Optics and Photonics Winter School and Workshop

University of Arizona College of Optical Sciences

Tucson, Arizona

January 5, 2016 – January 9, 2016

College of Optical Sciences
The University of Arizona

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Schedule – Optics and Photonics Winter School 2016

Tuesday, Jan. 5, 2016 Moderator: Prof. Poul Jessen

9:00	*Welcome*	Dean Tom Koch
9:10	*Optical Physics & Lasers*	Prof. R. Jason Jones
10:40	Break	
11:00	*Atom Optics*	Prof. Brian Anderson
12:00	Lunch	
1:30	*Quantum Optics*	Prof. Poul Jessen
2:20	Break	
2:40	*Biosensing with Optical Resonators*	Dr. Judith Su
3:30	Break	
4:00	*Lab Tours & Free Time*	
6:30	Dinner	

Wednesday, Jan. 6, 2016 Moderator: Prof. Jim Schwiegerling

9:00	*Introduction to Optical Engineering*	Prof. Jim Schwiegerling
10:40	Break	
11:00	*Interferometry and Optical Profilometry*	Prof. Jim Wyant
12:00	Lunch	
1:30	*Astronomical Optics*	Prof. Dae Wook Kim
2:30	Break	
2:50	*Thin film Optics*	Prof. Angus McLeod
3:40	Break	
4:00	*Lab Tours, including the Steward Observatory Mirror Lab*	
6:30	Dinner	

Thursday, Jan. 7, 2016 Moderator: Prof. Masud Mansuripur

9:00	*Optics in Biology and Medicine*	Prof. Jennifer Barton
10:20	Break	
10:40	*Applied Optics and Photonics*	Dr. Arturo Chavez
12:00	Lunch	
1:30	*Fiber Lasers and Optical Microscopy*	Prof. Khanh Kieu
2:20	Break	
2:40	*Infrared Fiber Lasers*	Dr. Shibin Jiang
3:30	Break	
4:00	*Careers in Optics*	Dr. Amber Dagel
4:30	*Careers in Optics: Panel*	Chavez, Dagel, Kieu, Kim
5:00	*Final Remarks*	Prof. Masud Mansuripur
5:15	*Free time*	
6:00	Dinner	
7:00:	Welcome Reception and Poster Session	

Schedule – Optics and Photonics Workshop 2016

Thursday, Jan. 7, 2016

7:00: Welcome Reception and Poster Session

Friday, Jan. 8, 2016

Morning Session Moderator: Masud Mansuripur

8:30 Dean's Welcome

8:45 Keynote: Eric Mazur, Harvard University

Confessions of a Converted Lecturer

10:00 Break

10:30 Kevin Jones, Williams College

Michelsons all the way down: Optics Experiments in the Williams College Physics Curriculum

11:00 Chad Hoyt, Bethel University

Low-cost fiber laser frequency combs for open-ended laboratory projects

11:30 Ertan Salik, California State Polytechnic University – Pomona

Optics Lecture, Lab, and Projects on Fiber Optic Sensors at Cal Poly Pomona.

12:00 **Lunch**

Afternoon Session Moderator: Dae Wook Kim

1:30 John Koshel, University of Arizona

The PhD Program in Optical Sciences at the University of Arizona

1:55 Lowell McCann , University of Wisconsin – River Falls

ALPhA's Impacts on Undergraduate Physics

2:15 Angela Ludvigsen, University of Wisconsin – River Falls

Whispering Gallery Modes Used to Characterize Levitated Aerosol Droplets in an Optical Trap

2:30 Ramen Bahuguna, San Jose State University

On Wave Particle Duality and The Classical Analog of Single Photon Double-Slit Experiment

3:00 Break

3:30 Jenny Magnes, Vassar College

Live Diffraction Patterns as a Path to Fourier Transforms

4:00 Jonathan Friedman, Puerto Rico Photonics Institute

Optics and Photonics for Space Weather Research.

4:30 Michael Hart, University of Arizona)

Taking the Twinkle Out of Stars with Adaptive Optics

5:00 Lab tours and free time

7:00 **Banquet**

Speaker: Prof. Roger Angel (University of Arizona), *Optics, Photonics, and Solar Energy*

Saturday, Jan. 9, 2016

Morning Session Moderator: Poul Jessen

8:30 Keynote: Charles Falco, University of Arizona

Optics at the Dawn of the Renaissance

9:15 Robert Bunch, Rose Hulman Institute of Technology

Evolution of optical engineering senior capstone design and curriculum

9:45 Alex Small, California State Polytechnic University – Pomona

Teaching Computation in Optics and Information Literacy in Computation

10:15 Break

10:45 Theresa Lynn, Harvey Mudd College

Toward Quantum Communication with Qudits: Measuring Orbital Angular Momentum Entangled Photon Pairs from SPDC

11:15 Arjendu Pattanayak, Carleton College

Entanglement in a 2-qubit system is related to the classical dynamics

11:45 Hyung Choi, Greenville College

Going beyond Bell¹s Inequalities by Quantum Hyper-entanglement

12:15 **Lunch**

Afternoon Session Moderator: R. Jason Jones

1:45 Rufino Diaz Uribe, National Autonomous University of Mexico (UNAM)

The development of Optics at the UNAM

2:15 R. Jason Jones, University of Arizona

Ultrafast optics from seconds to attoseconds

2:45 Austin Riedeman, Bethel University

Inexpensive ultrafast optics laboratory projects with mode-locked erbium fiber lasers

3:00 Break

3:30 Euan McLeod, University of Arizona

Developing field-portable biomedical imaging technologies

4:00 Final remarks

4:15 Discussion: *Ideas and plans for future workshops*

4:45 Lab tours and free time

7:00 **Group Dinner**

Sunday, Jan. 10, 2016

Activities (e. g., hiking, museum visits, and exploration of Tucson and its environment) can be arranged for interested students and/or faculty who are leaving later in the day.

Abstracts – Workshop Oral Presentations

Friday, Jan. 8, 2016

Morning Session

8:45 Keynote: Erik Mazur, Harvard University

Confessions of a Converted Lecturer

I thought I was a good teacher until I discovered my students were just memorizing information rather than learning to understand the material. Who was to blame? The students? The material? I will explain how I came to the agonizing conclusion that the culprit was neither of these. It was my teaching that caused students to fail! I will show how I have adjusted my approach to teaching and how it has improved my students' performance significantly.

10:30 Kevin Jones, Williams College

Michelsons all the way down: Optics Experiments in the Williams College Physics Curriculum

The teaching laboratory experiments associated with the standard sequence of physics major courses includes optics at all levels, starting with a (well known) experiment using a Michelson interferometer to measure the index of refraction of air and ending with an experiment - also involving a Michelson interferometer - to record the interference of non-classical light produced by a parametric down-conversion source. Non-physics majors also have the option to explore optics during a January term course on Holography that has been taught to 30 students a year for many years. This talk will lay out the sequence of experiments and highlight the details of a few.

11:00 Chad Hoyt, Bethel University

Low-cost fiber laser frequency combs for open-ended laboratory projects

Ultrafast optics and optical frequency combs can be valuable teaching and research tools. We describe a project to inexpensively bring both to the undergraduate context and graduate teaching laboratory. Over the past three years, open-ended project groups in Optics and Lasers courses at Bethel University have developed a mode-locked erbium fiber oscillator (~3400 USD), amplifiers, an auto-correlation apparatus (~2000 USD), and a parallel grating dispersion compensation apparatus (~1600 USD). Students have also made recent progress toward a self-referencing stabilization system that may result in an optical frequency comb. This talk will review the academic and laboratory contexts for these projects and describe particulars that may help implement similar work elsewhere. NSF #1208930.

11:30 Ertan Salik, California State Polytechnic University – Pomona

Optics Lecture, Lab, and Projects on Fiber Optic Sensors at Cal Poly Pomona

Cal Poly Pomona Physics and Astronomy Department offers Optics Lecture and Lab as optional courses to satisfy the major requirements. In the recent years, typically 30 students take the lecture and the lab class. The lecture includes topics for mostly wave optics, starting from electromagnetic wave propagation in dielectric media to polarization, interference, and diffraction. In the Optics lab, students select from a list of experiments on Fresnel reflection, polarizers and wave plates, stress-induced birefringence, diffraction and interference through slits and circular apertures, and semiconductor lasers. Students are asked to write a journal-style paper for each experiment, and they present on one of them.

We also offer opportunities for students to do undergraduate research in fiber optic sensors. Typically, about 8-10 students participate in research activities at any time involving students from physics, biology, and various engineering disciplines. We develop tapered fiber optic sensors for applications in biological sensing, and single mode-multimode-single mode fiber sensors for temperature or strain sensing.

Afternoon Session

1:30 John Koshel, University of Arizona

The PhD Program in Optical Sciences at the University of Arizona

1:55 Lowell I. McCann, University of Wisconsin – River Falls

ALPhA's Impacts on Undergraduate Physics

ALPhA, the Advanced Laboratory Physics Association, was formed in 2007 to provide faculty teaching non-introductory physics laboratory courses with forums in which to share ideas with their peers. In this talk, I will discuss ALPhA's activities over its first 8 years, the breadth of its impact, and directions for its future.

2:15 Angela M. Ludvigsen and Lowell McCann, University of Wisconsin – River Falls

Whispering Gallery Modes Used to Characterize Levitated Aerosol Droplets in an Optical Trap

A laser can be used as an optical trap to catch and hold small, transparent objects. Observations of optically trapped aqueous aerosol droplets have demonstrated that the droplet moves between two or more stable positions dependent upon the power of the trapping laser. It is hypothesized that this movement coincides with a resonance between the trapping light and the droplet's surface, called a Whispering Gallery Mode. When this resonance occurs, forces acting on the droplet cause it to move. To investigate this behavior, we use Cavity Enhanced Raman Spectroscopy (CERS) and the droplet's position to determine the size of the droplet and its refractive index to see if the movement is correlated with a resonance. In this talk, we will give an overview of optical trapping and show results of using CERS to characterize aerosol droplets.

2:30 Ramen D., Bahuguna, San Jose State University

On Wave Particle Duality and The Classical Analog of Single Photon Double-Slit Experiment

The double slit experiment using single photons has been a topic of debate for almost a century. The interference pattern obtained with single photons is essentially the same as with multiple photons. When the photons impinge on the slits one at a time, as in a single photon experiment, the interference pattern which in the beginning is akin to random dots gradually turns into a regular interference pattern provided one waits long enough. Feynman has discussed the phenomenon at length in his, "*Feynman Lectures on Physics*". The question is: how can one obtain an interference effect unless a single photon passes through both slits. To date there has not been any satisfactory explanation of the above phenomenon, often known as the "central mystery" of quantum mechanics. In this presentation I will introduce a classical analog of the single photon double slit experiment, which will shed light into what is physically going on at the slits.

3:30 Jenny Magnes, Vassar College

Live Diffraction Patterns as a Path to Fourier Transforms

Fourier analysis is generally considered one of the most challenging mathematical concepts. Fourier series are typically introduced analytically in electricity and magnetism using "Fourier's trick." Later Fourier transforms are introduced in other areas such as quantum mechanics. Fourier analysis and related concepts such as reciprocal space are often hard to digest for students and faculty. Using computational tools, Fourier transforms can be calculated without much mathematical background and the results can be verified experimentally using diffraction experiments. With this pathway, the students can build an intuition for these mathematically complex systems. The implementation in a four-year curriculum is presented here.

4:00 Jonathan Friedman, Puerto Rico Photonics Institute

Optics and Photonics for Space Weather Research

Optics have long provided tools for the study of Sun-Earth connections. Photonics is bringing new techniques to this research. At the Arecibo Observatory, lidars are employed to actively investigate the edge of space, at an altitude range of ca. 80-100 km where meteors disintegrate, and passive optical systems register vital data on the neutral atmosphere in which the ionospheric plasma is embedded. At the Puerto Rico Photonics Institute inertial sensor research and development explores use of in situ methods to increase our knowledge of the near-space environment through precision measurements of satellite drag. In this presentation, each of these methods will be presented, showing the techniques and some examples of observational results.

4:30 Michael Hart, University of Arizona

Taking the Twinkle Out of Stars with Adaptive Optics

When we look up at the night sky, the stars twinkle. The culprit is turbulent flow in the atmosphere, mixing air of slightly different temperatures, which bends the light rays in random and dynamic ways. The same process also degrades the image quality of large ground-based telescopes, blurring the images of astronomical objects to a substantially lower resolution than would be achieved in the absence of the atmospheric aberration. I will briefly describe what is happening in the air, how it affects image quality, and how sharp imaging may be restored through the techniques of adaptive optics in which the atmospheric aberration is sensed and corrected in real time. Along the way, I will review some of the significant astrophysical results that have been established by the use of adaptive optics.

Saturday, Jan. 9, 2016

Morning Session

8:30 Keynote: Charles Falco, University of Arizona

Optics at the Dawn of the Renaissance

Recently, renowned artist David Hockney observed that certain drawings and paintings from as early as the Renaissance seemed almost "photographic" in detail. Following an extensive visual investigation of western art of the past 1000 years, he made the revolutionary claim that artists even of the prominence of van Eyck and Bellini must have used optical aids. However, many art historians insisted there was no supporting evidence for such a remarkable assertion. In this talk I show a wealth of optical evidence for his claim that Hockney and I subsequently discovered during an unusual, and remarkably productive, collaboration between an artist and a scientist. I also discuss the imaging properties of the "mirror lens" (concave mirror), and some of the implications this work has for the history of science as well as the history of art (and the modern fields of machine vision and computerized image analysis). These discoveries convincingly demonstrate optical instruments were in use -- by artists, not scientists -- nearly 200 years earlier than commonly thought possible, and account for the remarkable transformation in the reality of portraits that occurred early in the 15th century.

(for more information see http://fp.optics.arizona.edu/ssd/art-optics/index.html)

9:15 Robert Bunch, Rose Hulman Institute of Technology

Evolution of optical engineering senior capstone design and curriculum

The undergraduate optical engineering program at Rose-Hulman Institute of Technology is accredited by the Engineering Accreditation Commission of ABET. One of the specific ABET criteria requires that all accredited degree programs must contain "a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints." Our capstone design course sequence and supporting curriculum has evolved over the past ten years and now consists of three courses, one taken in the spring of a student's junior year, and the other two taken during the senior year. The capstone project portion of the courses are team-oriented, deliverable-driven, and interdisciplinary (combining Optical Engineering and Engineering Physics majors). We have found that client-sponsored projects offer students an enriched engineering design experience as it ensures consideration of constraints and standards as well as an opportunity for regular customer interactions which help shape the product design. The evolution of this course sequence and a description of the current course contents will be discussed. In addition, an overview of the optical engineering curriculum that provides depth and breadth in optical engineering topics to prepare students for their design experience will be discussed.

9:45 Alex Small, California State Polytechnic University – Pomona

Teaching Computation in Optics and Information Literacy in Computation

I will describe the ways in which I have integrated two very different approaches to computation into two undergraduate classes. In the first example, most relevant to an audience focused on optics, I will describe how I have integrated ray-tracing activities in Zemax into an undergraduate optics course. One of the biggest challenges of teaching with Zemax is that it is, first and foremost, a tool for optical design engineers, but most physics faculty working in optics are not conversant in optical design engineering, and most undergraduate optics textbooks used in physics courses emphasize paraxial optics and wave optics over geometrical optics. I will describe how I developed Zemax assignments that play to the strengths of a physicist while also helping students learn enough about Zemax that they can subsequently learn whatever else they will need to know in the professional settings that they wind up in.

In my second example, I will discuss a project-based computational physics class. While emphasizing projects in computational physics is hardly novel, I recently took a new approach and started challenging students to come up with project topics that require them to test claims on Wikipedia or other websites not subject to professional peer review. I will describe some of the lessons learned (by both the students and the instructor) from blending information literacy with computational physics.

10:45 Theresa Lynn, Harvey Mudd College

Toward Quantum Communication with Qudits: Measuring Orbital Angular Momentum Entangled Photon Pairs from SPDC

We describe experimental progress in manipulating orbital angular momentum of entangled photon pairs from spontaneous parametric down-conversion (SPDC). Orbital angular momentum (OAM) provides an in-principle infinite-dimensional state space per particle; our present work is restricted to the OAM = -1, 0, +1 subspace but nevertheless should lead to quantum secret sharing and other experiments with qutrit and (polarization qubit) x (OAM qutrit) states. Our current OAM measurements are performed with forked-hologram blazed gratings, produced photographically in our own lab. These diffract into the first order with 37% efficiency while imparting an OAM shift to the diffracted beam. To perform measurement in an arbitrary superposition of the OAM 0 and +/- 1 states, a hologram is positioned in the beam and the first-order diffraction is coupled into a single-mode fiber. We present the current sensitivity of these OAM measurements, along with plans for further OAM measurements and manipulations using q plates that we will fabricate in house.

11:15 Arjendu Pattanayak, Carleton College

Entanglement in a 2-qubit system is related to the classical dynamics

We present a new analysis of entanglement in the quantum kicked top focusing on the time-averaged entanglement for initial spin coherent states. This work is in the regime of a few qubits, like recent experiments. We show a very strong connection between the classical phase-space and the average entanglement quantum phase-space, even at extreme quantum regime of 2 spin-1/2 qubits. We further show that this connection does not relate to the presence or absence of chaos in the classical dynamics. We show that the reason for the connection between classical and quantum phase-spaces is that both are organized around the symmetry points of the Hamiltonian (and the dynamics).

11:45 Hyung Choi, Greenville College

Going beyond Bell[1]s Inequalities by Quantum Hyper-entanglement

Quantum hyper-entangled states have been proved to be a powerful tool in quantum information process. Due to their multiple degrees of freedom, hyper-entangled systems also have shown to yield stronger violations of Bell[1]s inequalities. By making use of a hyper-entangled two-photon state, entangled in polarization and momentum, produced by a parametric down-conversion, we show that local realistic models cannot reproduce the results of quantum mechanical multi-degree entanglements.

Afternoon Session

1:45 Rufino Diaz Uribe, National Autonomous University of Mexico (UNAM)

The development of Optics at the UNAM

2:15 R. Jason Jones, University of Arizona

Ultrafast optics from seconds to attoseconds

2:45 Austin Riedeman, Bethel University

Inexpensive ultrafast optics laboratory projects with mode-locked erbium fiber lasers

We describe a set of relatively inexpensive ultrafast optics projects intended for undergraduate laboratories or introductory graduate optics teaching labs. These include the design and construction of a connector-based, mode-locked, erbium fiber laser oscillator (~3400 USD), an auto-correlation apparatus (~2000 USD) based on two-photon absorption in a common silicon photodiode, and a free-space, parallel grating dispersion compensation apparatus that can compress laser pulses to less than 200~fs. NSF #1208930.

3:30 Euan McLeod, University of Arizona

Developing field-portable biomedical imaging technologies

In the last few years, there has been an explosion in the capability of portable consumer computing and imaging technologies, such as smartphones and their integrated camera modules. This surge in technology can be harnessed to develop high-performance, high throughput, inexpensive, and field-portable microscopic and macroscopic imaging platforms to be used as diagnostic tools in point-of-care and resource-limited settings. We have found that the development of these platforms is well-suited for undergraduate research, and we will present a range of imaging devices where undergraduates have played a major role in their design, fabrication, testing, and analysis. Example devices include lateral flow assay readers, colorimetric sensors, fluorescence microscopy imagers, and digital holographic microscopes. In many cases, the image quality obtained using these devices rivals the image quality of much larger and more expensive laboratory-based equipment.

Poster Session

7:00 pm. Thursday, Jan. 7, 2016 .

Juan Vasquez, Razvan Stanescu, Jenny Magnes, Vassar College

Analysis and computational modeling of C. elegans locomotion through Fraunhofer diffraction patterns.

Using the diffraction pattern of thrashing *C. elegans,* we study the motion of microorganisms in a medium using Fraunhofer diffraction and Fourier analysis. To identify trends due to different methods of locomotion, computational simulations were also analyzed using the same methods. Supported by Vassar College Undergraduate Research Summer Institute and NSF.

John Kam, Brianna Conroy, Robert Norris and R.D. Bahuguna, San Jose University

Some experiments with polarized light

Two beam interference is explored between two coherent beams where the two beams are in various states of polarization with respect to each other. The polarization states in the two beams can be manipulated by half wave and quarter wave plates. In situations where the two beams do not show interference, placing an analyzer restores the interference pattern.

Ella Johnson[1], Austin Riedeman[1], Connor Fredrick[1], Chad Hoyt[1], and Jason Jones[2], 1) Bethel University, 2) College of Optical Sciences, University of Arizona, Tucson, AZ.

A connector-based, mode-locked erbium fiber laser for the advanced lab.

We describe an ultrafast optics advanced laboratory based on a mode-locked erbium fiber laser (~3400 USD). Ceramic connectors between cavity fibers avoid an expensive fusion splicer. An auto-correlation apparatus characterizes the 181 fs pulses and a parallel gratings apparatus compensates dispersion and compresses the pulses. NSF #1208930.

David Vega, California State Polytechnic University

Computational Microscopy on a Cellphone Using Super Resolution

Jeremy Wang, Harvey Mudd College

Investigating Dislocation Impurity Interactions Using Colloidal Crystals

Crystal structures often contain many defects, such as impurities and dislocations, and these defects play a large part in determining the properties of the crystal. Dislocation and impurity motion are well studied in large crystals, but are not as well understood in smaller crystals. Our research investigates the relationship between impurities and dislocations in order to better understand how they interact. Crystals are assembled from colloidal suspensions that contain silica beads of two different sizes, 1 micron and 1.2 microns, the larger size representing impurities in a crystal. Our experimental method consisted of disrupting our crystal with an IR laser, and collecting images after the laser is turned off. In looking at high impurity and no impurity regions, we found that the number of defects over time for the two regions differed. The crystal grain without impurities gained about twice as many dislocations while being blasted by our laser, suggesting that the presence of impurities may limit dislocation production.

Nikolaus Howe, Fermilab and Williams College

T0 Calculation in MicroBooNE with PMT Flashes.

We propose a technique to identify the absolute timing information (T0) of any interaction in the MicroBooNE detector. We achieve this by means of a point-matching technique. A single point is assigned to each interaction recorded by the PMTs by using energy and position information. Similarly, a single point is assigned to each interaction recorded by the TPC by weighting by energy and distance to detection plane. These points are matched based on their position. Acquisition of timing information allows us to reconstruct the absolute 3D position of an interaction in the detector, which is essential for event visualization and removal of cosmic ray data.

Walter Lynn, Carleton College

Simulating Anomalous Chaos in a Quantum Duffing Oscillator

We simulated a driven double well oscillator with coupling to the environment (with coupling strength given by a parameter Γ). We search for the existence of chaos in the problem by calculating the Lyapunov exponents (which measure the divergence between initially nearby trajectories) using classical, semi-classical, and quantum simulations for a large range of dissipations and effective Planck's constant $\hbar$. For certain coupling strengths Γ we showed that this system becomes chaotic as we changed system size from classical to quantum (hence changing effective Planck's constant), which is contrary to the standard intuition.

Fernando Arturo Araiza Sixtos, National Autonomous University of Mexico (UNAM)

Inverse function of the Fresnel coefficients to measure the refractive index

Simple formulae to measure quantitatively the refractive index of isotropic media considering the Fresnel coefficients in both polarizations (P and S) are provided. In other words, we obtain the inverse functions for the refractive indexes by using the Fresnel coefficients on a planar interface between air and an isotropic media. These equations are functions of the amount of reflectance, the incidence angle, and the index of refraction of the air where is immersed the sample. On the other hand, we exclusively consider the Fresnel coefficient for the S polarization and expanding in Taylor's series we obtain an even polynomial equation. We have studied the precision considering this approach to provide the value of the refractive index for the sample under test using an even polynomial fitting.