoctoral fellow, Dr. Michelle Smith hosted the students. The tour introduced the students to the entire facility. Of particular interest were the greenhouse where some plant species were grown and the optical instruments that were used for research and analysis in the Systems Biology group including the fluorescence microscopes used to do Fluorescence Lifetime Imaging Microscopy studies and the spectrometers used to do Fourier transform infrared spectroscopy.

c) On July 22nd, the REU students visited the IBM Almaden Research Center in San Jose, CA, for a day long ‘Career Day’ event hosted by the Center on Polymer Interfaces and Macromolecular Assemblies (CPIMA), an NSF sponsored partnership among Stanford University, the IBM Almaden Research Center, the University of California at Davis and the University of California at Berkeley. This invitation was extended to us by Dr. Kristin Black, the education director of CPIMA. The event included three panels with speakers from varied backgrounds in science and technology. The students also got an opportunity to tour various labs at IBM that were hosting students in the summer. The agenda for the event is presented below.

CENTER ON POLYMER INTERFACES AND MACROMOLECULAR ASSEMBLIES
A STANFORD/IBM ALMADEN/UC DAVIS/UC BERKELEY PARTNERSHIP
STANFORD UNIVERSITY, STANFORD, CALIFORNIA 94305-5025

CPIMA CAREER DAY
IBM Almaden Research Center

July 22, 2010
Auditorium B

9:15-9:45 am Registration and Continental Breakfast

9:45-10:00am Opening remarks and Introduction to IBM ARC
Chuck Wade, Co-Director, CPIMA

10:00-11:30am Panel #1: Teaching
John Allen, Teacher, Oak Grove High School
Amelia Fuller, Assistant Professor, Santa Clara University
Marc d'Alarcao, Professor, San Jose State University
Thomas Jaramillo, Assistant Professor, Stanford University

11:30-12:00pm Tour IBM labs, set #2

12:00-1:00pm Lunch (provided) / Talk to members of panel #1

1:00-2:30pm Panel #2: Industry
Luisa Bozano, IBM Almaden Research Center
Rachel Kurtz, Clorox Company
Michelle Poliski, Solyndra
2:30-2:45pm Break / Talk to members of panel #2

2:45-4:15pm Panel #3: Nontraditional
Kathleen Gust, Engineering Librarian, Stanford University
Tony Svensson, Executive Director of North America Invest Sweden
Robby Beyers, Morgan, Lewis & Bockius LLP
Michael Ross, Freelance Science Writer

4:15-4:30pm Break / Talk to members of panel #3 / Evaluation surveys

4:30-5:00pm IBM lab tours, set #2

4. Ethics Training

This year, we started a formal mechanism to train the students in the ethics of scientific research. As part of this training, the students were required to take an online course to educate themselves about ethics in a research environment. The online course is available freely at:
http://ori.dhhs.gov/education/products/montana_round1/issues.html#intro.

The study of the following three sections was mandatory; Section One: Ethical issues in Research, Section Two: Interpersonal Responsibility, and Section Four: Professional Responsibility. At the end of their study of each section, this website provided a test. The students were asked to take the test and furnish copies of their scores to Dr. Sanhita Dixit.

5. Social Events

The students organized several outings on their own over the summer. They also visited the California Academy of Sciences, a world-class scientific and cultural institution based in San Francisco. The Academy recently opened a new facility in Golden Gate Park which houses an aquarium, a planetarium, a natural history museum and a 4-story rainforest all under one roof. SRI International provides discounted tickets to its employees and the students availed of this opportunity.

The students also attended the bi-weekly pay day coffee meetings in the MPL. The institute also hosted the students at a New Staff Luncheon, during which the students were able to interact with the CEO of SRI International.

A farewell celebration was hosted by the lab for the REU students just before the end of the 12 week program.

6. James R. Peterson Award for Excellence in Undergraduate Education

This award is given to the REU student who best combines technical excellence with a spirit of friendliness and cooperation. The award was established in the MPL in 2006 and is dedicated to the memory of James R. Peterson; the first hire into SRI International's newly formed Molecular Physics Laboratory in 1956. The decision for the award is based on the nominations of the students at the end of the summer. The award recipient for 2010 was Alejandro Ceballos (Northern Arizona University).