

## SRI REU 2005 Student Projects and Program Activities



**REU 2005 Students at SRI's Molecular Physics Laboratory**

### **Project Descriptions**

**Alana Celia (Linfield College)**

**Mentors: Drs. Gregory Faris and Jeanne Haushalter**

#### ***Surface Enhanced Lanthanide Luminescence for Bioassays***

We are studying surface enhanced lanthanide luminescence as a novel method for performing bioassays. For this approach, proximity between a noble metal nanoparticle and a lanthanide ion leads to a very large enhancement in lanthanide luminescence, by one or more orders of magnitude. The enhancement occurs from the enhanced electric fields produced by the oscillation of free electrons on the metal nanoparticle, called the surface plasmon resonance. By coupling one probe molecule to the nanoparticle and another to an organic ligand holding the lanthanide, one can detect when the two probes are brought close to each other. In this way, we can examine molecular interactions or identify the presence of specific molecules such as

proteins or DNA. We have shown that surface enhancement can be quite large for lanthanide ions that are not ordinarily good light emitters. Measurements were performed on silver island films with and without a spacer layer produced with spin coating. A large increase in radiative rate was confirmed using time-resolved fluorescence measurements.

**Kristina Closser (Smith College)**

**Mentor: Dr. Konstantinos Kalogerakis**

*O(<sup>1</sup>D) Relaxation by O(<sup>3</sup>P)*

Laboratory experiments were performed investigating the relaxation of O(<sup>1</sup>D) by O(<sup>3</sup>P) atoms. Rate coefficients for this process have appeared in the literature deduced from atmospheric observations and theoretical calculations that differ by more than an order of magnitude. No previous laboratory measurement of the rate coefficient has been reported, despite its importance in determining the energy flow in the upper atmosphere and controlling the intensity of atomic oxygen emissions. In the experiments, the 157-nm output of a fluorine laser photodissociated molecular oxygen to O(<sup>1</sup>D) and O(<sup>3</sup>P) atoms. Detection of the 630-nm emission monitored the temporal evolution of the O(<sup>1</sup>D) concentration. The experiments determined the rate coefficient at room temperature. The O(<sup>1</sup>D) relaxation by O(<sup>3</sup>P) atoms is very efficient and needs to be accounted for in atmospheric models. Kristi presented her project's results at the 2005 Fall Meeting of the American Geophysical Union in San Francisco, CA in December 2005.

**Patricia Engel (University of Notre Dame)**

**Mentor: Dr. Konstantinos Kalogerakis**

*Spectroscopic Characterization of Ammonia Ices Relevant to Jupiter's Atmosphere*

Observational evidence and thermochemical models indicate an abundance of ammonia ice clouds in Jupiter's atmosphere. However, spectrally identifiable ammonia ice clouds are found covering less than 1% of Jupiter's atmosphere, notably in turbulent areas [Icarus 159, 74 (2002)]. This discrepancy highlights an important gap in our understanding of ammonia and its spectral signatures in Jupiter's atmosphere. Current literature suggests two possible explanations: coating by a hydrocarbon haze and/or photochemical processing ("tanning"). We have been performing laboratory experiments that investigate the above hypotheses. Thin films of ammonia ices were deposited in a cryogenic apparatus, coated with hydrocarbons, and characterized by infrared

spectroscopy. The ice films can also be irradiated by ultraviolet light. These spectroscopic measurements aim to identify the photophysical and chemical processes that control the optical properties of the ice mixtures and quantify their dependence on the identity of the coating, the temperature, and the ice composition. Our current results indicate a consistent suppression of the ammonia absorption feature at 3  $\mu\text{m}$  with coverage by thin layers of hexane, cyclohexane, and benzene. Furthermore, strongest suppression is observed in the case of benzene, followed in magnitude by hexane and cyclohexane. Pat presented her project's results at the 2005 Fall Meeting of the American Geophysical Union in San Francisco, CA in December 2005.

**Ashley Gibbs (Whitworth College)**

**Mentor: Dr. Gregory Faris**

### **Optical Imaging for Cancer Detection**

Light in the near-infrared portion of the electromagnetic spectrum passes fairly readily through human tissue, particularly in the spectral region from 700 to 1300 nm, or the tissue window. This is of interest because by using optical spectroscopy one can derive information on chemical composition and tissue function to an extent not possible with other in vivo imaging techniques. We are examining methods for cancer detection based on in vivo optical imaging. Our current project uses the unusual behavior of the blood vessels in tumors to enhance cancer detection. To allow their own growth, tumors create blood vessels through a process called angiogenesis. These vessels are generally tortuous and leaky and have vasoactive response that differs from ordinary vessels. This unusual behavior provides a means for improved cancer imaging using light. Our recent work includes improvement in the sensitivity of the imaging system, measurements in rats as well as mice, and modifications of the system to perform human imaging.

**Student from Santa Clara University**

**Mentor: Dr. Harald Oser**

### ***Detection of Explosive Compounds Using Laser Ionization Mass Spectrometry***

We performed proof-of-concept experiments with a state-of-the-art short pulse laser system used to study photoionization processes of explosives in combination with a time-of-flight mass spectrometer. The results provided a preliminary validation of the proposed concept that a

femtosecond (fs) laser ionizes nitro compounds before they dissociate almost completely into NO. With the fs approach she found parent molecule ions and a few fragment ions, which could be used for structural identification. We investigated the wavelength dependence of photoionization and photodissociation processes involving these molecules and determined detection limits for these molecules. The results were submitted to the 2006 Conference on Laser Applications to Chemical, Security and Environmental Analysis. This research project was supported by a grant from NSF's Major Research Instrumentation Program.

**Amos Irwin (Amherst College)**

**Mentor: Dr. Harald Oser**

***Analysis of Liquid Samples by Direct Laser Ionization***

Amos performed scientific studies with a state-of-the-art pulsed laser system investigating photoionization processes in aqueous samples containing air pollutants, explosives, and chemical agents in combination with a time-of-flight mass spectrometer. During the course of his project Amos worked with a complex laser system, time-of-flight mass spectrometer, and associated equipment. He characterized a membrane based inlet system for the mass spectrometric analysis of aqueous samples, applied different laser based ionization methods for the detection of contaminants in water, determined and analyzed mass spectra of a wide variety of molecules as well as determined detection limits. The results were submitted to the 2005 Fall Meeting of the American Geophysical Union, the 2006 Conference on Laser Applications to Chemical, Security and Environmental Analysis, the 25<sup>th</sup> Semiconductor Pure Water and Chemicals Conference.

**Francisco Robles (North Carolina State University)**

**Mentor: Dr. Gregory Faris**

***Stimulated Scattering Measurements in Supercritical Fluids***

When intense light from a pulsed laser interacts with matter, the light can elicit a nonlinear optical response. One type of nonlinear optical response is stimulated scattering, in which the intense light causes a tremendous increase in the amount of scattered light from atoms or molecules. We use stimulated scattering to measure inherent properties of matter including chemical properties (using stimulated Raman scattering from vibrational and rotational modes), elastic properties (using stimulated Brillouin scattering from acoustic modes) and thermal

properties (using stimulated Rayleigh scattering from thermal modes). We have recently modified our apparatus to enable measurements with much narrower spectral resolution. We have developed a new laser system to amplify narrowband light from a diode-pumped Nd:YAG laser in a two-stage double-pass amplifier. The light from an external cavity diode laser has been amplified with a fiber amplifier and used as both the source light for the pulsed amplifier and a probe beam. This new light source should allow high spectral resolution measurements with very high sensitivity.

**Colin Rogers (Vanderbilt University)**

**Mentor: Dr. Jochen Marschall**

***Oxidation of Refractory Ceramics in Dissociated Oxygen***

In this project we measured the oxidation rates of various refractory materials exposed to atomic oxygen. Oxidation is a primary factor limiting the use of refractory materials in high temperature oxygen-bearing gas environments. In some extreme aerothermal environments, as encountered at the leading edges of spacecraft during atmospheric entry or by components tested in arc-jet test facilities, a significant fraction of the oxygen-bearing molecules are dissociated. Oxidation by atomic-oxygen can be much more aggressive than by molecular oxygen.

We used a high-power microwave discharge to generate dissociated gas streams and directed these reactive gas streams over samples heated in a tube furnace to different temperatures. Experiments documented the oxidation behaviors of the silica formers Si, SiC, and Si<sub>3</sub>N<sub>4</sub>. In addition, the gas temperature, pressure and flow rates were systematically measured at different microwave discharge powers, to characterize the performance of the discharge and the transport behavior in the oxidizing flow. Oxidized samples were examined at SRI using electron microscopy and energy dispersive X-ray analysis, as well as by spectral ellipsometry and Rutherford backscattering by our collaborators at Vanderbilt University. Experiments confirmed greatly accelerated oxidation rates in the presence of atomic oxygen on all three materials. The results were presented at the 2005 AFOSR Ceramics Program Review meeting in Sedona, AZ in August 2005.

**Octavi Semonin (Harvey Mudd College)**

**Mentors: Dr. Gregory Faris**

***Optical Microfluidics***

We are developing a new method for moving very small volumes of fluid using light. This approach may be used for performing reactions and assays on a very small scale, the so-called “lab-on-a-chip”. The droplet motion is produced through surface tension gradients produced by laser heating, a phenomenon called the thermal Marangoni effect. This force is can be several of orders of magnitude stronger than the conventional optical trapping force. Surrounding the droplets with a second fluid (decanol) facilitates droplet motion and minimizes evaporation. This approach can be used to move droplets covering 6 orders of magnitude in volume, from ~1.7  $\mu\text{L}$  to 1.7 pL. Droplet speeds of up to 3 mm/s have been achieved. We have applied this technique to performing a simple chemical assay using horseradish peroxidase, demonstrating detection limits near zeptomoles of the enzyme. Most recently, we have used the optical microfluidic method to locate liquid samples to silicon substrates. To obtain appropriate conditions for droplet motion on silicon, we spin coated a thin polymer layer onto the silicon. Smaller droplets were prepared by allowing droplets to dissolve in a surrounding solvent.

**Kara Mann (Vanderbilt University)**

**Mentor: Dr. Jochen Marschall**

***High-Velocity Impact Resistance of Ultra-High Temperature Ceramic (UHTC) Materials at Low and High Temperatures***

In this project we explored the high-velocity impact resistance of the UHTC materials  $\text{ZrB}_2/\text{SiC}$  and  $\text{HfB}_2/\text{SiC}$ . UHTC materials and coatings are under development for the leading edges of hypersonic flight vehicles. As demonstrated by the recent Shuttle disaster, high-velocity impacts are a major concern for leading edges, because leading edges are exposed to the most extreme aerothermal environments and directly influence vehicle flight characteristics.

Experiments were conducted using a compressed gas gun facility to fire tungsten carbide spheres with diameters of 800 microns at speeds of 100 to 300 m/s at room temperature. Impact velocities were measured using a photodiode array. We also conducted preliminary experiments with samples cooled down to dry ice/alcohol temperatures (~195 K). The resulting impact

damage on the UHTC surfaces - the residual impression and cracking pattern - was characterized by optical and electron microscopy. Both ring crack formation and radial crack formation were observed, with very shallow residual impressions, indicating that the UHTC materials respond in a classically brittle manner to impact loading. Kara's results were presented at the 2005 AFOSR Ceramics Program Review in Sedona, AZ in August 2005. She is also included on a poster to be presented at The 30th International Conference and Exposition on Advanced Ceramics & Composites in January 2006 at Cocoa Beach, Florida. A grant from the NSF Ceramics Program and an SRI Academy Scholarship supported Kara's research.

**Allison Widhalm (University of Southern California)**

**Mentors: Drs. Brian Sharpee and Tom Slanger**

*Analysis Of Data From The Keck 10-Meter Telescopes*

Large ground-based astronomical telescopes simultaneously record light from stellar objects and from the earth's nightglow, a faint emission that originates with the chemistry of the upper atmosphere. Astronomers find this glow to be an annoyance, and do their best to make it go away, but in fact it contains an enormous amount of information on atmospheric processes, and is proving to be a valuable resource to aeronomers studying the atmosphere. We take advantage of the superb tools used by the astronomers to obtain the highest quality spectra ever obtained of the night sky. These spectra contain emissions from oxygen atoms and molecules, nitrogen atoms, sodium, potassium, and OH. The OH emission is intense, and its study is important, as it relates to atmospheric temperature, chemistry, spectroscopy, and dynamics.

In addition, the large telescopes have been used to study the atmosphere of Venus, and we have found both similarities and differences in the emission from the two environments, with the common thread being emission from oxygen atoms and molecules. We study the various emissions from both the earth and Venus to learn how the atmosphere changes in an hour, a night, a season, and a solar cycle. Work on this project involves learning how to handle the data files, and represents a unique opportunity to explore our environment as made accessible by the world's largest telescopes. A grant from NSF's Planetary Astronomy Program (REU supplement) supported Allison's research.

## Program Activities

1. Tutorial Seminars
2. Student Presentations
3. Academic/Industrial Visits
4. Social Events

### 1. Tutorial Seminars

The REU program at the Molecular Physics Laboratory has weekly meetings throughout the summer. During the first half of the summer, the SRI staff or guest speakers present a series of 45-minute seminars. The following is the schedule of tutorial seminars for the summer of 2005:

| Date    | Time     | Speaker                                    | Seminar Title                                                                                                 |
|---------|----------|--------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| June 9  | 11:00 AM | Dr. David Huestis<br>(SRI)                 | Earth, Venus, Mars, and the Greenhouse Effect                                                                 |
| June 17 | 4:15 PM  | Dr. Elizabeth Gerken<br>(SRI)              | Remote Sensing of the Upper Atmosphere by HF-Induced Airglow                                                  |
| June 24 | 10:30 AM | Dr. Gregory Faris<br>(SRI)                 | Topics in Biomedical Optics                                                                                   |
| July 5  | 10:00 AM | Dr. Sanhita Dixit<br>(UC Davis / SRI )     | Molecular Interactions: Simple Concepts, Complex Manifestations                                               |
| July 8  | 10:30 AM | Dr. Tom Slanger<br>(SRI)                   | Aeronomy by Astronomy                                                                                         |
| July 12 | 11:00 AM | Dr. Abneesh Srivastava<br>( LLNL/SRI/SCU ) | Real-Time Detection and Characterization of Individual Bioaerosol Particles with Bioaerosol Mass Spectrometry |
| July 21 | 11:30 AM | Dr. Laura Mazzola<br>(CEO, Excellin)       | Presentation of Excellin Life Sciences                                                                        |
| July 27 | 10:30 AM | Professor Eugene Chiang<br>(Berkeley)      | Puzzles and Prospects in Planetary Systems                                                                    |
| July 29 | 2:00 PM  | Dr. Ben Rusholme<br>(Stanford)             | The Cosmic Microwave Background Radiation                                                                     |



## 2. Student Presentations

All the students present their work at the end of the summer. These presentations last approximately 20 minutes, with an additional 10 minutes reserved for questions and discussion.

The following is the schedule of student presentations for the summer of 2005:

| Date      | Time     | REU Student                         | Seminar Title                                                                                         |
|-----------|----------|-------------------------------------|-------------------------------------------------------------------------------------------------------|
| July 21   | 10:30 AM | Kara Mann                           | Impact Resistance of Ultra-High-Temperature Ceramic Material and Damage Characterization              |
| August 5  | 10:00 AM | Patricia Engel                      | IR Spectroscopy of Ammonia-Hydrocarbon Ice Films Relevant to Jupiter's Atmosphere                     |
| August 5  | 10:30 AM | Colin Rogers                        | Oxidation of Silica Formers with O <sub>2</sub> /O-atoms at High Temperature and Low Pressure         |
| August 8  | 11:00 AM | Ashley Gibbs                        | Optical Imaging for Cancer Detection                                                                  |
| August 8  | 11:30 AM | Octavi Semonin                      | Optical Microdroplet Manipulation with Near-IR Light                                                  |
| August 9  | 11:00 AM | Student from Santa Clara University | Detection of Explosive-Like Compounds Using Mass Spectroscopy                                         |
| August 9  | 11:30 AM | Francisco Robles                    | Stimulated Scattering Measurements in Supercritical Fluids                                            |
| August 10 | 10:30 AM | Kristina Closser                    | Processes Important in the Terrestrial Upper Atmosphere: Collisional Deactivation of O(1D) by O Atoms |
| August 10 | 11:00 AM | Alana Celia                         | Surface Enhancement of Lanthanide Chelates                                                            |
| August 27 | 11:30 AM | Amos Irwin                          | Single-Photon Ionization Time-of-Flight Mass Spectroscopy                                             |

### **3. Academic / Industrial Visits**

- a) On June 23, we toured SRI's Engineering Group and had an introduction to SRI's artificial muscle, telepresence control for surgery and experiments performed in space, and diamagnetic levitation technologies (host: Roy Kornbluh)
- b) On July 7, Dr. Christophe Lecuyer, a historian of science and technology at the Chemical Heritage Institute, Philadelphia, PA, had lunch with the students and led a discussion on the history of Silicon Valley. The students also had the opportunity to watch excerpts from a DVD on the pioneers of Silicon Valley entitled "The Fairchild Chronicles" the following week.
- c) On July 21, we had lunch with Dr. Laura Mazzola who shared with us her experiences from graduate studies in physical chemistry, to employment as an R&D scientist, followed by her transition to management. Dr. Mazzola is currently the CEO of Excellin Biosciences, a biotechnology start-up company in the San Francisco Bay Area.
- d) On July 29, we had a tour at the Stanford Linear Accelerator Center in the morning, followed by a visit at the Stanford Physics Department and a tour of the laboratory of Prof. Sarah Church (hosted by Dr. Benjamin Rusholme).
- e) On August 1, we were hosted at Vitex Systems Inc., a Silicon Valley company developing barrier technologies for Organic Light Emitting Diode Displays. Dr. Lorenza Moro, Director of the Encapsulation Technology, and her group gave us a presentation of the company and a tour of the company facilities. The students also gave each a brief slide presentation of their summer projects to the group of Vitex scientists.
- f) On August 22, Drs. Regis Vincent and Benoit Morisset from SRI's Artificial Intelligence Center introduced us to the robotics technologies they are developing and we witnessed a live robot test for a project.

### **4. Social Events**

Besides several weekend outings and activities the students organized on their own, MPL hosted the annual summer pool party at the Huestis residence, birthday parties for the students who had their birthdays in the summer, various "happy hour" and pizza lunches, payday bagel meetings, and a farewell gathering. In addition, the students attended several SRI events (e.g., New Staff luncheon, meeting with SRI's CEO, SRI Summer BBQ, etc.).