



THE UNIVERSITY OF ARIZONA  
GRADUATE COLLEGE

# Undergraduate Research Opportunities Consortium



# UROC

## Abstract Review

August 2015

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UROC: Undergraduate Research Opportunities Consortium 2015



## RESEARCH IN OPTICS (RIO)

PI: R. John Koschel, PhD

Coordinator: Melissa Sarmiento Ayala

The UA College of Optical Sciences is internationally recognized for its innovative research programs. Our research covers a broad set of technologies and techniques for using the properties and applications of light, touching virtually every field of science and industry. Our faculty are innovative and decorated — and constantly expanding the boundaries of optics knowledge. This program is geared toward students in STEM fields and open to rising juniors and seniors or second year community college students.

# KALEB CAMPBELL

RESEARCH IN OPTICS (RIO)



## MIAMI UNIVERSITY

OXFORD, OHIO

MENTOR: DR. POUL JESSEN

### FINDING QUANTUM STATES FROM HUSIMI-Q DISTRIBUTIONS

**ABSTRACT:** Developing techniques for accurate, arbitrary control of atoms is a necessity for Quantum Information Science. Essentially, we want to exploit the natural tendencies of quantum systems in order to control them. We trap cesium atoms in a magneto optical trap and cool them down to micro-Kelvin temperatures using frequency-detuned lasers. Then, we use microwave and radio frequency magnetic fields to control the state of the atoms. The state that we want to imprint on the atoms can be represented by a quasiprobability distribution in phase space called a Husimi-Q distribution. Using numerical search routines, we look for states that correspond to any arbitrary Husimi-Q distribution. For example, we wrote a “U” onto a Husimi-Q distribution, and then performed a search to find states corresponding to that distribution. Once we found an interesting state, we prepared the cesium atoms in that state by altering the phase of the microwave and radiofrequency magnetic fields. Then, we imaged the atoms using a stern-gerlach technique. Our results showed that the numerical search routine successfully found distributions closely resembling known states, but was less successful in finding targets like the arbitrary “U” Husimi-Q. However, since our search routines maximized and minimized the correct areas on the distribution and the difference between the target and resulting Husimis was relatively small, we demonstrated proof of concept. We also noticed that thicker “U”s were easier to find than thinner “U”s, probably due to the fact they are closer in size to the features for known states.

# AMORETTE DUDGEON

RESEARCH IN OPTICS (RIO)



## **P**IMA COMMUNITY COLLEGE

TUCSON, ARIZONA

MENTOR: DR. JENNIFER K. BARTON

### THE MULTIFACETED USE OF SWEEPED-SOURCE OCT IN TISSUE IMAGING

**ABSTRACT:** Biomedical optics is a multidisciplinary field that seeks to improve human health using the tools of optical engineering. To be effective in this environment, a broad understanding of biology and optics is necessary. Optical Coherence Tomography (OCT) is a powerful imaging technique and is currently being explored as a method for detecting minute tissue changes on, and beneath, the tissue surface. Primarily, small animals are in use for this research, with human application the ultimate goal. Histology, tissue sectioning, is the gold standard to verify conclusions drawn from the OCT images. Specifically, a Thorlabs OCS1050SS Swept-Source OCT system was in use at the Tissue Optics Lab, to image the colon and the female reproductive system to identify pre-cancerous tissue changes, and tendons were imaged to monitor the healing response to therapeutic ultrasound. One aspect of each of the three applications was investigated. MATLAB code was written to correct for the dispersion seen, on mouse colon images, due to the endoscopic attachment to the OCT system. It was successful in narrowing the axial point spread function, therefore increasing resolution. For the female reproductive system, an everting catheter was needed to shield soft tissue from damage during the use of a Falloposcope. A single balloon prototype was designed and built for this purpose; further design modification is needed. Intensive Therapy Ultrasound (ITU) was explored as a possible catalyst for tendon healing. ITU sites, as well as incision sites, were observed in the histology, while only the incisions were seen on OCT.

# KYLE JOHN GAG

RESEARCH IN OPTICS (RIO)



## **S**T. BENEDICT & ST. JOHN'S UNIVERSITY

COLLEGEVILLE, MINNESOTA

MENTOR: DR. ROLF BINDER

### **THEORETICAL STUDY OF POLARITON DYNAMICS IN SEMICONDUCTOR MICROCAVITIES**

**ABSTRACT:** This study is a small part of a larger research project with theory groups at the Chinese University of Hong Kong and the University of Paderborn, and an experimental group in CNRS, Paris. The larger project aims to further our understanding of polariton pattern formation and control in semiconductor microcavities in the hopes that it will lead to the development of optical transistors and useful applications of the optical spin Hall effect. When light is pumped into a semiconductor microcavity and creates polaritons, their polarization changes due to the energy difference between the transverse magnetic(TM) and transverse electric(TE) energy states of a polariton. The polariton's polarization can be expressed in terms of the polariton's pseudospin. In this study, the steady state solution of the pseudospin was studied using computer science and two models describing the pseudospin. The first component of the pseudospin was studied in particular because it showed the degree of linear polarization. It was found that both the maximums and minimums of this component rotated clockwise or counter-clockwise in k-space when the microcavity was pumped with plus or minus polarized light, respectively. It was also found that as  $\gamma$ , a decay factor of the polariton, increased, the polarization of TM polaritons and TE polaritons mixed, ruining the optical spin Hall effect.

# NAVEED JAFARI

RESEARCH IN OPTICS (RIO)



## UNIVERSITY OF NEW MEXICO

ALBUQUERQUE, NEW MEXICO

MENTOR: DR. YUZURU TAKASHIMA

**RAY ABERRATION GENERATOR**

**ABSTRACT:** Optical systems are critical for many industries and attaining optimum image quality is essential. Aberrations are an anomaly that occur in every optical system. These abnormalities degrade the performance of a lens and, therefore, the resulting image quality. Creating an understanding and familiarity with each geometrical aberration can result in the development of a solution to ultimately reduce aberrations in the lens. The goal of the aberration generator is to show each of the five third order geometrical aberrations that can occur. An optical system was constructed with collimated light using lasers with a combination of lenses, gratings and beam splitters to showcase particular aberrations exhibited by a large hemispherical acrylic lens. The optical design software called Zemax assisted in the evaluation and research of the individual aberrations exhibited by the hemispherical lens. An acrylic box was constructed around the optical system and filled with fog in order to examine the ray bundle as they enter and exit the lens. The laser beams passing through the lens are very clear and easy to see making the point of focus and apparent aberrations clear to examine. The outcome of the system was astounding, being able to see where the rays are in 3D space and how they interact with the lens veering the marginal rays creating these captivating aberrations for people to see up close. This system will help understand aberrations better in addition to creating a way to spot the aberrations within images to reduce their affect.

# TIARA SHIYON KAYE

RESEARCH IN OPTICS (RIO)



## UNIVERSITY OF SOUTHERN CALIFORNIA

LOS ANGELES, CALIFORNIA

MENTOR: DR. RONGGUANG LIANG

LASER-ASSISTED BLOOD VESSEL SEALING

**ABSTRACT:** The goal of this project is to design a laser-assisted vessel sealing device and determine the optimal wavelength and power density required to effectively cauterize blood vessels. Laser-assisted vessel sealing would be advantageous over the widely used electrothermal cautery during surgery, since there is a decreased risk of off-site burns using lasers. Various lens systems were modeled using Zemax, and several lens systems were selected for testing based on the theoretical irradiance at the sample plane. A beam profiler was used to select the lens system with the smallest beam diameter. This 3-lens system was used to focus a 6W 791nm laser diode to a point 54  $\mu\text{m}$  in diameter onto chicken tissue up to 2mm thick. Videos of the heating process were analyzed for color change. The color change was used as an indication of when the structural proteins were denatured by heat. The time required to burn the tissue and the diameter of the burnt hole were also recorded. In 11 trials, it took an average time of 3.91 minutes for the proteins to denature and 12.37 minutes for the tissue to burn. The average burn diameter was 1.27mm. For tissue to burn in under 2 minutes, a minimum power density of 166 W/mm<sup>3</sup> is required. In the future, the system can be designed using cheap materials and miniaturized, so it can be mass-produced as disposable forceps with a tip diameter of .5 to 1.5 mm.

# YITBAREK HABTEMARIAM KAZENTET

RESEARCH IN OPTICS (RIO)



## **G**ORGIA PERIMETER COLLEGE

DECATUR, GEORGIA

MENTOR: DR. DAE WOOK KIM

**MID-SPATIAL FREQUENCY OPTICAL SURFACE ERROR CONTROL**



**ABSTRACT:** Optical surfacing consist of polishing and grinding of all/part of the surface of optical material (lenses or mirrors) to create a desired form/shape and finish. The traditional polishing involves moving a polishing lap over the entire surface to be polished in such a way that eventually almost every portion of the optics will be rubbed by the polisher. Most traditional methods lack the precision in creating aspherical smooth finish without damaging the desired details of the surface. The introduction of Computer Controlled Polishing (CCP) empowered the industry to overcome the disadvantages of traditional polishing. CCP uses a computerized small tool which can rotate and travels on the intended work-pieces to create the parts of the optics. CCP enabled to create a more accurate and precise, controlled, fast, and various shapes. The deviation of an optical surface from the correct shape is typically expressed in fractions of a visible wavelength of light. This project is aimed to develop a method to remove tool marks from various optical surfacing technologies such as diamond turning, and other machine manufacturing. To achieve this target, it is important to generate small stroke pattern that will effectively smooth out the tool marks without damaging the surface figure. In the study, parts were made using 3D printing and mounted to a CNC machine to run stroke patterns generated by SAGUARO/MATLAB program. The prototype machine system for experiment has been set-up and fully tested including fabrication and testing process.

# ISABELLA MARY PAGANO

RESEARCH IN OPTICS (RIO)



**C**ARNEGIE MELLON  
**UNIVERSITY OF ARIZONA**  
PITTSBURG, PENNSYLVANIA

MENTOR: DR. **STANLEY PAU**

## **FULL STOKES POLARIZATION IMAGING FOR APPLICATION IN ASTRONOMY**

**ABSTRACT:** The polarization of light can provide information about different astronomical objects such as planets and asteroids. This includes knowledge about the grain size of extraterrestrial soil and weaker absorption line spectra that currently cannot be accurately detected. The image output of an SBIG camera/polarimeter apparatus was used to determine the capabilities of a division of focal plane (DoFP) polarimeter in capturing polarization signatures of planets and other astronomical objects. Past DoFP polarimeters have implemented an array of linear polarizers where only linear Stokes parameters can be calculated. The micropolarizers used in the current DoFP polarimeter detect four different orientations of elliptical polarization, allowing for all Stokes parameters to be calculated. The full-Stokes DoFP imaging polarimeter was previously constructed and attached to the SBIG camera. Images were collected through observation at the 21 and 61 inch Steward Observatory telescopes. Different techniques to align multiple frames of astronomical objects were explored to achieve a clearer polarization signature using Matlab. The averaged images clearly display a weak polarization signature, with some images not having enough intensity to be considered. Due to inclement weather, telescope time was cut short and more images could not be collected, specifically Jupiter, which has a strong polarization signal. Current results suggest that it would be beneficial to continue to test the polarimeter/camera setup.

# ERIC REICHEL

RESEARCH IN OPTICS (RIO)



## **W**HITWORTH UNIVERSITY

SPOKANE, WASHINGTON

MENTOR: DR. R. JASON JONES

### **LASER CAVITY STABILIZATION UTILIZING PIEZOELECTRIC ACTUATORS**

**ABSTRACT:** Our research focused on determining an optimal piezoelectric mirror design to be used for intra-cavity laser stabilization. Piezoelectric mirrors can be utilized to compensate for exterior noise introduced to a laser system. This noise, such as sound or vibrations, can cause a laser's output frequency to fluctuate. However, piezoelectric mirrors allow for the regulation and control over these frequencies. This can be achieved through the integration of a piezoelectric mirror in a negative feedback loop. In order for this to function properly, a piezoelectric mirror must maintain a consistent response to an applied signal over a wide range of frequencies. Due to resonances within mechanical systems, maintaining a constant response proves to be difficult to maintain. Therefore, by focusing on structural aspects of piezoelectric mirror designs, we were able to test differing mounting structures, piezoelectrics, and adhesives to reduce the effects of resonance. Through our comparisons we were able to determine an optimal mirror design, which provided the largest frequency bandwidth. We found that a tapered aluminum mount, paired with a Noliac piezoelectric and bound with Mounting Wax 80 gave an overall frequency bandwidth of 80 kHz. This result allows for precise control over a laser's frequency and is suitable for cavity stabilization.



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## PROGRAM STAFF AND SPONSORS • 2015

### **SUMMER RESEARCH INSTITUTE (SRI)**

Coordinator: Donna Treloar, MA  
Instructors: Andrew Huerta, PhD, Renee Reynolds, ABD,  
Joanna Sanchez-Avila

Sponsors: University of Arizona; Graduate College; The Partnership for Native American Cancer Prevention (NACP) training program, a collaboration between Northern Arizona University and the University of Arizona Cancer Center, funded by the National Cancer Institute; College of Medicine – Office of Diversity and Inclusion, Health Resources and Services Administration (HRSA) Centers of Excellence; Western Alliance to Expand Student Opportunities (WAESO); Department of Physics.

### **MINORITY HEALTH DISPARITIES SUMMER RESEARCH PROGRAM (MHD)**

Coordinator: Stephanie Adamson, Holly Lopez  
Sponsors: University of Arizona; Graduate College; Western Alliance to Expand Student Opportunities (WAESO).

### **MAXIMIZING ACCESS TO RESEARCH CAREERS (MARC)**

PIs: Megan McEvoy, PhD; Marc Tischler, PhD, Maria Teresa Velez, PhD  
Coordinator: Cindy Neal, MEd  
Sponsor: NIGMS/TWD Division GM 08718

### **HOOKED ON PHOTONICS RESEARCH EXPERIENCE FOR UNDERGRADUATES (HOP)**

PIs: Nasser Peyghambarian, PhD  
Sponsors: University of Washington/National Science Foundation (NSF). Funding for this research was provided by NSF Grant No. CHE-1156598.

### **CIAN INTEGRATED OPTICS FOR UNDERGRADUATE NATIVE AMERICANS (IOU-NA) RESEARCH EXPERIENCE FOR UNDERGRADUATES**

PI: Allison Huff Mac Pherson, DHEd, Robert Norwood, PhD  
Coordinator: Ameé J. Hennig, Daniel Lamoreaux  
Sponsors: National Science Foundation (NSF) Engineering Research Center for Integrated Access Networks (ERC CIAN).

Funding for this research was provided by the NSF Engineering Research Center No. EEC-0812072.

### **BIOSPHERE 2**

PI: Katerina Dontsova, PhD  
Sponsors: National Science Foundation Research Experiences for Undergraduates Program.

### **STUDENT AFFAIRS RESEARCH PROGRAM (STAR)**

Coordinator: Nura Dualeh, MA  
Instructors: Andrew Huerta, PhD, Renee Reynolds, MA, Joanna Sanchez-Avila  
Sponsors: University of Arizona; Graduate College; Division of Student Affairs; Western Alliance to Expand Student Opportunities (WAESO).

### **UROC-PREP**

Coordinator: Donna Treloar, MA  
Instructor: Andrew Huerta, PhD  
Sponsors: University of Arizona; Graduate College, Western Alliance to Expand Student Opportunities (WAESO).

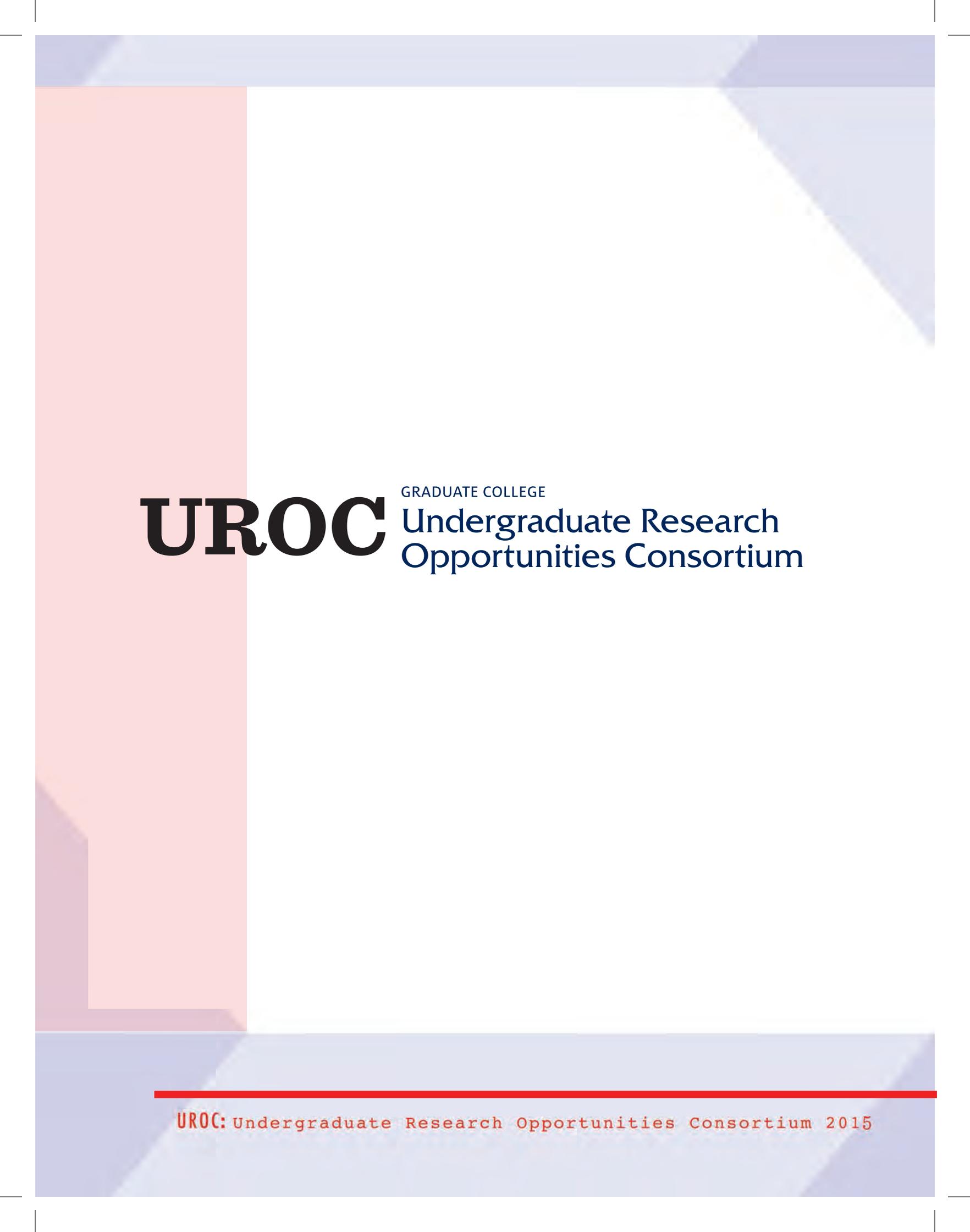
### **CAT VEHICLE PROGRAM/ ECE REU**

PI: Jonathan Sprinkle, PhD  
Coordinator: Nancy Emptage  
Sponsor: National Science Foundation Research Experiences for Undergraduates Program

### **RESEARCH IN OPTICS (RIO)**

PI: R. John Koshel, PhD  
Coordinator: Melissa Sarmiento Ayala, MEd  
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