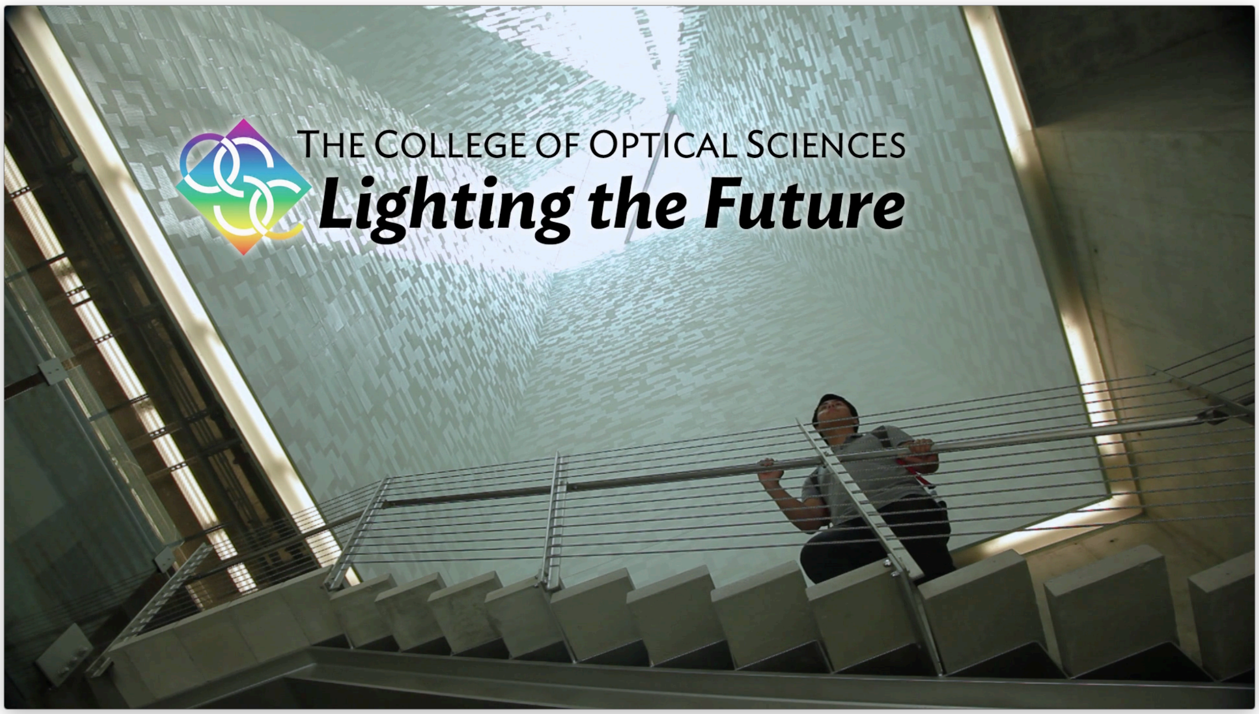
Optics and Photonics Winter School and Workshop



University of Arizona College of Optical Sciences

Tucson, Arizona

January 4, 2018 – January 8, 2018

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Optics and Photonics Winter School & Workshop 2018

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Schedule – Optics and Photonics Winter School 2018

Thursday, Jan. 4, 2018

(All sessions at Optical Sciences 307)

8:50	**Welcome**	Dean Tom Koch
9:00	*Introduction to Optical Physics*	Prof. Jason Jones
10:00	Break	
10:20	*Lasers*	Prof. Khanh Kieu
11:00	*It is Wonderful to Have a Career in Optics and Photonics*	Prof. James Wyant
11:40	**Lunch** (Optical Sciences)	
1:00	**Lab Tours**	
3:00	*Introduction to Photonics*	Dean Tom Koch
4:00	Break	
4:20	*Solar Energy*	Prof. Robert Norwood
5:00	*Nanophotonics*	Prof. Euan McLeod
5:40	Break	
6:00	**Lab Tours**	
7:00	**Dinner** (Gentle Ben's)	

Friday, Jan. 5, 2018

(All sessions at Optical Sciences 307)

9:00	*Introduction to Optical Engineering*	Prof. Jim Schwiegerling
10:00	Break	
10:20	*Lens Design*	Prof. Jose Sasian
11:00	*Adaptive Optics*	Prof. Michael Hart
11:40	**Lunch** (Optical Sciences)	
1:00	**Lab Tours**	
3:00	*Introduction to Image Science*	Prof. Lars Furenlid
4:00	Break	
4:20	*Tissue Optics and Biomedical Imaging*	Prof. Jennifer Barton
5:00	*Biosensing*	Prof. Judith Su
5:40	Break	
6:00	**Lab Tours** (Including the Richard F. Caris Mirror Lab)	
7:00	**Bus to La Quinta Inn and Suites**	
7:30	**Dinner and Poster Session** (La Quinta Inn and Suites)	

Schedule – Optics and Photonics Workshop 2018

Saturday, Jan. 6, 2018 (CAREER DAY)

(All sessions at Optical Sciences 307)

8:40 Tom Koch, University of Arizona
Welcome, Introduction to Optical Sciences at the UA

9:00 **Keynote:** Christian Drouet d'Aubigny
Optics for NASA's OSIRIS-Rex Mission

10:00 **Break**

10:30 Andrew Wall, Microsoft (UA Optics Alumnus)
The Role of Optics in Big 5 Tech Companies: The Yellow Brick Road to a Career in Consumer Electronics

10:50 Jed Hancock, Space Dynamics Laboratory (UA Optics Alumnus)
Vision

11:10 Panel discussion: Careers in Optics

12:00 **Lunch** (Optical Sciences)

1:30 Bonnie Peterson, SPIE
SPIE

1:45 David Hagan, University of Central Florida
Optics and Photonics at CREOL

2:10 Jenny Magnes, Vassar College
Nonlinear Time Series of Live Diffraction Signals in C. Elegans

2:35 Jonathan Ellis, University of Arizona
At the Intersection of Optics, Mechanics, and Biology

3:00 **Break**

3:30 Lowell McCann, University of Wisconsin – River Falls
The State of 'Beyond the First Year' Physics Labs and the Resources to Support Them

3:45 Mansoor Sheik-Bahae, University of New Mexico
Research and Education in Optics and Photonics at the UNM, and Advances in Laser Cooling of Solids

4:10 Enrique Galvez, Colgate University
Interference One (or Two) Photons at a Time

4:35 Brett Pearson, Dickinson College
Single-Photon Experiments in (and out of) the Classroom

5:00 **Lab Tours** (Including the Richard F. Caris Mirror Lab)

7:00 **Banquet** (Silver and Sage Room, UA campus)
After Dinner Speaker: Dae Wook Kim, University of Arizona

Sunday, Jan. 7, 2018

(All sessions at Optical Sciences 307)

9:00 **Keynote**: Aydogan Ozcan, University of California Los Angeles
Computational Microscopy, Sensing and Diagnostics

9:50 Scott Carney, University of Rochester
Optics and Photonics at the University of Rochester

10:15 **Break**

10:45 Marty Baylor, Carleton College
Holographic Materials for Optical Signal Processing

11:10 Nathan Lysne, University of Arizona
Analog Quantum Simulation: Quantum Computing in the Near Term

11:35 David Hanneke, Amherst College
Optical Control of Atomic and Molecular Quantum States

12:00 **Lunch** (Optical Sciences)

1:30 **Keynote**: Richard Peterson, Bethel University
On the Joys of Teaching Experimental Optics

2:20 Amy Lytle, Franklin and Marshall College
Converting Light at F&M

2:45 Eric Black, Caltech
Teaching and Learning in Advanced Exp. Physics Labs: ALPhA's Lab Immersion Program

3:10 **Break**

3:30 Greg Gbur, University of North Carolina - Charlotte
Optical Science and Engineering at UNC Charlotte

3:55 Scott Kirkpatrick, Rose Hulman Institute of Technology
A Design Class in the Cleanroom

4:20 Kenneth Singer, Case Western Reserve University
Nano-optics at Case Western Reserve University

4:45 **Break**

5:00: **Keynote:** Charles Falco, University of Arizona
Optics and Art History

5:40 **Lab Tours/Free Time**

7:00 **Dinner** (Culinary Dropout)

Monday, Jan. 8, 2018 (Immersion Day)

(Morning and Wrap-up Sessions in Optical Sciences 307)

9:00 Overview and Instructions

9:30 Session I

12:00 **Lunch**

1:30 Session II

4:00 Wrap-up

6:00 Dinner (Optical Sciences)

Abstracts – Workshop Oral Presentations

Saturday, Jan. 6, 2018

9:00 Keynote: Christian Drouet d'Aubigny, University of Arizona
Optics for NASA's OSIRIS-Rex Mission

The OSIRIS-REx spacecraft is traveling to Bennu, a carbonaceous asteroid whose regolith may record the earliest history of our solar system. Bennu may contain the molecular precursors to the origin of life and the Earth's oceans. Bennu is also one of the most potentially hazardous asteroids, as it has a relatively high probability of impacting the Earth late in the 22nd century. OSIRIS-REx will use a complement of remote sensing instruments spanning the electromagnetic spectrum from X-rays all the way to the far infrared to map and navigate around the asteroid, determine Bennu's physical and chemical properties, and guide the spacecraft to a location where the spacecraft will take a sample of the asteroid to return to Earth for analysis. This presentation will introduce the optical remote sensing and navigation instruments onboard the OSIRIS-REx spacecraft and take a more in depth look at the design, fabrication, qualification, and calibration of the three camera systems which make up the OSIRIS-REx Camera Suite (OCAMS) that was developed at the University of Arizona.
Learn more about OSIRIS-REx: **click here**

10:30 Andrew Wall, Microsoft (UA Optics Alumnus)
The Role of Optics in Big 5 Tech Companies: The Yellow Brick Road to a Career in Consumer Electronics

10:40 Jed Hancock, Space Dynamics Laboratory (UA Optics Alumnus)
Vision

1:30 Bonnie Peterson, SPIE
SPIE

1:45 David Hagan, University of Central Florida
Optics and Photonics at CREOL

CREOL, the Center for Research and Education in Optics and Lasers was created to assist the development of the optics and laser industry in central Florida. Of the many ways to achieve this goal, by far the most significant is the creation of programs to educate a workforce to supply talent to the industry. Thus the College of Optics and Photonics was born. We will describe how our programs at the PhD, Masters and Bachelor's degree levels have developed over the years to meet the needs of the optics and photonics industry.

2:10 Jenny Magnes, Vassar College

Nonlinear Time Series of Live Diffraction Signals in C. Elegans

Microorganisms locomotion is presently understood by taking a video of a moving microorganism under a microscope, then performing video analysis on the collected data. This method is time-consuming, computationally heavy and omits subtle components of the motion. Time dependent diffraction signals are a complimentary method that speeds up aspects of the data collection and analysis. It maintains an accurate worm structure and reduces user error.

Caenorhabditis elegans nematodes, or *C. elegans*, were used to generate motion data. These nematodes are a model organism with a simple, bilaterally symmetrical structure that makes them ideal for the analysis of microscopic locomotion. A mutant "Roller" OH5747 with a restricted range of motion was selected for further simplification, as its oscillating motion tends to be confined to one side.

A spectral analysis of diffraction patterns generated by directing laser light at *C. elegans* in a cuvette has been conducted. A nonlinear time series analysis of nematode diffraction data is presented for mutant (roller type) and non-mutant (wild type) *C. elegans*. The Largest Lyapunov Exponents of roller and wild type C. elegans are found to be 1.56±0.64 and 0.91±0.42 (base *e*) respectively, which indicates that motion of these nematodes is chaotic.

2:35 Jonathan Ellis, University of Arizona

At the Intersection of Optics, Mechanics, and Biology

3:30 Lowell McCann, University of Wisconsin – River Falls

The State of 'Beyond the First Year' Physics Labs and the Resources to Support Them

Undergraduate physics laboratory experiences after the introductory sequence are not as common nor as uniform as faculty may believe. I will discuss what the Advanced Laboratory Physics Association (ALPhA) has learned about the state of these courses around the nation and the resources that exist to support faculty and staff who teach them.

3:45 Mansoor Sheik-Bahae, University of New Mexico

Research and Education in Optics and Photonics at the UNM , and Advances in Laser Cooling of Solids

In the first part of this talk, I will provide an overview of the Optical Science and Engineering (OSE) graduate program at UNM. Established in mid 1980's, this program has >25 affiliated faculty, and currently enrolls >70 PhD and MS students in various tracks of Optical Sciences, Photonics, Imaging Science and Quantum Optics.

In the second part, recent advances in laser cooling in solids or "optical refrigeration" will be reviewed. Most recently, our group has demonstrated laser cooling of Yb:YLF to <90K which has subsequently led to the world's first all-solid-state cryocooler prototype. In parallel, this concept has been applied to developing lasers without internal heat generation also known as radiation-balanced lasers (RBL). I will discuss demonstration of such "athermal' laser operation in Yb:YAG and Yb:YLF thin-disk lasers.

4:10 Enrique Galvez, Colgate University

Interference One (or Two) Photons at a Time

Experiments with individual photons offer us a window into striking aspects of quantum physics predicted by quantum mechanics. At the heart of these experiments is quantum interference. Exploiting this phenomenon through various experiments with single photons helps us learn more deeply about the fundamentals quantum physics. In this talk I will present experiments with entangled photons that illustrate quantum interference, which also makes us think more deeply about light itself.

4:35 Brett Pearson, Dickinson College

Single-Photon Experiments in (and out of) the Classroom

Recent advances in technology have decreased the cost and complexity of experiments investigating the quantum mechanical nature of light. We have incorporated a series of experiments into our curriculum, with the primary motivation of bringing undergraduate students face to face with some of the fascinating and subtle aspects of quantum mechanics in a hands-on setting. Building on notions of classical wave interference, sophomore-level students are introduced to the quantum aspects of light through labs demonstrating the existence of photons, single-photon interference, and the quantum eraser. The classroom experiences have inspired a number of senior research projects, including a test of Bell's theorem. We present an overview of our approach and discuss a current project looking at interference from partially-coherent sources with an eye towards “ghost interference.”

Sunday, Jan. 7, 2017

9:00 Keynote: Aydogan Ozcan, University of California Los Angeles
Computational Microscopy, Sensing and Diagnostics

My research focuses on the use of computation/algorithms to create new optical microscopy, sensing, and diagnostic techniques, significantly improving existing tools for probing micro- and nano-objects while also simplifying the designs of these analysis tools. In this presentation, I will introduce a new set of computational microscopes which use lens-free on-chip imaging to replace traditional lenses with holographic reconstruction algorithms. Basically, 3D images of specimens are reconstructed from their “shadows” providing considerably improved field-of-view (FOV) and depth-of-field, thus enabling large sample volumes to be rapidly imaged, even at nanoscale. These new computational microscopes routinely generate >1–2 billion pixels (giga-pixels), where even single viruses can be detected with a FOV that is >100 fold wider than other techniques. At the heart of this leapfrog performance lie self-assembled liquid nano-lenses that are computationally imaged on a chip. These self-assembled nano-lenses are stable for >1 hour at room temperature, and are composed of a biocompatible buffer that prevents nano-particle aggregation while also acting as a spatial “phase mask.” The field-of-view of these computational microscopes is equal to the active-area of the sensor-array, easily reaching, for example, >20 mm^2 or >10 cm^2 by employing state-of-the-art CMOS or CCD imaging chips, respectively.

In addition to this remarkable increase in throughput, another major benefit of this technology is that it lends itself to field-portable and cost-effective designs which easily integrate with smartphones to conduct giga-pixel tele-pathology and microscopy even in resource-poor and remote settings where traditional techniques are difficult to implement and sustain, thus opening the door to various telemedicine applications in global health. Some other examples of these smartphone-based biomedical tools that I will describe include imaging flow cytometers, immunochromatographic diagnostic test readers, bacteria/pathogen sensors, blood analyzers for complete blood count, and allergen detectors. Through the development of similar computational imagers, I will also report the discovery of new 3D swimming patterns observed in human and animal sperm. One of this newly discovered and extremely rare motion is in the form of “chiral ribbons” where the planar swings of the sperm head occur on an osculating plane creating in some cases a helical ribbon and in some others a twisted ribbon. Shedding light onto the statistics and biophysics of various micro-swimmers’ 3D motion, these results provide an important example of how biomedical imaging significantly benefits from emerging computational algorithms/theories, revolutionizing existing tools for observing various micro- and nano-scale phenomena in innovative, high-throughput, and yet cost-effective ways.

9:50 Scott Carney, University of Rochester
Optics and Photonics at the University of Rochester

10:45 Marty Baylor, Carleton College
Holographic Materials for Optical Signal Processing

Although holograms can be used to create amazing 3D images, they can also facilitate manipulating optical information. In this talk, I will introduce some of my work with photorefractive crystals and diffusive photopolymers and how these materials can be used to make interesting devices based on holography.

1:10 Nathan Lysne, University of Arizona

Analog Quantum Simulation: Quantum Computing in the Near Term

The state-of-the-art in controlling quantum systems has advanced dramatically over the past decade. While there are many systems, such as trapped ions and superconducting circuits, that seem promising for building universal digital quantum computers, that eventual goal is still thought to be many years in the future. Fortunately, a quantum computer may not have to be universal and/or digital to be useful for solving problems today. Through analog quantum simulation, using one well-controlled system to model the behavior of another, we may be able to shed light on complex phenomena like quantum many-body physics that are currently difficult to study otherwise. A number of research groups are already using their rudimentary quantum processors for this kind of analog simulators today, and several are thought to be on the cusp of investigating novel physics. However, as they push beyond what we can verify with classical methods, there are open questions rooted in our experience with analog classical computers as to how confident we can be in the outcomes of such analog simulations. This overview will cover the basic ideas behind analog computing and analog quantum simulation, work we have done using our ultracold atom experiment as a quantum simulator of chaotic systems. Along the way I will highlight a few contributions to the project by undergraduate students participating in REUs.

11:35 David Hanneke, Amherst College

Optical Control of Atomic and Molecular Quantum States

Exquisite control of atomic quantum states has enabled timekeeping at the parts-per-quintillion level, precise investigation of fundamental physics, and the first steps towards large-scale quantum information processing. There are prospects for molecules to contribute to each of these fields as well. Because of their additional degrees of freedom, molecules can have enhanced sensitivity to certain new physics models, such as parity- and time-reversal violation or time-variation of the proton-to-electron mass ratio.

I will discuss work in my lab using lasers to control the quantum states of atoms and molecules with the ultimate goal of searches for new physics. We work with oxygen molecular ions and co-trap them with beryllium atomic ions, which cool the ions' motion in the trap. I will discuss resonant multi-photon ionization of the atomic and molecular ions as well as plans for precision spectroscopy of the molecules. Undergraduates have made important contributions in the lab, including work on laser frequency control and nonlinear optics.

I will briefly describe other optics work at Amherst College.

1:30 Keynote: Richard Peterson, Bethel University

On the Joys of Teaching Experimental Optics

50 years ago I was greatly impacted while serving as an optics graduate teaching assistant at Michigan State, and that experience (much more than formal research) led directly to a postdoc at Los Alamos doing optical plasma measurements. I will highlight several subsequent challenging optics-lab teaching experiments that have been personally satisfying and fun, while it has sometimes been tricky to find experiments that creatively engage and challenge a very diverse group of students. We will reflect on some uses of light interference: stroboscopic real-time holographic interferometry, imaging sound in gas-filled resonators, and an interferometric Faraday effect study.

2:20 Amy Lytle, Franklin and Marshall College

Converting Light at F&M

I will give an overview of some of the research happening in optics at Franklin & Marshall College, an undergraduate-only liberal arts college in Lancaster, PA. Along with my colleague and collaborator (and husband), Etienne Gagnon, I've established a research lab where we work on methods of frequency conversion using ultrafast lasers. In one project, we're examining an all-optical method for quasi-phase matching second harmonic generation. In another, we're developing new tools for generating terahertz radiation and doing terahertz spectroscopy that can be used with low-powered laser systems. Finally, I'll briefly describe the Optics course we've developed as the intermediate lab component of our physics and astrophysics curriculum.

2:45 Eric Black, Caltech

Teaching and Learning in Advanced Exp. Physics Labs: ALPhA's Lab Immersion Program

Once upon a time, all physicists could agree on what should be taught in an undergraduate laboratory curriculum. Every physicist, no matter what school they attended, would have been exposed to Geiger counters, the Wheatstone Bridge, and perhaps the Milliken oil-drop experiment. As physics has grown more sophisticated and more diverse, the number of experiments available at the advanced undergraduate level has proliferated wildly. Many, many people at a variety of institutions have built exciting undergraduate teaching labs with experiments in fields ranging from condensed matter to cold atoms to quantum optics. With few exceptions every program is now unique, and that is a wonderful thing.

In 2011 the Advanced-Lab Physics Association, or ALPhA, initiated a program to bring together people who teach junior- and senior-level experimental physics. It is called the ALPhA Immersion Program, and it is a series of workshops where advanced-lab teachers visit each others' labs, do the experiments there, and learn from each other in a three-day workshop.

In this talk I will give an overview of the program, with highlights from past and upcoming workshops, and lessons learned so far.

Teaching advanced physics lab can be one of the most challenging experiences in undergraduate education, but it is often also the most rewarding.

3:30 Greg Gbur, University of North Carolina - Charlotte

Optical Science and Engineering at UNC Charlotte

We will take a look at the people, places and things that make up the Optical Science and Engineering graduate program at the University of North Carolina at Charlotte. This includes a description of some of the faculty and their research, the facilities available for optics research (and information about the city of Charlotte itself), and the graduate courses available and required to get an M.S. or Ph.D in Optical Science and Engineering. The Department currently has 25 faculty total, 15 of whom have a background and interest in optics; including those in other departments, the total optics faculty numbers 30. There are 51 PhD students currently enrolled in our interdisciplinary program, and we're always looking for more.

3:55 Scott Kirkpatrick, Rose Hulman Institute of Technology

A Design Class in the Cleanroom

Cleanroom fabrication is great place to develop your own devices, but most labs in a clean room environment are "cook book" processes, often for good reasons. We have developed a follow-on course to our semiconductor fab class that allows the students to understand more of the design put into a device by creating their own semiconductor devices. Starting with process development, following with layer design, and finishing with device fabrication, students take ten weeks to create and test their own devices made in the cleanroom. For the first four weeks the students write standard operating procedures(SOP's) for the equipment in the lab. These procedures are to be followed by their peers in the final six weeks to finish their devices. The students successfully build and test FET's while expanding the library of available procedures for others to follow.

4:20 Kenneth Singer, Case Western Reserve University

Nano-optics at Case Western Reserve University

Case Western Reserve University (CWRU) was the location of one of the most important physics experiments of the 20th century: the Michelson-Morley experiment, which overturned the aether theory of electricity and magnetism and paved the way for Einstein's theory of relativity. In addition, Albert Michelson was the first American to win the Nobel Prize for his measurement of the speed of light. He was one of the founding members of the Case physics department. In this spirit, the CWRU physics faculty has a group of optics experimentalists whose research focuses on the interaction of light and matter at the nanoscale. In this presentation, I describe three lines of research carried out by me and Profs. Pino Strangi and Jesse Berezovsky.

I start with a short description of Prof. Strangi's work in developing miniaturized plasmonic biosensor platforms which outperform current sensing technologies and are based on hyperbolic metamaterials that support highly confined bulk plasmon modes coupling to biological materials and fascinating bio structures. In Prof. Berezovsky's laboratory, the interactions between light and single spins or nanoscale spin textures reveal the dynamics of coherent spin states for quantum sensing or quantum computing applications, and lead to new ways of manipulating spin textures for data storage or processing.

My own work examines the ultrastrong coupling regime of cavity polaritons, where dually resonant photons and excitons produce a system where the identity of light and matter are inextricably mixed. We have been investigating organic excitonic materials which uniquely display this optical coupling in the ultrastrong regime at room temperature. We have studied coupling in double cavity structures leading to new physics and potential application in lasers, nonlinear optics and optical data processing.

5:00 Charles Falco, University of Arizona

Optics & Art History

In this talk I will show optical evidence for discoveries made with the artist David Hockney that convincingly demonstrate optical instruments were in use -- by artists, not scientists -- nearly 200 years earlier than commonly thought possible, and that account for the remarkable transformation in the reality of portraits that occurred early in the 15th century.

Poster Session

7:30 pm. Friday, Jan. 5, 2017

Poster 1 – Claire Carlin, Amherst College

Effect of Microwaves on Cycling Thallium Fluoride

Thallium fluoride (TlF) is an ideal molecule to look for a permanent nuclear electric dipole moment due to the strong internal electric field experienced by the Tl nucleus and its potential for unit detection efficiency due to optical cycling. Cycling occurs when a particular transition is repeatedly excited, emitting several photons. We hope to achieve sufficient cycling so that a particular molecule state can be detected with unit efficiency. When molecules enter hyperfine dark states, they cease to cycle, but applying microwaves mixes these hyperfine dark states and allows for greater cycling.

Poster 2 – Lauren Weiss, Amherst College

Relatively blue red laser to manipulate topological defects in Bose-Einstein condensates

This project aims to create an intensity-controlled 660nm wavelength laser to manipulate Bose-Einstein condensates. To do so, I built a circuit that controls and stabilizes the laser beam intensity using feedback from a photodiode to an acousto-optic modulator (AOM) which deflects part of the beam. Next, this stable, controlled beam will be shined onto the condensate to pin and manipulate vortices. Using this laser, which repels the atoms, we can hold a vortex in place then release it in a controlled way in order to study its time evolution.

Poster 3 – Ella Johnson, Bethel University

Frequency doubled source for atomic state lifetime measurement.

The uncertainty of the ytterbium optical clock is dominated by the knowledge of the Stark shift due to room temperature blackbody radiation. This can be improved by an accurate measurement of the 3D1 state lifetime. To this end, a frequency doubled laser source was prepared at 556 nm. Supported by NIST.

Poster 4 – Annelise Slattery, Bethel University

Singularities in spinor 87Rb Bose–Einstein condensates

A digital micromirror device was used to create and characterize optical beams that contain phase singularities. These singularities are to be imprinted on a spinor Bose-Einstein Condensate (BEC) of Rubidium-87 via a coherent two-photon stimulated Raman interaction, therein creating complex, spatially-dependent spin textures in the BEC. Supported by NSF.

Poster 5 – Max Werner, Bethel University

Optical Path Length Stabilization for Al^+ Optical Clock

The Ion Storage Group at NIST is developing atomic clocks that utilize optical transitions in trapped, laser-cooled ions as a frequency standard. One major source of laser instability is optical path length (OPL) fluctuations due to variations in the refractive index along the beam path. An interferometer was designed and implemented to characterize the laser instability due to OPL fluctuations. This measured instability was used to model the effect of laser frequency fluctuations on spectroscopy of the optical clock transition. A similar interferometer was then designed for the optical clock experiment as a method of active path length compensation.

Poster 6 – Gillian Kopp, California Institute of Technology

Search for SUSY with Delayed Photons at the Compact Muon Solenoid

The Compact Muon Solenoid (CMS) experiment records data from proton-proton collisions at the Large Hadron Collider (LHC) to search for physics beyond the Standard Model, test theories of supersymmetery (SUSY), and measure properties of known particles with higher precision. I present results from a neutralino dark matter search with simulation data, with the signature of two delayed photons. The research focuses on photon identification and uses a Boosted Decision Tree (BDT) algorithm for separation of neutralino signal vs. background. In addition, the BDT results are compared against the 2016 CMS cut based photon ID, and the BDT performs with higher accuracy.

Poster 7 – Bianca Cruz, California State Polytechnic University, Pomona

Programmable, Fully Automated Microfluidic Control Design and Fabrication with Application to Water-Oil-Water Double Emulsion Micro-Droplets for Single Cell Analysis

Microfluidic technologies in the last 10 years have revolutionized biological and chemical experiments. Multilayer microfluidic devices, which contain valves to control fluid manipulation, have been used for many applications including cell culture and analysis, biochemical screening, and clinical detection - benefitting both basic research and clinical diagnosis. Automation of microfluidic devices is crucial for robust and portable assay operation, particularly for investigation of many reagents. Currently, no affordable automated control system exists for operating such devices. With the Fordyce Lab, I have helped build an open source pneumatics system for operating up to 48 control inlets and 18 sample inlets on microfluidics devices and have helped compile full build details for release to the microfluidics community. I have applied this system to droplet microfluidics, a powerful set of techniques for encapsulating reagents within precisely controlled nL to pL volumes. Droplet assays make it possible to profile millions of reactions in parallel with very high throughput (>1000 drops/second) while requiring very low reagent volumes. Double emulsions are particularly attractive because they can be sorted via traditional flow cytometry and are a powerful tool for biological reactions. I have developed novel microfluidic devices of various channel heights to generate Water-Oil-Water (W-O-W) double emulsion micro-droplets to produce droplets of various shell sizes. Subsequently, I will test various surfactant mixtures to identify stability of the double emulsions to help automate and guide single cell analysis experiments in droplets.

Poster 8 – Madeline Chosy, Carleton College

Diffusion Induced Δn Amplification in Holographic Photopolymers.

Holographic photopolymers are limited in the index contrast they can achieve. Most academic results are limited to ~0.005 while commercial formulations achieve ~0.05. My research focused on using multiple exposures to amplify index contrast by a factor of 3, providing an alternative route to high contrast optical devices. Supported by NSF.

Poster 9 – Geoffrey Mo, Carleton College

Analysis of Lorentz Violation in the MICROSCOPE Experiment.

The weak equivalence principle (WEP) states that objects fall at the same rate independent of their composition. Through monitoring the differential acceleration of two test masses freely falling in space, the MICROSCOPE mission aims to test this principle. Lorentz invariance, the idea that physical results should not change based on the rotation or boost of the experiment, can also be tested with MICROSCOPE. The general framework provided by the Standard-Model Extension describes possible Lorentz-violating effects that result in a unique WEP-violating signature. By calculating the theoretical differential acceleration of the masses in the MICROSCOPE experiment we provide a template for the Lorentz-violation search with MICROSCOPE.

Poster 10 – Hannah Goldberg, Case Western Reserve University

Structure Motivated Mechanistic Modeling of Triphasic Force Dependent E-Selectin/Ligand Adhesion Behavior

Force-mediated leukocyte tethering to and rolling on vascular walls by adapting to changes in shear flow is facilitated by triphasic bond lifetime versus force behavior exhibited by E-selectin/ligand bonds. We created a mechanistic, network analysis based model to describe this behavior which has been fitted to data from flow chamber experiments on E -selectin/ligand complex adhesion from Wayman et al.[1]. Best fit parameters have further been compared to estimates obtained from protein structural data of similar and near-identical complexes, and shown to agree within highly reasonable limits. With improvements in structural analysis and more research into the effects of defects and mutations at the lectin/ligand interface, this modeling approach can eventually shed great light onto the processes of healing and other biological functions that rely on a triphasic bond lifetime behavior.

Poster 11 – Nathaniel Hoffman, Case Western Reserve University

Tunable Black Gold: Controlling the Near-Field Coupling of Immobilized Au Nanoparticles Embedded in Mesoporous Silica Capsules

Efficient light-to-heat conversion is central to thermo-photovoltaics and solar steam generation. Excitation of surface plasmons can suppress metal reflection and convert a metal into a black metal. In this work, mesoporous silica capsules grafted with immobilized Au nanoparticles (NPs) with different sizes are synthesized. It is shown that changing the size of immobilized NPs modifies the interparticle coupling strength, thus, modifying the NPs absorption. The proposed approach broadens the possibilities of utilizing black gold in many applications.

Poster 12 – Nicholas Parrilla, Case Western Reserve University

Temperature Measurements of High-Z Plasma Exiting the Laser Entrance Hole of Ignition Scale Depleted Uranium Hohlraums

The temperature profile from the Laser Entrance Hole to 3.5 mm from the exit point was measured for plasma with high atomic number (high-Z) of Depleted Uranium ignition scale hohlraums. Each hohlraum was filled with 0.6 mg/cc He as part of the high foot CH campaign. Temperature of the flowing plasma is measured by fitting the velocity distribution to a Maxwellian and considering the Planckian spectral distributions with and without a 42 um Ge filter. The two spectra are then compared to determine the temperature of the high-Z plasma.

Poster 13 – Brianna Holmes, Colgate University

Polarimetry Imaging of Biominerals

The project I worked on this summer was called Polarimetry Imaging of Biominerals. Essentially, what I did was I shined light on a sample – either a sea urchin spine, pearl, or a various species of shell – using a Helium-Neon laser and I took a picture of either the reflected or transmitted light. The aim of the project was to use light to learn about a sample's microstructure. And by shining light on a sample and recording the reflected or transmitted light, we could determine not only if the sample influenced the light, but also *how* it influenced it. And by determining this *how*, it was then possible to learn about a sample's structure such as how its calcium carbonate layers – the material most biominerals are made up of – are formed.

Poster 14 – Ruth Strauss, Dickinson College

Implications of Double-Slit Interference Pattern Visibility for Ghost Interference

To understand and analyze double-slit interference with entangled photons one must first understand double slit interference from classical light sources. Double-slit interference patterns for partially-coherent light sources are presented. Experimental results are compared with mathematical models to analyze the visibility of the interference patterns. We show the effect of angular source size on the visibility and discuss the implications for ghost interference.

Poster 15 – Kaitlin Lyszak, Franklin and Marshall College

Generation and Detection of Terahertz radiation from an Photo-conductive antenna.

This research sought to find a more efficient way of generating terahertz with a photo-conductive antenna by preforming test with differing voltages and laser power. These tests showed that a higher voltage and laser power allowed for a higher signal-to-noise ratio of the terahertz but that saturation on the antenna reduced the ratio. To reduced saturation effects the laser beam was unfocused on the antenna, allowing the laser power to hit a larger surface area. The unfocused beam gave results 7 times larger then the focused beam.

Poster 16 – Hamzah Khan, Illinois Wesleyan University

Linear Position Detector with High Bandwidth

Position-Sensitive Detectors currently described in the literature can be divided into distinct categories: 'Spatial Light Separation Methods' (*e.g.*, Quadrant Photodiodes or D-Shaped Mirrors) and 'Electronic Signal Separation' (*e.g.*, so-called Position Sensitive Detectors). We argue that Spatial Light Separation Methods do not generally give *true* centroid positions and while Electronic Signal Separation Methods do give a linear response they come at a cost to bandwidth (< 100 kHz), which limits the kinds of systems that can be studied to those where the dynamics are 'not extreme.' Our project focuses on creating a 'hybrid' kind of detector, which is both accurate and extremely fast, a linear gradient "reflective filter" coupled to two small-area (*i.e.*, fast) photodiodes. Further, through the use of a DMD, which is an array of actuatable micro-mirrors that are highly reflective across the spectrum, such linear gradients may be multiplexed. The advantage, then, of the DMD-based approach over alternative methods of creating a linear gradient is that we can *dynamically* change (at 8 kHz) the gradient imposed, from horizontal to vertical, and even to radial gradients, thereby allowing "time-shared" measurements of x, y, and z motion of the centroid, where our measurement bandwidth (100 MHz or higher) is limited only by the photodiodes utilized, and not by the DMD. Anatolii Kashchuk, *et al*.[1] have demonstrated multiplexed high-bandwidth measurements within the context of one specific application (namely, tracking of an optically trapped bead). Our aim is to extend such methods to additional applications.

1. "High-speed position and force measurements in optical tweezers," A.V. Kashchuk, A.B. Stilgoe, T.A. Nieminen, H.H. Rubinsztein-Dunlop, *Optical Trapping & Optical Micromanipulation* (San Diego, Aug., 2017), Presentation 10347-44.

Poster 17 – Rachel Broughton, Rose-Hulman Institute of Technology

Propagation of Electric Field Waves in a DC Magnetron Plasma

This work superimposes an AC signal onto the high voltage supplied to the DC cathode to observe the effects within a magnetron plasma. A Langmuir probe was inserted into an argon DC plasma formed by a two-inch magnetron gun. The voltage from the probe was read on an oscilloscope in both the time domain, to obtain the appropriate IV-curve, and in the frequency domain, to observe if the driven frequencies propagated through the plasma. An 8 mm by 8 mm square probe was employed both parallel and perpendicular to the surface of the cathode. Variations depending on orientation were noted in the measured plasma temperature and density where typical density values of the observed plasmas were on the order of 10^10 cm^-3. The applied AC signal was detected in the time domain measurements only from probes oriented perpendicular to the surface of the cathode.

Poster 18 – Cobey McGinnis, University of North Carolina - Charlotte

Super Resolution Microscopy by Microspheres

Resolution is defined as the minimal distance between two objects that can be discerned by an observer or optical system. There are a multitude of resolution criteria which quantifies the resolution of the system. These all use point sources and all have different meaning and applications. The most meaningful criterions are Abbe, Rayleigh, Sparrow, and Houston. We focus on using the Houston criterion as the methodology for the resolution quantification in the Mesophotonics Laboratory at University of North Carolina Charlotte. According to this criterion the full width half at the maximum (FWHM) of the point spread function (PSF) is the resolution of the system. There are many components that degrade the quality of an image; these are generally known as aberrations. Ernst Abbe theorized that even with an aberration free optical system the achievable resolution is still limited due to the diffraction nature of light. This limit depends on the frequency of light that is used along with the acceptance cone from the object to the optical imaging system, $\varepsilon = \lambda/2NA$, where λ is the wavelength of light and NA is the numerical aperture of the optical system. This has become known as the, “classical diffraction limit,” and any resolution claims beyond this is considered to be in the realm of, “super-resolution.” Microspherical nanoscopy is a method that allows one to overcome this classical limit for imaging. This uses dielectric microspheres placed in contact with an object, which collect the objects’ optical near fields in order to relay information on the objects’ finer features and details. This information is presented in the form of a magnified virtual image. The depth and magnification of the virtual image depends on the refractive index contrast between the dielectric sphere and the surrounding medium as well as the separation distance between the sphere and the object, and on the diameter of the sphere. The theoretical mechanism of super-resolution imaging is debated in the literature [1]. It is generally accepted that the collection of the objects’ evanescent fields by the contact microsphere followed by the formation of a magnified image in the near-field proximity to the sphere are the key features of the super-resolution mechanism. Prof. Astratov’s group proposed the use of high-index ($n>1.8$) dielectric microspheres which made possible imaging of nanoplasmonic and biomedical samples with resolution ~ $\lambda/7$, far beyond the Abbe limit. Thus, in this area the development of new ways of collecting information about the objects encoded in their optical near fields has already resulted in applications of this technology for imaging subcellular structures and viruses with the resolution which is not achievable by standard microscopy.

[1] A.V. Maslov and V. N. Astratov, *Appl. Phys. Lett.* 108, 051104 (2016); 110,261107 (2017)

Poster 19 – Joseph Obeid, University of North Carolina - Charlotte

Design and Fabrication of a Thin Hologram Using the Nanoscribe Photonic Professional GT

Holograms reshape light wavefronts by diffraction through optical phase modulation. Micro-holograms are uneven surfaces, on the scale of microns, that when illuminated by monochromatic light, project an intensity image. We used the Nanoscribe Photonic Professional GT tool with direct-write laser lithography, a form of imprint lithography, to etch a hologram into a photoresist. The Nanoscribe accomplishes this via two-photon polymerization, inducing a hardening effect that can be used to shape and fabricate thin 3D structures. Using the Gerchberg-Saxton iterative algorithm, we optimized the performance of various hologram designs for a variety of test images. The design algorithm required the number of iterations and the addition of pixel “frames” as variable parameters for each image simulation. The computed intensities, contrast, and ratio of “noise” intensity to target intensity, were all numerically evaluated for each of the projected test images. An increase in pixel frames exhibited significant improvement in the contrast. In general, an increase in iterations results in an improvement of all three categories. The average computed target intensity reached a near maximum around 200 iterations and very slowly increased thereafter. The ratio of "noise" to the target intensity steadily decreased while the contrast showed a steady increase. The optimal image was chosen and its respective hologram was selected for fabrication with the Nanoscribe. The Nanoscribe interface software produced the structure with the following parameters: a) a variable number of phase levels; b) spacing between each exposure line; c) exposure scan speed, and; d) photoresist exposing laser power levels. A higher number of phase levels would allow for a better approximation during the fabrication of the hologram. Visible ridges in the hologram features could be kept at a minimum by setting the spacing between exposure lines below .1 microns. Slower scan speeds with higher laser power resulted in a better-defined structure with more precise edges. The best design combination was determined by producing several sample holograms. The parameters were then applied in the fabrication of a full size hologram. With such a large pixel count, full size holograms could only fit in the limited writing space of the Nanoscribe after being split into several tiles, each fabricated separately then stitched together. In conclusion, the Gerchberg-Saxton algorithm was employed to optimize the design of a micro-hologram. After, the Nanoscribe Photonic Professional GT tool allowed us to successfully perform direct-write laser lithography to produce sample micro-holograms and explore their fabrication parameters.

Poster 20 – Jaren Ashcraft, University of Rochester

Simulated Guide Stars: Adapting the Robo-AO Telescope Simulator

Robo-AO is an autonomous adaptive optics system that is in development for the UH 88" Telescope on the Mauna Kea Observatory. This system is capable of achieving near diffraction limited imaging for astronomical telescopes, and has seen successful deployment and use at the Palomar and Kitt Peak Observatories previously. A key component of this system, the telescope simulator, will be adapted from the Palomar Observatory design to fit the UH 88" Telescope. The telescope simulator will simulate the exit pupil of the UH 88" telescope so that the greater Robo-AO system can be calibrated before observing runs. The system was designed in Code V, and then further improved upon in Zemax for later development. Alternate design forms were explored for the potential of adapting the telescope simulator to the NASA Infrared Telescope Facility, where simulating the exit pupil of the telescope proved to be more problematic. A proposed design composed of solely catalog optics was successfully produced for both telescopes, and they await assembly as time comes to construct the new Robo-AO system.

Poster 21 – Cheris Congo, Vassar College

Temporal Diffraction Signal Analysis of *C. elegans* Locomotion

Current methods of analyzing microorganism movement require time-consuming video analysis, omit subtle motion components, and often involve manual data entry, making it subjective to user errors. We place the microorganism in a laser beam and monitor light intensity at a point off center within the resulting diffraction. A *C. elegans* with a mutation that restricts its movement was used as a sample organism due to its anatomical symmetry. Diffraction patterns contain information about the nematode's shape and locomotion. To better understand basic dynamic elements, we approximated the worm's motion and shapes using periodically rotating and translating rectangular segments at different speeds and directions. Resulting frequencies present in the Fast Fourier Transforms were identified, analyzed, and quantified. Individual segments were rotated and translated at a rate that matched those of a *C. elegans*' structure, assuming constant motion. The summation of these segments resulted in a closely-packed periodic function, similar to a mutant *C. elegans*' active thrashing pattern.

Poster 22 – Adam Wright, Willamette University

Magnetic Resonant Pulsing

Atoms with a magnetic moment experience a torque in an external magnetic field, leading to a precession of the atom's total angular momentum vector about the axis of the external magnetic field (Larmor Precession). This precession degrades the benefits obtained through optical pumping, a technique used to increase atomic fluorescence, through a redistribution of the atom's angular momentum. However, a technique known as magnetic resonant pulsing[1] suggests that laser light pulsed at the corresponding Larmor frequency can mitigate this degradation and increase atomic fluorescence by reestablishing the benefits of optical pumping. We test this technique by constructing a pulsed laser and measuring the fluorescence of rubidium atoms confined in various magnetic field configurations. Magnetic resonant pulsing has applications in optical magnetometry, atomic fluorescence, and laser guide stars.

[1]Kane, Thomas J., Paul D. Hillman, and Craig A. Denman. "Pulsed laser architecture for enhancing backscatter from sodium." Proc. of SPIE. Vol. 9148. 201.