ABSTRACTS OF REU FINAL REPORTS
The University of Toledo, Department of Physics &
Astronomy SUMMER 2013 (Faculty Mentor on parenthesis)

Atomic, Molecular, Optical Physics

Nate Ross, *Theoretical Examination of the 1203 Å Transition in Pb II* (David Ellis and Richard Irving)

A fully relativistic method is implemented to examine the transition in Pb II seen at 1203 Å. This line represents the transition from the ground state, $6s^2 6p\ ^2P^0$, to the $6s6p^2\ ^2D_{3/2}$ excited state at 83,083 cm-1. This excited state, however, is a mix of both the 6s6p2 2D3/2 configuration and the 6s26d 2D3/2 configuration. This configuration mixing has been highlighted in [1], [2] and [3]. The new GRASP2K [4] relativistic atomic structure program was used to make calculations for this transition of interest. GRASP2K is the most recent available version of a general-purpose multi-configuration Dirac-Hartree-Fock atomic structure program. Our first calculation included correlation effects between the 5d, 6s and 6p electrons and the 5f, 6d, 7s, 7p and 8s virtual orbitals, and gave a preliminary result for the A value of this line of 1.826 ns-1. Further work remains to be done to add more configurations in order to achieve more reliable results.

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Mathematical Physics

Luke Kwiatkowski, *Calculations of Null Geodesics in The Schwarzchild Metric* (Mao-Pei Tsui)

In this paper, I present what I have learned over the summer on the topic of general relativity. I begin with a review of elementary manifold theory and differential geometry, including transformations of contravariant and covariant vectors and tensors. I then reproduce the calculations carried out by Robert M. Wald [1] in _nding equations which describe the motion of light near a non-rotating black hole. Specifically, this is accomplished by solving the null geodesic equations in Schwarzchild spacetime. Although geodesics are the simplest geometric objects, we conclude from this work that they provide valuable insight into the geometry of 4-dimensional curved spacetime.

Jennifer Jin, "*Modeling and Simulating Gold Nanoparticle Interactions on a Liquid-Air Interface,*" (Jacques Amar)

Fully understanding the interaction of gold nanoparticles with each other on the surface of an evaporating toluene droplet is crucial for developing ways to self-assemble gold nanostructures and nanofilms. Unfortunately, the surface of an evaporating toluene droplet is a quasi-two-dimensional surface and is difficult to model. In addition, the reason behind gold nanoparticle island diffusion is not fully known. Running simulations is thus important for understanding more of the movement of gold nanoparticles and analyzing the results of physical experiments. Changing the parameters of the simulation aids in learning how different movement rates and detachment mechanisms affect the gold nanoparticle island size distribution. By calculating the Van der Waals attraction and dipole-dipole repulsion between nanoparticle islands and summing the two forces, we find an energy barrier for two nanoparticle islands to overcome before coalescing together. Adding the energy barrier to coalescence to simulations produces island size distributions that agree much better with experimental island size distributions, suggesting that gold nanoparticles suspended on the surface of an evaporating toluene droplet experience both attraction and repulsion.

Plasma Physics

Kevin Kelbach, *Optical Emission Spectroscopy (OES) used in relating atomic oxygen emission and ZnO:Al conductivity in RF sputtering* (Al Compaan)

The topic of interest is the optical emission lines of oxygen found in a sputtering plasma. Oxygen emission lines are examined at different pressures, flow rates, and powers using optical emission spectroscopy (OES). The goal is to find a relationship between the intensity of the oxygen peaks and the flow rate of the argon gas used in a sputter chamber.

Elise Mesenbring, *Optical Emission Spectroscopy of RF Magnetron Sputtered Zinc Oxide Thin Films* (Yanfa Yan)

Low temperature plasma was studied using optical emission spectroscopy (OES) during the deposition of zinc oxide (ZnO) films by rf magnetron sputtering. The emission spectra was analyzed to identify the zinc and argon peaks in the plasma and to determine how the intensities of these peaks changed as a function of zinc oxide target power. The peaks in the emission spectra correspond to those found in literature. These peak intensities lowered when target power was initially lowered from normal deposition parameters, but not all peaks decreased equally. Further research will be done to identify how the intensities of these peaks relate to the concentration of chemical species in the plasma and the impact of plasma characteristics on ZnO film properties.

Anna Barnes, *Optical Emission Spectroscopy to Study the Chemistry of Plasma Enhanced Chemical Vapor Deposition* (Nikolas Podraza)

Low temperature plasma was studied using optical emission spectroscopy (OES) during the production of solar cells through plasma enhanced chemical vapor deposition (PECVD) of hydrogenated amorphous silicon. This data was analyzed in order to determine how the chemistry of the plasma reacted to different deposition parameters and whether there was a change during the deposition of a single layer (p-, i-, or n-layer). A collection of the spectral data acquired shows that the plasma chemistry changes significantly for different deposition parameters including the plasma power density and gas mixture. The plasma is also probably changing during a deposition of a single layer. Further research will determine which deposition parameters are ideal for an efficient solar cell.

Timothy Anderson, *X-Ray Film Analysis of X-Pinch Plasmas* (Thomas Kvale and Rick Irving (Toledo), and Erik Mckee and Timothy Darling (NTF))

Image J is used to analyze a series of X-Ray films from three separate Zebra shots from the Nevada terawatt facility. The shots were x pinch plasma shots and it is hoped that by analyzing the luminosity densities of the plasma x-ray certain characteristics of x pinch generated plasma can be observed. This data can also be used to experimentally determine filter values used at the different pinholes on the camera.
Collaborative research project conducted at The University of Toledo and Nevada Terawatt Facility at The University of Nevada, Reno.

Brandon Schurter, *Equivalent Dosage from Neutron Radiation Produced by Deuterium-Palladium Plasma in the NTF Zebra Chamber* (Thomas Kvale and Rick Irving (Toledo), and Erik Mckee and Timothy Darling (NTF))

In this project, the radiation shielding for the console and safety rooms in the NTF (Nevada Terawatt Facility) Zebra bay was tested against neutron radiation by computer

simulation. The radiation flux through a person in the console and safety rooms was simulated using MCNP (Monte Carlo N-Particle simulation). The results were then analyzed using the flux-to-dose-rate conversion standards established by the American Nuclear Society. The calculated dosage received by the simulated person was compared to national standards for equivalent radiation dosage to determine if the console and safety rooms for the Zebra bay were safe from neutron radiation.
Collaborative research project conducted at The University of Toledo and Nevada Terawatt Facility at The University of Nevada, Reno.

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Astrophysics

Kody Kamunen, *Atmospheric Extinction for Ritter Observatory* (Jon Bjorkman)

We measured the atmospheric extinction at Ritter Observatory using the half-wave spectro-polarimeter (HPOL). We observed the flux standard Alpha 2 CVN on the nights of May 2nd, June 19th, and June 20th, 2013 at air masses ranging from 1.004 to 2.704. We determined the extinction coefficients using the standard technique of plotting the monochromatic brightness vs. air mass for each wavelength channel of HPOL. We found that the extinction in the red on the night of May 2nd was anonymously large and roughly constant with wavelength (3000-10500nm) possibly owing to the larger amount of pollen in the atmosphere that night. The extinction on the 19th and 20th of June were consistent with each other. As such, we combined the data gathered on those two nights for a finalized extinction curve. The results are consistent with typical extinction curves and slightly larger extinction values from when the HPOL unit was at the Pine Bluff Observatory (PBO) in Wisconsin.

Demi St. John, *Single Forming Star in LDN 1489, Not the Prototype You've Always Expected* (Adolf Witt)

I used optical data obtained from the Discovery Channel Telescope by Aditya Togi in February 2013 to analyze the interstellar dust cloud Barnard 207, also known as LDN1489. Barnard 207 is particularly interesting because there is currently a star forming ~10,000 AU to the west of the dense core. This research was to study Barnard 207 through 3 different methods in order to determine extinction. The methods carried out included surface brightness photometry, stellar BVRI photometry, and star counts. Extinction values of ~32 and ~38 magnitudes for V and B bands respectively were determined. Additionally, a density on the order of 10^5 $cm^{-3}$was determined for B207 with a mass of ~3.5$M_\odot$ for the core. We found evidence for grain growth from measurements of the dust albedo in B, V, R, I and from the detection of coreshine at 3.3 micron. Such grain growth suggests a minimum age for Barnard

207 of ~ 10^6 years. Finally we were able to show a correlation between surface brightness and optical depth.

Condensed Matter Physics

Rebekah Thomas, *Numerical Modeling of degradation of thin film solar cells* (Victor Karpov)

Thin film photovoltaics (TFPV) has evolved into a highly competitive technology. Given its simpler manufacturing processes, and growing market share, the success of TFPV will boost solar energy production. However, this will only be realized if the remaining problem of degradation under light and bias can be solved. As the unique attributes of TFPV became more evident, some degradation mechanisms related to the underlying physics have been proposed mostly at a qualitative level. That effort, however, remained peripheral to the major effort of maximizing TFPV efficiency, and hampered, in addition, by the proprietary nature of the relevant information. In many cases, TFPV efficiency and reliability have been thought of as inversely proportional: the higher efficiency, the shorter the lifetime. While true for a-Si based

PV, its degradation rates can be slowed at the expense of efficiency by 'presoaking', this concept has never been proven for other types of TFPV. From a monetary standpoint, efficiency and reliability appear to be complementary. For example, integrating the temporal efficiency decay $\eta(t) = \eta_0 F(t/\tau)$ over time, where F is an arbitrary function, yields the total energy collected by device, $E \propto \eta_0 \tau$ equally dependent on initial efficiency and degradation time τ. More complex kinetics can put even stronger weight on the degradation factor. Therefore, understanding the reliability of TFPV is practically important and requires insight into its physics. For this project, we developed a numerical model of laterally uniform degradation in CdTe based thin film photovoltaics. This brand of TFPV is currently leading industry. It was developed mostly by First Solar LLC with significant contributions from NREL, University of Toledo, and several other teams.

Andrew J Yandow, *Development of Zinc Phosphide Films for Use in Solar Cells* (Yanfa Yan)

The effect of hydrogen plasma treatments on the electrical properties of zinc phosphide (Zn3P2) thin films was tested. The plasma treatments were executed with a power of 10 W, a plasma chamber pressure of 1.5 Torr, and time lengths of 5, 10, and 25 minutes. For all treatments, a significant degradation of the film carrier density and mobility were observed, along with a sharp increase in the film resistivity. SEM imaging showed that the plasma treatments destroyed the crystal structure, rendering the surface amorphous. Attempts to recrystalize the surface by annealing in a helium ambient atmosphere with a pressure of 15 Torr and a temperature of 400^{o}C for 8 hours repaired some of the damage done by the plasma treatments, but did not have significantly improved carrier density than an untreated film.