

Molecular Physics Lab REU Students 2003



REU Participants (from left to right): Kyle Noble, Michael Weiss, Kristin Phillips, Jude Kessler, Allison Widhalm, William Boenig, Katy Briggs, Lauren Johnson

William Boenig

Student from Santa Clara University

Mentor: Dr. Gregory Faris

Project: **"Optical Imaging for Cancer Detection"**

Light in the near infrared portion of the electromagnetic spectrum passes fairly readily through human tissue, particularly in the region from 700 to 1300 nm, or 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. Tasks completed during this summer included design and construction of an improved light-emitting diode (LED) array light source, improvement and simplification of the frequency domain system, construction of a temperature control system, and application of these systems to an animal cancer model.

Katy Briggs

Student from the Pacific Lutheran University

Mentor: Drs. Harald Oser and Michael Coggiola

Project: **“Real-Time Detection of Hazardous Air Pollutants Using a Compact Laser Ionization Mass Spectrometer”**

During the course of the project the student helped to set-up a new compact laboratory prototype instrument based on laser-mass-spectrometry to measure trace levels of Hazardous Air Pollutants (HAPs). This real-time continuous emission monitor (CEM) combines a pulsed gas jet with resonance enhanced multi-photon ionization (REMPI) and time-of-flight mass spectrometry (TOFMS). After setting up the instrument we performed successful shake up tests in order to evaluate the performance of the new instrument

Lauren Johnson

Student from the University of North Carolina

Mentor: Dr. Philip Cosby

Project: **“Dissociative Recombination Products of O_2^+ on Mars and Venus”**

Dissociative recombination (DR) is the primary mechanism for electron loss in the atmospheres of Mars and Venus. Within these atmospheres, oxygen is the most abundant molecular ion and is produced in a wide range of vibrationally excited levels by the reaction of atomic oxygen ions with carbon dioxide. However, laboratory knowledge of oxygen DR is limited to only the ground vibrational level. The purpose of this project is to characterize O_2^+ DR for vibrationally excited levels.

A high-pressure electron-impact ion source is used to create the O_2^+ ions in a particular distribution of vibrational and rotational levels. This distribution produced by the ion source is characterized by translational energy spectroscopy using cesium vapor dissociative charge transfer (at SRI) and the DR cross section for that distribution is measured at the heavy-ion storage ring facility CRYRING (at MSL). By making these measurements with a wide variety of distributions, the DR cross sections for the individual vibrational levels are fully determined. This summer, the student measured the vibrational distributions created by the ion source used for the December 2002 DR measurements at CRYRING and participated in making modifications to the ion source to make it more efficient for future DR measurements.

Jude Kessler

Student from Trinity College

Mentor: Drs. Harald Oser and David Crossley

Project: **“Laboratory Studies of Explosives Using Laser Ionization Mass Spectrometry”**

The REU student learned to operate a laboratory prototype instrument, based on laser-mass-spectrometry. The instrument combines a pulsed gas jet with resonance enhanced multi-photon ionization (REMPI) and time-of-flight mass spectrometry (TOFMS).

We conducted and performed studies on the REMPI spectroscopy of explosives. We also measured explosives at very low concentrations in the laboratory. This project was fundamental research work, with the ultimate goal of land mine detection.

Kyle Noble

Student from St. Mary's University

Mentor: Dr. Gregory Faris

Project: **"Optical Microfluidics"**

A compelling need currently exists for rapid and inexpensive methods of detecting pathogens, diagnosing and prognosticating disease, developing new drugs, and performing genetic analysis. To meet these needs for processing large numbers of samples at high speed (high throughput), considerable interest has been placed on microfluidic devices, also called "lab-on-a-chip." Current approaches to microfluidics have undesirable limitations, including challenges in scaling, difficulty in reconfiguring assays, poor efficiency in sample use, poor interface between the macro- and microenvironments, and considerable complexity of circuitry on the substrate. We are developing a new approach to microfluidics that uses optical control to significantly increase efficiency and flexibility while reducing costs. Tasks performed during the summer included improvement in techniques for droplet dispensing, droplet motion, and droplet fusion.

Kristin Phillips

Student from the University of California, San Diego

Mentors: Drs. Kostas Kalogerakis, Eloy Wouters, and Dusan Pejakovic

Project: **"Laboratory Studies of $O_2(b^1\Sigma_g^+, _ = 1)$ Collisional Removal"**

In the Earth's thermosphere, energy transfer from $O(^1D)$ to O_2 generates oxygen molecules in the $_ = 0$ and 1 levels of the $O_2(b^1\Sigma_g^+)$ state. The emissions in the $O_2(b^1\Sigma_g^+ - X^3\Sigma_g^-)$ system (Atmospheric Band) present a major component of the Earth's airglow. Interpretation of the measured intensities of O_2 Atmospheric Band emissions can yield altitude profiles of oxygen atom density and local temperature in the lower thermosphere. To achieve this goal accurate measurements of the collisional removal coefficients of $O_2(b^1\Sigma_g^+, _ = 1)$ and their temperature dependence are essential. Atmospheric observations suggest that the relevant colliders for the removal of $O_2(b^1\Sigma_g^+, _ = 1)$ in the lower thermosphere are O_2 and $O(^3P)$.

This summer we performed measurements of the rate coefficients for the collisional removal of $O_2(b^1\Sigma_g^+, _ = 1)$ by O_2 , N_2 , and CO_2 , at temperatures in the range 300–1000 K. A state-specific two-laser technique was used, in which the visible pulsed output of the first laser directly excites O_2 to $O_2(b^1\Sigma_g^+, _ = 1)$, and the ultraviolet output of the second laser subsequently probes the $O_2(b^1\Sigma_g^+, _ = 1)$ population by resonance-enhanced multiphoton ionization via the $_ = 4$ level of the $d^1\Pi_g$ Rydberg state. The temporal evolution of the $O_2(b^1\Sigma_g^+, _ = 1)$ population was determined by varying the time delay between the two laser pulses.

The rate of collisional removal of $O_2(b^1\Sigma_g^+, _ = 1)$ by O_2 monotonically increases with temperature from about $1.5 \times 10^{-11} \text{ cm}^3\text{s}^{-1}$ to about $6 \times 10^{-11} \text{ cm}^3\text{s}^{-1}$ in the range 300–1000 K. Experiments with colliders N_2 and CO_2 determined the upper limits for the removal rate coefficients of $O_2(b^1\Sigma_g^+, _ = 1)$ by N_2 and CO_2 to be 2 orders of magnitude smaller.

Michael Weiss
Student from Vanderbilt University
Mentor: Dr. Gregory Faris
Project: **"Upconverting Chelates"**

Upconverting chelates are an unusual type of molecule we have recently discovered. These materials "upconvert" infrared radiation to visible radiation. That is, the emitted photons have higher energy than the absorbed photons. The upconverting chelates function through stepwise infrared excitation of individual lanthanide ions in a chelating ligand. When these molecules are attached to biological probe molecules such as antibodies or DNA probes, very sensitive medical tests may be performed.

The goal of our current research is to better understand and develop the capabilities of the molecular upconvertors through application to *in vitro* immunoassays on tissue sections. Current labels cannot provide both multiplexed assays and archival capabilities in a reasonable fashion. Fluorescent dyes can provide multiplexing, but are not good for archival samples because of photobleaching. Enzyme-based labels are good for archival samples, but cannot perform multiplexed assays well, usually relying on serial sections for multiplexing. By contrast, the upconverting chelates do not photobleach and can provide multiple emission and excitation wavelengths for multiplexing.

Various chelates were compared this summer, both in terms of their efficiencies and lifetimes at excited states. Specific tasks included preparing chelate samples, operating and maintaining a Nd:YAG-pumped dye laser system, and collecting and analyzing various types of data. Various lab techniques were learned, including analytical techniques and alignment procedures. The data collected will be useful in determining the best chelates to use in practice. Also, it may be used to help further understand the behavior of these mysterious new molecules.

Allison Widhalm
Student from the University of Southern California
Mentor: Drs. Tom Slanger, David Huestis, and Philip Cosby
Project: **"Analysis Of Data From The Keck 10-Meter Telescopes"**

We worked this summer on extracting vibrational distributions of the O_2 (A) and O_2 (A') states in the terrestrial nightglow, from data obtained with the Keck I 10-meter telescope. The distribution of O_2 (A) was found to be similar to that in literature reports except that observations on the $v=0$ level are unique. For the O_2 (A') state, the distribution was obtained for the first time. A paper entitled "Nightglow Vibrational Distributions in the A and A' States of O_2 Derived from Astronomical Sky Spectra" has been submitted to *Annales Geophysicae*.

REU 2003 Tutorial Seminars

Date	Time	Staff Member	Seminar Title
19 June	11:00 AM	Philip Cosby	Dissociative Recombination of O_2^+
26 June	11:00 AM	David Huestis	Chemistry and Astronomy of Planetary Atmospheres
3 July	11:00 AM	Greg Faris	Biomedical Optics
10 July	11:00 AM	Anja Stromme	Probing the Earth's Ionosphere by Incoherent Scatter Radars
16 July	11:00 AM	Tom Slanger	Aeronomy by Astronomy
21 July	11:00 AM	Radhika Srinivasan	Magnetic Resonance Imaging: From Spins to Images and Beyond
31 July	11:00 AM	Bethany Pond	Trace Species Detection by REMPI
8 August	10:00 AM	Nora Sabelli	Women in the Sciences: Then and Now