ABSTRACTS OF REU FINAL REPORTS

The University of Toledo
Department of Physics & Astronomy
SUMMER 2003
(Faculty Mentor on parenthesis)

Astrophysics/Astronomy

Erin Hardy *"Martian Cloud Motion"* (Philip James)

In the late summer of 2003, Mars will make its closest approach to Earth in almost 60,000 years. Consequentially, during this period more detailed surveys of the Martian atmosphere can be taken using the Hubble Space Telescope's Advanced Camera for Surveys system. Images are acquired over a single 45 minute orbit. During the course of one orbit, the planet rotates 10 degrees, making image projection a necessity. The first, middle and last images are taken with F435W, a blue-violet, cloud-sensitive filter. These recovered images are then processed and analyzed to track cloud motion from image to image. Although each image set consists of 3 shots, only the first and last shots are used, since the small change in time does not provide much in the way of cloud activity. The images acquired from the pertinent set are centered at sub-Earth latitudes of 17.8E and sub-Earth longitudes of 3.69E and 13.42E. The set was obtained May 9, 2003, with the images taken at 05:17:54 and 05:57:55 UT, respectively.

Benjamin Johnson *"Modeling Microturbulence in Stellar Atmospheres"* (Lawrence Anderson-Huang)

Current stellar modeling agrees very well with observed spectra over all wavelengths related to carrying the flux with one exception: the widths of the absorption lines. Observed line widths turn out to be slightly larger than they should be for the derived temperature. This discrepancy can often be resolved by introducing so-call “microturbulent” velocities. Atmospheric modelers currently just add arbitrary amounts of microturbulence until the line profiles match. The intention of this project is to model the turbulence in three dimensions using the equations of motion for a radiating fluid. A computer program was developed and tested which creates a successful three-dimensional model of a gray stellar atmosphere with radiation-driven velocities that with further additions can be used to model microturbulence.

Jacquelyn Must *"The Effects of Clumpy Dust on Hubble's Law for Reflection Nebulae"* (Adolf Witt)

Edwin Hubble did research on reflection nebulae in 1922. He found a relation between the magnitudes of the illuminating stars and the logs of the radii of the reflection nebulae. Much scatter was present in his graph that was not due to observational error. In this paper we investigate the clumpy structures within reflection nebulae to determine if they are the cause of the large scatter seen in Hubble's graph. Observational data from the van den Bergh (1966) reflection nebula catalogue [1] and the Racine (1968) star catalogue [2] were used in this study along with a radiative transfer model of reflection nebulae.

1. van den Bergh, S., Astron. J. 71, 990 (1966)
2. Racine, R., Astron. J. 73, 233 (1968).

Atomic/Molecular/Optical Physics

Matthew Frost *"Method for Improving MCHF Calculations of Atomic Energy Levels and Wave Functions"* (David Ellis)

The Multiple Configuration Hartree-Fock Method for Atoms provides reasonably accurate results in determining energies of atoms, with the exception of atoms that have a high occurrence of electron correlation. A new *Psi* function, $\Psi' = \Psi + \alpha\Phi$ was determined in order to account for these correlations. Here, *Phi* is a new basis function for an atom with *n* electrons, orthogonal to all the MCHF orbitals, in which two electrons are described using correlated variables, with *n-2* electrons in MCHF orbitals. Then the energy is minimized by varying the amplitude *alpha*. Once the necessary methods were developed, a program was written and trails were run. These results were compared to accurate solutions for non-relativistic energies in helium and lithium. The final result is an improved approximation of energies where electron correlations are concerned, but no substantial change where electron correlations are minimal.

Joshua Thomas *"A Design and Performance Study of Electrostatic Faraday Cup Detectors"* (Thomas Kvale)

Faraday cups have been used in accelerators for many years as a detector to measure beam currents. As such, they typically play an important role in the determination of interaction cross sections and understanding their operation is crucial to the accuracy of the reported measurements. When an energetic particle strikes the metal surface of the Faraday cup, secondary electrons are emitted from that surface. These escaping electrons then appear as positive current entering the detector, which will give an inaccurate particle current reading. We have conducted a study of the traditional cylindrically-symmetric Faraday cup design which utilizes an opposing electric field to recapture the secondary electrons versus a new design which utilizes a transverse electric field. A direct comparison between the new and old design was conducted for proton impact at 25 keV and the new design shows a vast improvement in recapturing electrons at a common suppression voltage. Further analysis of the measured current as a function of voltage provides a direct measurement of the secondary emission coefficient and the kinetic energy distribution of the secondary electrons. Manuscripts reporting both the Faraday cup design study and the measurement of secondary emission coefficients are in progress and will be submitted for publication.

Biological/Health/Medical Physics

Julie DeAnna *"Patient Positioning Using the B-mode Acquisition and Targeting System (BAT)"* (Lorenzo Curtis, Ishmael Parsai)

Patients have always been aligned for their prostate treatments, but the alignment procedures never accounted for the changes in the inside of the body until the BAT positioning system was developed. BAT allows doctors or therapists to position the patient to precisely align the body with the treatment plan from day one. This process helps to make sure the patient's body inside and out is in the same alignment every day and thus greatly cuts down the margin of error. Proper alignment using BAT helps to cut down on the margin of error and greatly increases a patient's chance of completely getting rid of the cancer. The results from this project found that the error between patient positioning by the previous method and the BAT method is up to 27.69% of the target area.

This error would mean that some cancerous tissue may not be treated while nearby healthy tissue would be irradiated.

Condensed Matter Physics

Michael Baker *"Gain Flattening With Passive Optical Integrated Circuitry"* (Brian Bagley)

The current trend in the communications industry is an increased utilization of fiber optics and optical integrated circuitry, due to the increased bandwidth and reduced transmission loss versus traditional electronic methods. The current model for commercial fiber optic use is "Fiber to the Curb" in which the fiber for a particular block is run to a common curb side terminal, then converted to an electronic signal and sent via coaxial cables to the individual customers. The next generation standard, "Fiber to the Premises" (FTTP), will rely exclusively on fiber optics, from source to customer. A passive gain flattener was designed using dual-channel directional couplers and simulated with BeamPROP 4.0. A 1550 nm beam was launched into a four-way splitter constructed with square channels and a core-cladding index difference of 0.01492. Couplers of various lengths were used to dump a percentage of the splitter's output power to the environment. Final circuit outputs were within 0.5% of the expected values.

Samantha Dizor *"Photoluminescence Fatigue in CdTe/CdS Solar Cells"* (Victor Karpov)

This project was aimed at studying transient effects in the photoluminescence from thin-film photovoltaics. More specifically, it was observed that junction photoluminescence intensity (PL) in a polycrystalline CdTe/CdS solar cell gradually decreased with time, similar to the PL fatigue in chalcogenide glasses. PL vs. time was studied at different laser beam powers and temperatures for both contact-free and metallized regions. We discriminated between the fatigue per se and concomitant short-time PL intensity drop due to the laser heating. The fatigue value shows substantial variations between different spots on the sample. It was found to be more profound at higher temperatures and laser beam powers where its value can be as large as 80 percent in two hours. At low temperatures and beam powers it saturates rather quickly not exceeding 10 percent of the initial PL intensity. For the first time a phenomenon of delayed degradation (fatigue) was observed where the device kept losing its efficiency after the laser beam was terminated. To verify that phenomenon we also studied possible effects of delayed degradation caused by the standard light soak and strong forward bias. We attributed the observed phenomena to defect creation by the light-generated electrons and holes. The defects provide additional non-radiative recombination channels thus decreasing PL. Simultaneously, this negative feedback makes the defect-generation rate slowing down, so that the PL fatigue saturates. We proposed a simple analytical model that fits the data.

Patricia Gallant *"Magnetic Properties of Thin Nickel Films"* (Alejandra Lukaszew)

This paper describes the properties of thin films of nickel and iron nitride that I have been studying. I have studied the magnetization in several epitaxial thin films of various thicknesses. I used Object Orientated MicroMagnetic Framework (OOMMF) to simulate the reversal and compare it with data gained experimentally using longitudinal Magneto-Optic Kerr Effect (MOKE). I also performed studies on the surface morphology of the films using Atomic Force Microscopy (AFM) to discover correlations between the surface morphology and the magnetic properties. I compared

the surface roughness of FeN films of two thicknesses and epitaxial Ni samples before and after annealing at mild temperature (300ºC).

Sarah Hickman *"Modulated PL in CdS/CdTe Solar Cells"* (Alvin Compaan)

Electromodulated photoluminescence (EMPL) is useful for collecting data to study the differences between stressed and unstressed solar cells. EMPL measurements are taken by applying a 164mV peak-to-peak modulated voltage across a solar cell while illuminating it with a 632.8nm, 8mW HeNe laser. The signal was collected through a lock-in amplifier, and then analyzed. Using this method, three different CdS/CdTe solar cells, both stressed and unstressed were studied. The results were interpreted using a widely accepted electric field model of a cell. This model indicates that the EMPL signal should be greatest near open circuit voltage, where the electric field is the weakest at the junction between the CdS and CdTe. This proved true in the case of the unstressed cell, but was not valid in the stressed samples. We used EMPL to study the effects of stress on cells, which were stressed by illumination under a one-sun solar simulator with a temperature of 60°C. One cell was stressed at open circuit voltage, while a negative 2V bias was applied across the other cell. The stressed samples produced EMPL graphs that had no real defined peak and had very low signal near open circuit. This was contrary to the expected result, and is not yet fully understood. It is, however, believed that the lack of a peak, especially near open circuit, is due to defects that are created near the CdS/CdTe junction during stressing.

Joseph Sawvel *"Optoelectronic Properties of Amorphous and Nanocrystalline Silicon Alloys"* (Xunming Deng)

In this project we analyzed the structure of amorphous and nanocrystalline silicon and silicon germanium films via Raman Spectroscopy. We also analyzed the photo and dark conductivity of several nanocrystalline silicon and silicon germanium materials deposited using hot-wire chemical vapor deposition process. The third aspect of the project was the construction and utilization of a Constant Photo Current Apparatus. The CPM could be used to measure the density of defects in the band gap of amorphous silicon and silicon germanium alloys

Travis Smith *"Parallel Kinetic Monte Carlo Simulations on a Shared Memory Multiprocessor System"* (Jacques Amar)

In order to simulate non-equilibrium processes over larger time scales and for realistic size systems, it is desirable to use parallel computing. Unfortunately, the standard algorithm for simulating activated processes, kinetic Monte Carlo (KMC) , is inherently serial and thus only suitable for use with a single processor. Recently, however, our group has developed parallel (KMC) algorithms which have been successfully tested on a Beowulf cluster using Message Passing Interface (MPI) Application Program Interface (API). Due to the lack of communication overhead such algorithms should be even more efficient on shared-memory machines. As a first step in investigating this possibility, I have been developing a parallel KMC code to simulate one-dimensional irreversible epitaxial growth on a shared memory machine using OpenMP. We have verified and tested this code on the Sunfire and Origin 2000 computers at the Ohio Supercomputer Center (OSC) using multiple processors. Unfortunately, so far we have not obtained a significant speed increase using this method. However, we believe that this is not due to a fundamental limitation in the algorithm but rather to computational and/or compiler limitations. In the near future, we hope to increase the parallel efficiency of our code so that it can then be applied

to more complex and realistic problems.

Nicholas Sperling *"Low cost scanning tunneling microscope and OOMMF simulations"* (Alejandra Lukaszew)

Using circuit designs from the "SXM Project" [I] at the Westfalische Wilhelms-Universitat Munster, a new prototype scanning tunneling microscope (STM) is in the process of being developed. The key features of this STM will be its relative low cost and the portability into an ultra-high vacuum system. The purpose of this device will be to do high, and possibly atomic, resolution on micromagnetic materials. This device will have to use materials readily available for the construction of the mechanical components, and they must be able to interface properly with the electronic components at hand. Since the study of the micromagnetic thin films are the core of the research, we have been using the Object-Oriented Micromagnetic Framework (OOMMF) released by the National Institute of Standards and Technology (NIST). The code has been slightly modified to facilitate the generation of hystersis loops of thin Ni films. The code has also been used to simulate experimental data taken on Nickel films.

Matthew Wescott *"Symmetric Mach-Zehnder Interferometer Optical Logic Device"* (Brian Bagley and Robert Deck)

The all-optical computer is a controversial idea. Most agree that it would be very powerful however, many challenge its functionality or even the possibility of its construction. There are many challenges to constructing a useful optical computer, but many of the problems are being overcome by better components, particularly logic devices. One of the problems with optical computing is the difficulty of controlling the relative phase of two input signals. Another is the inherent difficulty in cascading the logic devices. Most schemes of doing logic optically have both of these problems; a few have neither. One of the more promising logic devices involves the symmetric Mach-Zehnder interferometer. By incorporating a three-channel directional coupler into the input stage of the device, its size can be reduced. This project involved the theoretical analysis of the slab approximation with coupled mode theory.