Annual Progress Report (Year 2)

Research Experiences for Undergraduates in Physics and Astronomy

NSF-REU Grant PHY–0353899

Department of Physics & Astronomy
The University of Toledo
Toledo, Ohio 43606

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Left to Right (Standing): S. Federman, W. Ingler, D. Ellis, L. Curtis, T. Kvale, C. Lind, A. Lukaszew, **Andrew Larkoski**, **Zachary Ferraro**, S. Khare, **Christopher Muscatello**, **David Hunley**

Left to Right (Kneeling): A. Compaan, **DeMarco Camper**, **Randolph White**, **Sheriff Ceesay**, **Jacob Warner**, **Miguel Cervoni**, **Stephanie Torok**, **Meredith Rogers**, **Kevin Wells**

REU RESEARCH PARTICIPANTS, SUMMER 2005

NAME	INSTITUTION	MENTOR	RESEARCH
DeMarco Camper	University of Toledo	Lukaszew/Lind	Condensed Matter
Sherrif Ceesay	Wilberforce University	A.D. Compaan	Condensed Matter
Miguel Cervoni	Virginia Military Institute	T.J. Kvale	Atomic Physics
Zachary Ferraro	Earlham College	R.A. Lukaszew	Condensed Matter
David Hunley	Morehead State University	X. Deng	Condensed Matter
Andrew Larkoski	University of Washington	D.G. Ellis	Atomic Physics
Christopher Muscatello	Case Western Reserve Univ.	C.E. Theodosiou	Plasma Physics
Meredith Rogers	Marietta College	S.R. Federman	Astronomy
Stephanie Torok	University of Toledo	L.J. Curtis	Atomic Physics
Jacob Warner	University of Wisconsin	S. Khare	Condensed Matter
Kevin Wells	Ohio Northern University	R.W. Collins	Optical Physics
Randolph White	Francis Marion University	V. Karpov	Condensed Matter

II. SUMMARY OF SUMMER 2005

Introduction

The Summer 2005 NSF-REU program in Physics and Astronomy at Toledo gave enhanced research opportunities to 12 undergraduate students from 11 colleges and universities in 7 states spread from Virginia Washington. Of these twelve students, ten were fully funded by the REU grant, one was partially funded by the department as its pledge of support to the REU grant and one was partially funded by an external grant. The NSF-REU grant supplemented the other funding sources for these two students so that their level of support was commensurate with the students fully supported by the REU grant. This policy of supplementing external grant support allows us to involve more students (and faculty members as mentors) in the program than we could do with just the REU grant alone. Student participants were chosen competitively from the 109 applications from students in 30 different states in all regions of the U.S. All the participants were serious and talented young scientists, who tackled substantial problems, participating in all stages of a project, from formulation to conclusion, including oral and written presentations of results. We are very pleased that this year 50% of our participants were members of under-represented groups (gender/African-American/Hispanic). The initial web announcement (with secondary links to additional material) can be found at:

http://www.physics.utoledo.edu/~wwwreu/reusummer2005/nsf-reu2005a.html

We are pleased to report that Summer 2005 was a success from both the students' and faculty mentors' perspectives. Two manuscripts have been submitted to archival, refereed journals involving REU student co-authors in 2005; at least one additional conference proceedings manuscript is expected to be submitted in 2006 (to be included in next year's report); four manuscripts are in preparation and are expected to be submitted to archival, refereed journals shortly, and five presentations were made in regional or national conferences in 2005.

Advertisement and Selection

Again this year (Summer 2005) we utilized a web-based advertisement and application system. Based on a pattern of past applications and inquiries, we believe that the internet is the main search vehicle for the vast majority of students. Because of this pattern, paper announcements were sent to only a few targeted institutions. The mailings included a very brief letter alerting the prospective students to our website and a paper copy of our Application form in case the students didn't have readily available access to the internet. The selection committee was composed of Thomas Kvale (PI) and R. Alejandra Lukaszew (Co-PI). We also performed the initial matches of the prospective students with their faculty mentors. Various criteria were used for the selection and matching, including the student's course background and class performance, out-of-class experiences, research interests, faculty recommendations, and personal goals. We also tried to select students with a variety of personal, educational, and geographical backgrounds. Again, we are very pleased that this year 50% of our participants were members of under-represented groups (gender/African-American/Hispanic).

Registration and Housing

All student participants were registered in PHYS4910, *Research Problems in Physics and Astronomy*, for 1 semester hour credit. The REU program paid all the instructional and other required fees. We find that there are many advantages to having the REU participants be registered UT students with all associated benefits and privileges. One of the major benefits is access to the university health center. Other benefits include: course credit to transfer back to the student's home institution if desired,

access to recreational facilities, and borrowing privileges at the University library.

This year 11 of the twelve student participants lived in the same campus dormitory with the NSF-REU grant providing the housing costs to these students. The students stayed in the International House, which is organized into suites adjoining a common area that encouraged social interactions among the REU students. This dorm also has kitchen facilities for the students to cook their meals if they choose to do so. One of the goals of the NSF-REU program is to enable social interactions among the students, who will become the scientists of tomorrow. This infrastructure of friendships leads to the fruitful exchange of ideas, which is useful in the advancement of physics and astronomy. We feel that we can best accomplish this goal by housing the students together on campus and to foster off-hours social activities.

Social Activities

Social activities were coordinated by Stephanie Torok (UT & REU participant) and some graduate students. The students again this year formed a close-knit group. Weekly activities included Wednesday nights at a local, family restaurant (Uncle John's Pancake House) and Ultimate Frisbee games. Some of the other special events included: windsurfing twice, several BBQ's at faculty members' homes and/or at parks, a trip to Cedar Point Amusement Park, and welcome and farewell dinners at local restaurants. Many of the evaluation comments mentioned these activities favorably.

Weekly Seminars

During the first week, the students attended an orientation seminar to cover the basic items such as ID cards, parking, health services, food services, stipend checks, etc. After that, a weekly "Brown Bag" seminar series played an important part of our summer program. Faculty members and/or outside speakers presented a talk over the lunch hour for their chosen day. This bag lunch format fosters more of an informal atmosphere, which the students appreciate when it is their turn to give a presentation at the close of the summer session. This weekly meeting of the entire REU group also provided an opportunity to plan social events and field trips, and discuss any topics of interest to the group. The whole department was invited to attend the Bag Lunches, and the participation was very good with many graduate students and faculty members also attending each week. The Bag lunches provided a useful departmental weekly gathering, otherwise absent in the summer. The talks at these weekly meetings were for the most part similar to standard physics research talks, but chosen to be appropriate for the REU audience, and with all the speakers being careful to give undergraduate-level introductions. We also required the students to give a 5 minute presentation of their research about midway into their summer period. These midway progress talks went well and kept the students focused on their projects. We plan to repeat the mid-term Progress talks for this coming summer.

NSF-REU SUMMER 2005 BROWN BAG SEMINARS

TUESDAY NOON - MH 4009

May 31	Orientation & Pizza Lunch	
June 02	BBQ Lunch	
June 07	R.A. Lukaszew	(Summer Camp planning & Magnetic Thin Film research)
June14	A. Miroshichenko	(Astrophysics)
June 20 - 24	Physics Summer Camp	
June 28	Mid-term REU Progress Reports	

July 05	T. Kvale	(Atomic Physics)
July 12	L. Curtis	(Physics pedagogy & Atomic Physics)
July 19	L. Allamandola	(Condensed Matter)
July 26	F. Guilaran	(Magnetic Thin Films)
August 02-04	REU2005 Final Presentations	

Reports and Conclusion

We feel it is important to involve the students with all aspects of the scientific research process. To the extent possible, depending on the nature of the project, students participate in the selection of the problem, the choice of research method, the collection and analysis of data, the formulation of conclusions, and the presentation of the results. The research problems are parts of ongoing faculty research programs, which are in most cases supported by external grants. At the same time, every effort is made to identify a piece of the research for which the REU student has the primary responsibility. The students are asked to write a final report, including a carefully-written abstract which could be submitted as a contribution to a regional or national meeting, as well as give a 20 minute presentation at a Bag Lunch in the final week of their research period. The typical length of the final reports is about 20 - 25 pages. These requirements have helped the students to become experienced in technical writing and presentations. The success of this philosophy is attested by the fact that at least six manuscripts have been submitted or are in preparation to be submitted from our REU students.

We are very excited about this coming summer and beyond. The University of Toledo is in the process of merging with the Medical University of Ohio at Toledo (MUO). MUO has a national reputation of being an excellent medical school. For several years now, our department of Physics and Astronomy has had a collaborative Ph.D. program in medical physics with the Medical Physics department at MUO. The merging of the two institutions into UT will provide enhanced opportunities for our REU students to select projects in the medical physics fields (radiation oncology and diagnostic radiology).

II. PHYSICS SUMMER CAMP 2005

During the Physics Summer Camp 2005 event we had seven participants from local schools and even one student that was visiting his family and came from the American School in London, UK. As usual the event was a complete success. The activities involved participation of the REU students, and following their recommendations from last year's event, we had participations of 2-3 different REU students per/day instead of the entire group each day. The REU students co-organized the activities, and led very interesting and amusing discussions followed by trivia questions. We initiated the event asking campers what did they think physicists do, and many didn't know.

For the final survey we asked them: "What do you think physicists do?", and their answers were: "almost everything", "they measure and study how nature works...". When we asked them what did they liked most and they answered: "the different experiments", "the LN2 ice-cream", "building bridges", "tour [of] the planetarium", and [of-course] "the free food!"

During one of the brown-bag lunches R. A. Lukaszew (Co-PI) introduced to the REU team the concept of Physics Summer Camp for high-school students interested in science. She explained that the idea was to minimize the age-gap between organizers and participants in order to foster discussions about science in general and physics in particular. The REU team was very enthusiastic about the concept and all wanted to share experiences that they had at one time or another and that inspired them to study Physics. The schedule of activities was sketched and perfected in a second short meeting after another brown-bag lunch.

The schedule of activities was fully designed by the REU team under the supervision of R. A. Lukaszew. The activities ran daily for one week from 9 a.m. till 3 p.m. The activities comprised informal talks about how things work, with presentations by the REU-team, formal talks by faculty from the department, and hands-on activities. We asked two anonymous surveys at the beginning and end of the camp in order to find out the expectations of the campers as well as their satisfaction with the activities. The results from the surveys were shared and discussed with the REU team. The general outcome of the event was that there was considerable interaction between the two groups and several of the campers were quite impressed by the performance and involvement in research of the REU-team and left the camp with a renewed interest in science.

The activities that were developed and performed this year with the help of our REU team are shown in the table on the following page. A sampling of summer pictures from REU activities (including the Summer Camp) are included in section VII: Summer 2005 Pictures.

Physics Summer Camp 2005

McMaster Hall, Department of Physics and Astronomy, University of Toledo

Monday morning:
Who are we? What do we do in Physics?
Trivia
Introductory survey
11:30 Pizza!!

Monday afternoon:
Optics day:
Light and color! (Prof. L. Anderson-Huang)
3:00 Bye

Tuesday morning:
A tour to see the UT Rube Goldberg Machine (won UT competition, 2005. Participated in national competition)
11:30 Phoenicia Restaurant

Tuesday afternoon:
Demos: Electromagnetism and Power
3:00 Bye

Wednesday morning:
2005 the year of Albert Einstein (Prof. D. Ellis)
11:30 Pizza!!

Wednesday afternoon:
Hands-on: Building bridges
3:00 Bye

Thursday morning:
Reinventing Introductory Physics (L. Curtis)
http://astro1.panet.utoledo.edu/~saturday/abs05_curtis.html
Tour of THIA (Toledo Heavy Ion Accelerator)
11:30 Phoenicia Restaurant

Thursday afternoon:
Hands-on: Testing bridges
Tour: Ritter Planetarium
3:00 Bye

Friday morning:
Cold temperature day (Prof. R. A. Lukaszew).
Trivia
11:30 Lunch: Department BBQ!!!

Friday afternoon:
Fun with LN2
LN2 ice-cream
Fare-well survey
3:00 Bye

IV. DEMOGRAPHICS

NSF-REU SUMMER 2005 APPLICATIONS

Geographical distribution by undergraduate institution
(Applications Received / REU Offers Made /REU Accepted)

Alabama
University of Western Alabama ..... (1/0/0)

Arizona
University of Arizona ..... (1/0/0)

California
CalPoly - San Luis Obispo ..... (1/0/0)
Humboldt State University ..... (1/0/0)
Santa Clara University ..... (1/0/0)
Sierra College ..... (1/0/0)

Connecticut
Wesleyan University ..... (1/0/0)
Yale University ..... (1/1/0)

Florida
University of Florida ..... (1/1/0)

Georgia
Georgia Inst. of Tech. ..... (2/2/0)

Hawaii
University of Hawaii at Manoa ..... (1/1/0)

Illinois
Northern Illinois University ..... (1/0/0)

Indiana
Earlham College ..... (1/1/1)
Rose-Hulman Inst. of Tech ..... (1/0/0)
Purdue University ..... (1/1/0)
University of Evansville ..... (1/0/0)
Wabash College ..... (1/0/0)

Kentucky
Cumberland College ..... (1/0/0)
Morehead State University ..... (1/1/1)

Maine
Bates College ..... (1/0/0)

Maryland
Hood College ..... (1/0/0)
Salisbury University ..... (1/0/0)

Massachusetts
Mount Holyoke College ..... (1/0/0)
University of Mass ..... (1/1/0)

Michigan
Eastern Michigan University ..... (2/0/0)
Hillsdale College ..... (1/0/0)
Michigan State University ..... (4/1/0)
University of Michigan ..... (2/1/0)

Minnesota
Carleton College ..... (1/0/0)

Mississippi
Miss. University for Women ..... (1/0/0)

Missouri
Truman State University ..... (1/0/0)

New Jersey
The College of New Jersey ..... (1/1/0)

New York
Binghamton University ..... (1/0/0)
Columbia Univ. (Barnard Coll.) ... (1/1/0)
Cornell University ..... (2/1/0)
Hamilton College ..... (1/0/0)
Rochester Inst. of Tech. ..... (1/0/0)
Skidmore College ..... (1/0/0)
St. Bonaventure University ..... (1/0/0)
St. John's University ..... (1/0/0)
SUNY Oneonta ..... (1/0/0)

North Carolina
North Carolina State Univ. ..... (1/0/0)

Ohio
Case Western Reserve Univ. ..... (1/1/1)
College of Wooster ..... (1/1/0)
Kenyon College ..... (1/0/0)
Marietta College ..... (2/1/1)
Mount Union College ..... (1/0/0)
Ohio Northern University ..... (4/2/1)
University of Toledo ..... (8/2/2)
Wilberforce University ..... (1/1/1)

Oregon
Oregon State University ..... (1/0/0)

Pennsylvania
Allegheny College ..... (1/0/0)
Bucknell University ..... (1/0/0)
Carnegie Mellon ..... (7/0/0)
Grove City College ..... (2/0/0)
Lehigh University ..... (1/0/0)
Swarthmore College ..... (2/0/0)

South Carolina
Clemson University ..... (1/0/0)
Francis Marion University ..... (1/1/1)

Tennessee
Sewanee - University of South ..... (1/1/0)

Vanderbilt University ..... (1/0/0)

Texas
Austin College ..... (1/0/0)
Baylor University ..... (1/0/0)
Rice University ..... (1/1/0)
Texas A&M ..... (1/0/0)
Texas State University ..... (1/0/0)
University of Texas at Austin ..... (1/0/0)

Utah
University of Utah ..... (2/0/0)

Virginia
College of Wiliam & Mary ..... (1/1/0)
Hollins University ..... (1/0/0)
Virginia Military Inst. ..... (1/1/1)

Washington
Seattle University ..... (2/1/0)
University of Washington ..... (2/1/1)

Wisconsin
Carthage College ..... (1/0/0)
Marquette University ..... (2/0/0)
Saint Norbert College ..... (1/0/0)
University of Wisc.-River Falls ..... (1/0/0)
University of Wisconsin ..... (2/1/1)

* includes two UT students with only partial REU support.

SUMMARY
109 Applications received
29 Offers made
12 Offers accepted

NSF-REU Participant* Demographics

Summer 2005

Gender	
Female:	2
Male:	10

Class Rank	
Freshman:	0
Sophomore:	4
Junior:	8
Senior:	0
Higher:	0

Ethnicity	
International Student:	0
American Indian:	0
Alaskan Native:	0
Asian American: (or Pacific Islands)	0
African American:	3
Hispanic American:	1
Caucasian/White:	8
Other:	0

Home State	
Virginia	1
Massachusetts	1
Kentucky	1
Pennsylvania	1
Minnesota	1
South Carolina	1
Washington	1
Ohio	5

Home Institution:	
Case Western Reserve Univ.	1
Earlham College	1
Francis Marion University	1
Marietta College	1
Morehead State University	1
Ohio Northern University	1
University of Toledo	2
University of Washington	1
University of Wisconsin	1
Virginia Military Institute	1
Wilberforce University	1

REU Students Grade Point Average: 3.30

* Includes two students with partial REU support.

V. RESEARCH

REU 2005 Final Presentations

Tuesday, Aug 02		
12:00pm - 12:15pm	Zachary Ferraro	*Nano-Magnet Growth in Thin Films* (A. Lukaszew)
12:15pm - 12:30pm	Randolph White	*Electron Tunneling through a Metal Semiconductor Junction* (V. Karpov)
12:30pm - 12:45pm	Sheriff Ceesay	*Other Trace Elements During CdS/CdTe Deposition* (A. Compaan)
12:45pm - 1:00pm	DeMarco Camper	*Low Temperature Routes to Negative Thermal Expansion Materials in the ZrW_2O_8 Family* (C. Lind/A. Lukaszew)
Wednesday, Aug 03		
12:00pm - 12:15pm	Patrick Hunley	*Sputter Deposition of Fe_2O_3/In Films for Photoelectrochemical Hydrogen Production* (W. Ingler/X. Deng)
12:15pm - 12:30pm	Stephanie Torok	*Experimentally Analyzing the Branching Fractions and Life Times of PII using the THIA* (L. Curtis)
12:30pm - 12:45pm	Miguel Cervoni	*Beam Transport in the UT-P/NIELS Accelerator* (T. Kvale)
12:45pm - 1:00pm	Meredith Rogers	*Chemical Analysis of CO-rich Diffuse Interstellar Clouds* (S. Federman)
Thursday, Aug 04		
12:00pm - 12:15pm	Kevin Wells	*Optical Analysis of Thin Films for Photovoltaics Technology: Spectroscopic Ellipsometry of Multi-Layer Transparent Conducting Oxide Films* (R. Collins)
12:15pm - 12:30pm	Jacob Warner	*Ab Initio Calculations for Properties of MAX Phases Ti_2GaN, V_2GaN, and Cr_2GaN* (S. Khare)
12:30pm - 12:45pm	Andrew Larkoski	*Numerical implementation of Einstein-Brillouin-Keller quantization for arbitrary potentials* (D. Ellis)
12:45pm - 1:00pm	Chris Muscatello	*Calculation of UV Production Efficiencies in the Glow Discharge Cathode Fall of Ne/Xe Mixtures* (A. Shvydky/C. Theodosiou)

ABSTRACTS OF REU FINAL REPORTS
The University of Toledo, Department of Physics & Astronomy
SUMMER 2005
(Faculty Mentor on parenthesis)

Astrophysics/Astronomy

Meredith Rogers, "*Chemical Analysis of CO-rich Diffuse Interstellar Clouds*," (S. Federman)

Contrary to popular belief, space is not a cold, dark vacuum devoid of matter. There are regions that have a higher density that are referred to as diffuse molecular clouds. Unlike dense clouds, which look black and empty because the dust and gas absorbs or scatters the light of background stars and those forming inside, diffuse clouds are invisible, betrayed only by the reddening of stars whose light passes through them. These clouds are being studied because they maintain a rich chemistry within them which allows the formulation of evolutionary models of interstellar space. This will provide answers as to how galaxies form and if the appearance of galaxies changes with respect to stellar birth and death. The goal of this project was to focus on extracting the density of these clouds from a chemical analysis of CH and CN observations. This work can be linked with the work of others in the research group to determine the relationship between density and amount of CO present.

Atomic/Molecular/Optical Physics

Miguel Cervoni, "*Beam Transport in the UT-P/NIELS Accelerator*," (T. Kvale)

The UT-P/NIELS accelerator is a positive/negative ion energy loss spectrometer. Recently the research conducted with it has dealt with the excitation of helium by proton impact where the resulting positive ions are diverted to an energy analyzer. To attain accurate results, high beam intensities are needed to resolve the different excitation states at certain energies. The problem is that the majority of the beam is dispersed and lost before the target cell but energy loss afterwards was negligible meaning that the problem was in the acceleration portion. This research project dealt with modeling the acceleration portion in two sections. The first section modeled the ion source and einzel lens, while the second section modeled the injector and accelerator column. The einzel model showed that the beam behaved normally and this was later confirmed by experimental data. The accelerator column model showed that the beam did disperse before the target cell. The electrical configuration of the accelerator was altered by adding a resistor at the beginning of the column which helped improve the beam transport percentage at the target cell. The potential on the center element of the injector was also related to beam dispersion. The model found that the center element should be at the same potential as the other elements. Experimentally this could not be verified due to a possible wiring problem in the deflection plates which could have caused experimental error.

Andrew J. Larkoski, *Numerical implementation of Einstein-Brillouin-Keller quantization for arbitrary potentials*, (D. Ellis)

The Einstein-Brillouin-Keller (EBK) quantization equation can be used in lieu of the Schrödinger equation to determine quantized energy levels of a bound system in an arbitrary potential. For all but the simplest potentials, an analytic solution does not exist, thus numerical methods must be used to approximate the equation. The diatomic molecule system is given as an example of the numerical

application of the EBK equation. From the energy eigenvalue solutions to the EBK equation which are determined by the Newton-Raphson method, a multitude of aspects of the system can be systematically analyzed such as the effect of the angular momentum of the system on the effective potential, or the classical orbits and the possibility for closed orbits. While the treatment is nearly purely classical, the Wentzel-Kramers-Brillouin (WKB) approximation of the wave function can also be readily derived for any state of the system.

Stephanie Torok, "*Experimentally Analyzing the Branching Fractions and Life Times of PII using the THIA*," (L. Curtis)

This purpose of this experiment was to determine the accuracy and reliability of theoretical and semiempirical estimates of branching fractions in singly ionized phosphorus, P II. We specifically studied the transitions between the levels $3s^2 3p4s\ ^3P^o_J$ levels and the ground configuration $3s^2 3p^2$. Lifetimes were measured for *J*=0 and *J*=2 and branching fractions were measured for J=*1* and *J*=2. The results were compared with MCHF calculations of Tayal, Hibbert, and Fischer and semiempirical estimates of Curtis. The results have applications both in the interpretation of astrophysical data and in providing intensity calibration standards in the ultraviolet spectral region.

Condensed Matter Physics

DeMarco Camper, "*Low Temperature Routes to Negative Thermal Expansion Materials in the ZrW_2O_8 Family*," (C. Lind/A. Lukaszew)

Thermal Expansion is the process that always occurs when materials are heated. This concept is based on the coefficient α, which is defined as the change of length per unit length of material for a one degree centigrade change in temperature. Negative thermal expansion (NTE) occurs in materials that shrink upon heating. Zirconium Tungstate (ZrW_2O_8) is a known NTE material that exhibits NTE behavior in its cubic form. As NTE materials have the potential to be used in controlled thermal expansion composites, small particles are desirable. My research investigates low temperature routes for ZrW_2O_8 that allow us to control particle morphology. Powder X-ray Diffraction and Scanning Electron Microscopy are used for characterization.

Sheriff Ceesay, "*Other Trace Elements During CdS/CdTe Deposition*," (A. Compaan)

In the development of thin film relative to solar technology, Spectrography becomes very important in determining efficiency of solar cells. One way Spectrography can be used is for elemental identification. Since Spectrography allows us to use light given off by different elements at different wavelengths of light to identify an element. In thin film application in relation to solar technology, Spectrography can be used during a process called deposition. Deposition applies to the use of sputtering an elemental target, CdTe for example. During this process a thin layer of the element from the target is place on to a surface of glass/substrate. However another event occurs during deposition, light is given off during the process of sputtering caused by ionization of gasses during deposition. All this occurs inside of a sealed vacuum environment called a Sputter Deposition Chamber. To obtain our data for Spectroscopic analysis, we ensure that we can acquire light from the sputter chamber. Most likely the sputter chamber has a glass window allowing easy viewing of the process of sputtering. While deposition occurs, light

emitted from the Sputter Chamber is used for spectroscopic analysis. With Spectrography we can find elements that are present within the thin film solar cell. To ensure the elements that we find are indeed what they are, we use a common reference NIST (National Institute of Standard and Technology). We used NIST in finding the type of elements present within layers of thin film solar cells. Spectrography gives an insight of how efficiency is affected within a solar cell, by telling us what contaminants exist within it.

Zachary Ferraro, "*Nano-Magnet Growth in Thin Films*," (A. Lukaszew)

In this project we wished to create nano sized magnets in a thin film. There are several ways to create such magnets, growing thin films of ferromagnetic metals, laser etching them, or creating masks to evaporate the metals through. All these techniques limit the amount you can restrict the dimensions of the magnets. To get nano-magnets which were truly small in each dimension, we had to take a different approach than what is traditionally taken when creating nano-magnets. Our choice was to use ion implantation, traditionally avoided because of lack of any accuracy in creating any structure. But our goal was not to make regular structures, just small ones, so ion implantation was a reasonable choice. We wanted to do this because interesting effects occur when you reduce the dimensions of a magnet. This is evident when the thickness is reduced, but the reduction of the other two dimensions is relatively unexplored.

Patrick Hunley, "*Sputter Deposition of Fe_2O_3/In Films for Photoelectrochemical Hydrogen Production*," (W. Ingler/X. Deng)

Indium-doped Fe2O3 films were created by RF magnetron sputter deposition at temperatures ranging from 150ºC to 250ºC with a deposition rate of 100 watts for Fe2O3 and deposition rates ranging from 5-20 watts for Indium in both an Argon atmosphere and an Argon/Oxygen atmosphere. The effects of the Indium doping on Iron Oxide's conductibility, band gap, stability, and photoactivity in a 5.9M KOH solution were examined for possible future use in a-Si triple-junction solar cells.

Jacob Warner, "*Ab Initio Calculations for Properties of MAX Phases Ti2GaN, V2GaN, and Cr2GaN*," (S. Khare)

Using ab initio calculations we have computed the lattice constants, bulk moduli, and local and total density of states of the MAX phases, Ti_2GaN, V_2GaN, and Cr_2GaN in the hexagonal $P6_3/mmc$ space group. The results for lattice constants are in reasonable agreement with experiments. The bulk moduli are predicted to be 158, 170, and 180 GPa respectively. The electronic density of states shows that all three materials are conducting and that the Cr_2GaN compound is the most conducting.

Randolph White, II, "*Electron Tunneling through a Metal Semiconductor Junction*," (V. Karpov)

Quantum tunneling is the physical phenomenon that allows particles to pass through seemingly impenetrable barriers. The overall purpose of my project was to in some small way contribute to the further understanding of quantum tunneling. More specifically my assignment was to emulate the statistical output (current readings) of lab research that showed signs of electron tunneling through a

barrier created within a metal semiconductor. I ultimately accomplished this with a computer program written in the C++ programming language. The final program consists of two particles moving randomly within a barrier of controlled size. The location of each particle is simultaneously recorded 50 times, almost like a snapshot of the particles' movement within the barrier. At each new set of locations the program determines the best possible path an electron would take in order to pass from one side of the barrier to the other via quantum tunneling. This output is then turned into graphical data which can be compared to the original lab statistics for similarity.

Optical Physics

Kevin Wells, "*Optical Analysis of Thin Films for Photovoltaics Technology: Spectroscopic Ellipsometry of Multi-Layer Transparent Conducting Oxide Films*," (R. Collins)

Spectroscopic ellipsometry (SE) is extremely useful in photovoltaics research for determining the optical properties of solar cells from the polarization state change that occurs when polarized light is reflected at an oblique angle from the surface. Tec-15 glass is a commercially produced glass that is coated with transparent conducting oxide layers and is used as a substrate in the production of solar cells. Using various techniques, we have developed a model for the dielectric functions of the layers on Tec-15 glass that leads to an improvement in the quality of the fit to SE data over that provided by previous models. This improvement came primarily from substituting Tauc-Lorentz oscillators for Lorentz oscillators in the previous models. Further analysis found that this model can be further improved in the future through the use of transmittance measurements in addition to the SE measurements.

Plasma Physics

Christopher Muscatello, "*Calculation of UV Production Efficiencies in the Glow Discharge Cathode Fall of Ne/Xe Mixtures*," (A. Shvydky/C. Theodosiou)

A one-dimensional Monte-Carlo / Particle-in-cell kinetic code was used to simulate a self-sustaining glow discharge between two electrodes. The code provided calculation of the electric potential, electric field, charged-particle densities, and distribution among particles of power dissipation along the length of the discharge. The distribution of power dissipation among electrons and ions in the cathode fall region was studied for nine different Ne/Xe mixtures at varying applied voltages. From this, UV production efficiencies were calculated for each unique Ne/Xe-mixture-and-applied-voltage combination.

NSF-REU External Publications and Presentations*
(Calendar Year 2005)

REFEREED PUBLICATIONS - Submitted/accepted/published.

1. **J. A. Warner (2005)**, S. K. R. Patil, S. V. Khare, K. C. Masiulaniec, "*Ab Initio Calculations for Properties of MAX Phases Ti_2TlC, Zr_2TlC, and Hf_2TlC*," (Applied Physics Letters, submitted).

2. **J. A. Warner (2005)**, S. K. R. Patil, S. V. Khare, K. C. Masiulaniec, *"Ab Initio Calculations for Properties of MAX Phases Ti_2GaN, V_2GaN, and Cr_2GaN*," (Physical Review B Brief Reports, submitted).

REFEREED PUBLICATIONS - in preparation

1. **Andrew J. Larkoski (2005)**, D. G. Ellis, and L. J. Curtis, *"Numerical implementation of the Einstein-Brillouin-Keller quantization for arbitrary potentials"*, (expected journal: American Journal of Physics).

2. **C. Muscatello (2005)**, "*Calculation of UV Production Efficiencies in the Glow Discharge Cathode Fall of Ne/Xe Mixtures*," (expected journal: Journal for Undergraduate Research in Physics).

3. A.A. Shvydky, **C. Muscatello (2005)**, C.E. Theodosiou, "*Estimation of UV Production Efficiencies in DC Cathode Fall in Ne/Xe Mixtures*," (expected journal: Plasma Sources Science and Technology).

4. A. Ritchey, **M. Martinez (2002)**, K. Pan, S.R. Federman, and D. L. Lambert, *"The Nature of Interstellar Gas toward the Pleiades Revealed in Absorption Lines*," (expected journal: The Astrophysical Journal).

REFEREED PUBLICATIONS - update on previous report

1. **J.D. Thomas (2001, 2003)**, G.S. Hodges, D.G. Seely, N.A. Moroz, and T.J. Kvale, "*Performance Enhancement Study of an Electrostatic Faraday Cup Detector,*" Nucl. Instrum. and Meth. A. 536, 11 (2005). Listed in last year's report as "accepted".

PRESENTATIONS.

1. **D. V. Camper (2005)**, C. Lind*, J. Colin, "*Low Temperature Routes to Negative Thermal Expansion Material in the ZrW_2O_8 Family*," Sixteenth (16th) Annual Argonne Symposium for Undergraduates in Science, Engineering and Mathematics, Argonne National Laboratory, November 4-5, 2005 (Abstract: 113).

2. **Miguel Cervoni (2005)**, "*Beam Transport in the UT-P/NIELS Accelerator*," The Seventh Annual Mid-Atlantic Regional Conference of Undergraduate Scholarship (MARCUS), Sweet

Briar College, Saturday October 8, 2005.

3. **Kevin Wells (2005)**, "*Optical Analysis of Thin Films for Photovoltaic Technology: Spectroscopic Ellipsometry of Multi-Layer Transparent Conducting Oxide Films*," Fall 2005 Meeting of the Ohio Section of the American Physical Society and the Northern Ohio Section of the AAPT, Cleveland State University, October 14-15, 2005 (D1.4)

4. **Zachary Ferraro (2005)**, John Skuza, Fonsie Guilaran, Ale Lukaszew, "*Growth and Characterization of Co-Implanted Epitaxial Thin Films of Copper on Silicon*," 2005 Sigma Xi Annual Meeting, November 3-6, 2005, Seattle, Washington (Poster PA-13).

5. G.S. Hodges, J. Kang, **J.D. Thomas (2001, 2003)**, T.J. Kvale, and D.G. Seely, "*Measurements of Total Cross Sections of the n = 2 Excitation of Helium from the Impact of 10-25 keV Protons*," Spring 2005 Meeting of the Ohio Section of the American Physical Society and the Southern Ohio Section of the AAPT, University of Dayton, April 08-09, 2005 (D1.00001)

* REU students' names in **bold face type*** with year of participation.

VI. PROGRAM EVALUATION

NSF-REU Summer Research Program
Department of Physics & Astronomy
The University of Toledo
2005

(Total REU Participants: 12, Responses Received: 10)

To help us improve our summer research program in future years, please give us your confidential opinion on the following questions. Thanks very much.

Did this summer's experience live up to your expectations in general?

Definitely Yes			**Neutral**			**Definitely No**
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7

2005 mean (pop. 10): 2.0

How do you rate your research experience this summer in helping you get a better idea of what a career in scientific research might be like?

Very Helpful			**Neutral**			**Not Helpful**
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7

2005 mean (pop. 10): 1.8

How do you rate your summer research experience in helping prepare you for graduate study?

Very Helpful			**Neutral**			**Not Helpful**
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7

2005 mean (pop. 10): 2.9

How do you rate your faculty advisor's interactions in helping you in your summer research experience?

Very Helpful			**Neutral**			**Not Helpful**
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7

2005 mean (pop. 10): 2.5

How do you rate the weekly seminar series in helping you learn more about physics and astronomy?

Very Helpful			**Neutral**			**Not Helpful**
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7

2005 mean (pop. 10): 3.7

How do you rate the Social Activities organized by the REU Staff?

Very Enjoyable			**Neutral**			**Not Enjoyable**
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7

2005 mean (pop. 10): 2.4

How do you rate your summer experience personally?

Great Fun			**Neutral**			**A Real Drag**
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7

2005 mean (pop. 10): 1.9

How do you rate your summer experience educationally?

Learned a Lot			**Neutral**			**Not Worth Much**
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7

2005 mean (pop. 10): 1.9

How would you change the division of time between general activities (seminars, visits, outings) *vs.* research work.

More general learning			**Neutral**			**More research time**
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7

2005 mean (pop. 10): 4.2

What do you think about having some of the seminar talks on subjects such as: "choosing a graduate school", "careers in physics and astronomy", "how to achieve greater diversity among physicists", etc., rather than only the traditional scientific talks such as we had this summer?

A great idea			**Neutral**			**A waste of time**
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7

2005 mean (pop. 10): 2.4

What do you think about the average level of the weekly Bag Lunch talks?

Much Too Advanced			**About Right**			**Much Too Elementary**
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7

2005 mean (pop. 10): 3.1

How do you rate your research experience in terms of the freedom you had to do things your own way?

None: I did what I was told			**About Right**			**Too much: I got lost**
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7

2005 mean (pop. 10): 3.5

Were you given enough advance information before coming to Toledo to begin the summer?

Yes, the mailings in May were very helpful			**Neutral**			**No, I didn't know what to expect.**
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7

2005 mean (pop. 10): 3.3

Were you made to feel welcome when you arrived and comfortable overall in the program?

Yes, very much so			**Neutral**			**No, definitely not**
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7

2005 mean (pop. 10): 1.4

Please list the **best and/or worst** thing(s) about your summer experience (research and/or social/recreational).

"One of the best things about this REU program was the effort put in to make our off-time enjoyable. Everyone here was friendly and it was great to learn that graduate students are just 'regular people' who work hard."

"My professor was prepared for me w/ a research program setup."

"Best: General kindness and hospitality of the faculty within the Dept. of Physics and Astronomy.
Worst: Just the isolation as a student (not many folks on campus to interact with)."

"Best: Besides working in the lab, the dinner at Dr. Ellis & Dr. Compaan house.
Worst: Feeding ourselves."

"My advisor was gone 4 out of the 10 weeks of the program. Given more structure and guidelines as far as time management goes, I could have been more productive. Getting started on the report sooner would have helped me to turn it in sooner. Playing Frisbee 2-3 times a week and going out for pancakes were some of the best times this summer. All of the faculty and graduate students treated us like gold and made our stay VERY pleasant and enjoyable."

"There is not much to do in Toledo. The weekend activities helped, but apart from research, there wasn't much else. The best part was learning things I otherwise wouldn't be exposed to."

"I would have liked to do more work this summer. I spent many days sitting around with nothing to do. I loved the social activities that Stephanie planned. I had so much fun hanging out with everyone."

"<u>Best</u>:
- Bonding w/ REUer's
- Getting some sort of experience

<u>Worst</u>:
- Long walk to the International House."

"Best: Getting to work /on/with a professor, meeting students in physics from all over the US, making friendships, and actually learning things that I can apply to both future schoolwork, research & life.
Worst: Slightly unorganized with housing & tuition."

Please list any additional comments.

"One thing that would have been nice is more visits to the recreational center on campus. I know that the stereotypical physics major may get very little use from them but 15 isn't even twice per week! Other than that, everything has been great and I will recommend this program to my friends at home"

"The amount of work a student completed during the summer depended a lot on their advisor. Some students had slave drivers (well that may be a little severe) while others did VERY little. I never actually figured out which was more important: learning something about the research process, graduate school, and my project, or having a lot of research completed at the end. I tend to think the first was more important, but the expectations of each advisor for their student were NOT the same. It made knowing what to do exactly, difficult at times, b/c we really couldn't compare our project to anyone else."

"Bag lunch talks should talk more about graduate school

- getting accepted
- studies –> classes
- Research
- Programs."

"Overall, the REU experience was absolutely incredible and I will definitely recommend the U of T REU to friends back in UW."

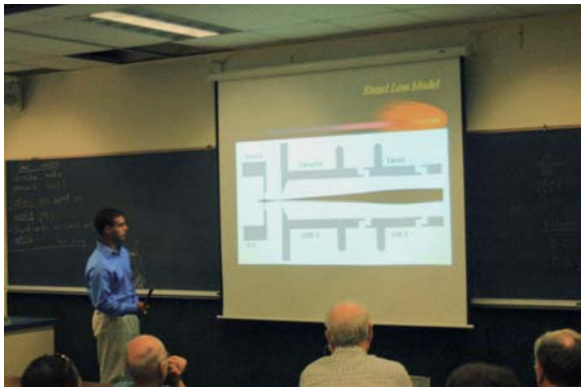
Thanks again for your time, and best wishes for continued success in everything you do. As part of the tracking we need (and want) to do, we need for you to tell us about your degrees received and your career activities (grad school, work, etc) after participating in our program. Please keep in touch with us!

Please return this questionnaire in the anonymous envelope provided to:

Sue Hickey
Department of Physics & Astronomy, M/S111
The University of Toledo
Toledo, Ohio 43606

VII. SUMMER 2005 PICTURES

Prof. Compaan and Sheriff Ceesay



Final Talk - Miguel Cervoni

Prof. Federman and Meredith Rogers

Windsurfing

Summer Camp 2005

LN2 ice cream at Summer Camp 2005