COLLEGE OF OPTICAL SCIENCES

RIO

RESEARCH IN OPTICS PROGRAM

# Oral Presentations
# 2016

## Tucson, Arizona

THE UNIVERSITY OF ARIZONA

# RiO Oral Presentation Program

## 9:00: Dr. John Koshel

### RiO Welcome

## 9:05: Cameron Chavez

### Influence of Dislocations on Optically Pumped VECSELs

Semiconductor chips are used in the construction of lasers due the fact that they are easily tunable, have a high power output, and produce a wide bandwidth. These chips are manufactured by layering AlAs, GaAs, InGaAs and GaAsP to create a Bragg reflector, quantum wells and barriers respectively. Differences in lattice constants among adjacent layers applies a stress to the chip, which may lead to dislocations. These dislocations, if present in the cavity mode, adversely affect laser quality. To quantify these effects, an ultrafast probe laser incident on a VECSEL chip is used to excite the carriers at 80MHz; photoluminescence from the decay is recorded for sites which contain dislocations and those that do not. Results indicate there is a nontrivial shortening of carrier lifetime due to pumping on dislocations. Resonant periodic gain structures, structures which have a single quantum well placed at each antinode of the standing wave to maximize field enhancement, exhibited an upper-state lifetime near a dislocation that was 21.5% less than that of carriers on a clean pump location. Multiple quantum well structures, which broaden bandwidth by placing two wells off center from each antinode, show a decrease of 16.7% and 9.2% for separate chips. Gain at pump location permitting, a power curve of the laser was recorded; threshold pump power for a clean pump location on an RPG structure was 4W compared to a threshold of 5W for a dislocation.

## 9:20: Cody Poole

### *Shrinking the Ring Resonator with Plasmonics*

The Finite-Difference Time-Domain (FDTD) method was used to investigate a purely plasmonic ring resonator consisting of evenly spaced silver nano-spheres arranged in a circle. The effect of changing the number of spheres in the ring on the position of the resonances was explored. The geometry of the ring allows either the radius of the nano-sphere components or the radius of the ring formed by the components to stay constant while the other changes with the number of spheres. In all cases, three prominent resonances in the optical range were found. These resonances were seen to shift towards longer wavelengths as the radius of the ring was increased with the number of spheres. Similarly, these resonances were seen to shift to longer wavelengths as the size of the individual spheres were increased. The resonances are substantially broader than those typically seen in purely dielectric ring resonators.

## 9:35: Nicolette Fudala

### *3D Printed Interferometer Design and Affordable DOEs for Optical Demonstration*

While laboratory and industrial quality interferometers and diffractive optical elements (DOEs) are available for very precise application, costs reach $5,000 and upward. There is a lack of devices suitable in quality, portability, and flexibility for demonstration and educational purposes at the mid-to-low price range.

To address the need for affordable, yet effective parts in interferometry, new models were designed in Solidworks and manufactured using 3D printing. Interferometer parts were designed to be compatible with a previous Physical Optics Demonstration Bench made to exhibit diffraction, interference, and coherence effects. Based on the Michelson interferometer, the system was constructed from simple ABS piping, 3D printed modules, and other low cost optical elements. Of the 3D printing methods explored, selective laser sintering (SLS) delivered the best quality while keeping overall cost under $500.

Additionally, various methods for manufacturing DOEs were investigated. While high-end DOEs are typically created using a custom direct write lithography tool, such as the Maskless Lithography Tool (MLT) at the University of Arizona, these are largely unavailable. To make DOEs available for educational purposes, several low- and mid-cost fabrication methods were investigated. Low-cost methods included transparency prints, paint-on-glass etching, punctured HDPE plastic on glass, and burning through papers and plastics. Mid-range options involved third party laser etching or lithography mask shops.

Because of the high demand for these products in education, a website or blog with component lists, design instructions, STL files, and experiments will serve as outreach to the public.

## 9:50: Jacob Guttman

### Point Cloud Stitching and Mid-Spatial Frequency Error Control

Modern optical fabrication techniques often result in mid-spatial frequency errors, which can be harder to detect and address than other surface errors. One way to detect these errors is by creating a point cloud of depth/height data of an optical surface. However, many modern optics are too large for modern 3D imaging devices to generate sufficiently high resolution point clouds of the entire surface. Therefore, it is necessary to take point cloud images of smaller areas across the surface and stitch these point clouds together to create a high resolution point cloud across the entire optical surface. We investigated methods of stitching together point clouds gathered using the Microsoft Kinect sensor. The goal of this work is to better understand the available methods for addressing this problem and working toward a high-resolution imaging process to detect mid-spatial frequency errors. During this process, a preliminary method for stitching was developed using a version of the iterative closest point algorithm. This method is shown to be better at given tasks than some previously used methods, but is not ideal, and the investigation performed helps to identify areas that require future development and gives a look into possible future implementations.

## 10:05: Hannah Knaack

### *Analog Quantum Simulation of a Quantum Kicked Top*

An analog quantum simulator (AQS) is a highly controllable quantum system whose evolution is manipulated to simulate the behavior of a different quantum system. AQS has been proposed as a way of studying quantum systems too complex to model with classical computers. However, unlike in a computer simulation, we have no framework to understand how experimental errors and imperfections could affect our results. With this work we hope to address a key question: what, if any, parts of an AQS can we trust? To this end, we used an ensemble of ultracold cesium atoms as AQSs to simulate a well-understood model of both classical and quantum chaos: the kicked top. Simulating a chaotic system is interesting because it is hypersensitive to errors and thus cannot be reliably tracked by an AQS. Instead, we looked for global features in our simulation that might be reliably captured even if the exact quantum state is not. One such feature might be the boundary between stable and chaotic regions of the kicked top's evolution. We first studied the eigenstates of the quantum kicked top operator and classified them as stable or chaotic. Then we experimentally measured the evolving probabilities of finding our AQS in these states over time, and used this to quantify leakage between stable and chaotic regions. We found these boundaries to be quite robust given the imperfections currently found in our experiment, a preliminary indicator that AQS could be useful even without error management protocols.

## 10:20: Break

*Light refreshments will be provided.*

## 10:45: Sawyer Miller

### *Study of Thin Film Polymer Polarizer under Ultraviolet Radiation*

The fabrication of liquid crystal polymer polarizers involves the use of linear polarized ultra-violet (UV) light. This work studied the change of the alignment polymer and dichroic dye when exposed to large amounts of unpolarized UV light. Samples with a protective optical coating and samples without were exposed to a UV source. Between each exposure, the samples' Mueller matrix was measured using a polarimeter. Using the Stokes vector and Mueller calculus, characteristics including transmittance, diattenuation, polarizance, depolarization index, and average degree of polarization, were calculated. These characteristics as a function of wavelength at different exposures were compared. Polarizer characteristics at 500 nm were plotted as a function of exposed energy density. A downward trend was predicted and observed for diattenuation and polarizance. An upward trend was predicted and observed for the minimum transmittance and little to no increase was observed for the depolarization characteristics. Among the different empirical models of the photodegradation of polymers, an exponential decay in azo dye concentration was found to best fit the data. The change in absorbance was calculated from the transmittance data using Beer's law as a function of exposure, data fitted an exponential decay with R2=0.955. For the coated sample, the average transmittance remained constant at 500 nm. While there was no trend in the change in maximum transmittance for the uncoated sample, the minimum transmittance had a constant increase, correlating to the degradation of the dichroic dye and thus the qualities of the polarizer. The samples with optical coating degraded six times slower than the samples without optical coating.

## 11:00: Adam Moreau

### Mechanical Resonance Damping for Piezoelectric-Actuated Mirror Mountings

A piezoelectric-actuated mirror with greater than 360kHz servo bandwidth was developed, and the principal factors that lead to low frequency mechanical resonances were examined. In order to keep the gain cavity length of an ultrafast laser uniform, a small piezoelectric transducer (PZT) is attached to the backside of one of the mirrors. A major difficulty encountered when working with PZT-actuated mirrors is their very limited bandwidths, often < 20-40kHz. A number of variables were considered for the design of the mounting structure, such as the size of the mounting head, the material used on the surface and the core of the mount, the type and amount of adhesive applied, the methods of application, and fabrication techniques. Out of those analyzed, the two dominant factors, which most affect the frequency of the first resonance, are the methods for applying the adhesive, and the thickness of the adhesive used. When adhering the PZT to the mirror and mounting head, a large adhesive mound must be depressed, pushing excess material to the sides, thus eliminating irregularities within the adhesive itself and ensuring a thin, uniform layer is applied. With this addressed, secondary and tertiary factors have been shown to be the presence of a damping core to prevent longitudinal resonance modes, and the Young's Modulus of the outer material's respectively. The optimal mount design for a piezoelectric-actuated mirror is the 0.25"Ø Tungsten-Carbide filled design, with an outer material of either Brass or Copper.

## 11:15 Katherine Overend

### *On-Machine Testing of Freeform Optics using a Chromatic Confocal Sensor*

This project focuses on developing on-machine testing methods in freeform optics fabrication. When an optical surface is cut using a diamond turning machine it must be removed for testing and if the surface needs to be altered or refined, it is nearly impossible to replace the surface in exactly the same position. Therefore, this process will introduce additional manufacturing errors. Furthermore, because traditional interferometric measurement methods are restricted by the surface shapes, they are not applicable for all freeform optics testing. In this study, the chromatic confocal method is investigated for on-machine metrology of freeform optics. This method does not require removing the optic from the turning machine and can measure a large variety of freeform optics with the built-in scanning mechanism in the diamond turning machine. Communication between the chromatic confocal sensor and the diamond turning machine is achieved by a custom developed program: the program tells the turning machine to move the optic incrementally to specified positions; then the sensor measures the distance of the optical surface from the probe. The combined position data from the turning machine and distance data from the sensor are saved and then used to create a 3-D image of the optical surface.

## 11:30: Luke Ender

### *3-D Interactive Visualization Platform for Ray Aberration Generator*

The Ray Aberration Generator (RAG) developed by the Takashima Lab is an excellent tool for teaching students how real-world ray aberrations manifest, enabling them to more fully understand optical systems and correctly identify and treat aberrations. However, the entire RAG is far too bulky to be mobilized, limiting its teaching potential as a pedagogical device to only those on-site. To resolve this limitation, a remote viewing system was created which does not sacrifice either the 3-D visualization or the spatial interactivity of the RAG. The system was developed for the Google Cardboard platform, utilizing a uFactory uArm robotic arm and two HD webcams such that students anywhere in the world with access to an Android cellphone with a gyroscope and an internet connection can view a live 3-D video and spatially interact with the system.

## 11:45: Jessica Steidle

### Freeform Optics for Lighting

Lighting conditions are a major concern in the art world. Poor lighting can distract viewers, alter the emotional impact of art, and even permanently damage multi-million dollar pieces of artwork. The proposed solution is an optical system, to be used to illuminate a painting, consisting of an LED source and freeform optic to create a uniform spatial and spectral distribution of light. This system would help improve both the presentation and preservation of paintings, as well as increase efficiency. This is not a trivial problem, but involves illuminating a rectangular painting on the wall using a light on the ceiling. Freeform optics have more degrees of freedom and so can be used to solve complicated lighting problems such as this, but are challenging to design and manufacture. As part of the design process for this system, the reflectance spectrum of the painting to be illuminated, Mark Rothko's Green on Blue, was measured in order to determine the light source required to produce a uniform spectral distribution. The optical design software LightTools, assuming a point source, can generate a point cloud representation of the required freeform surface. A variety of polynomial representations of this surface were explored. These representations were evaluated by the quality of their fit to the point cloud as well as by the resulting spatial distributions of light. This will allow for the optimization of the surface to allow for an LED source, and will eventually lead to the manufacturing and testing of this system.

## 12:00: Closing Remarks

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