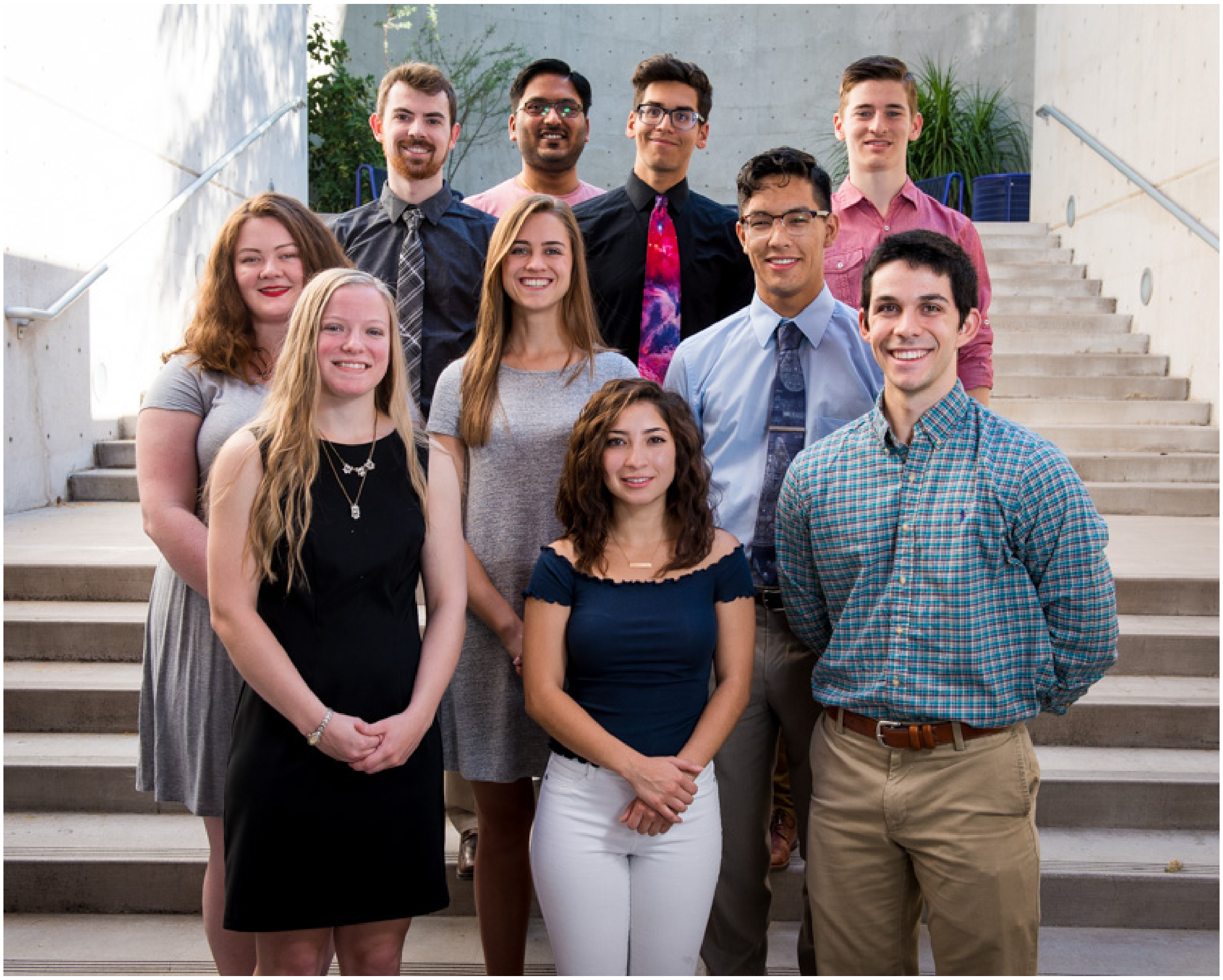
RESEARCH IN OPTICS (RiO)

PI: R. John Koshel, PhD
Coordinator: Melissa Ayala
Sponsor: The University of Arizona; NSF-REU.



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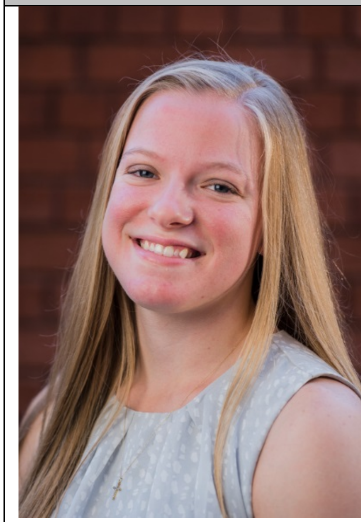


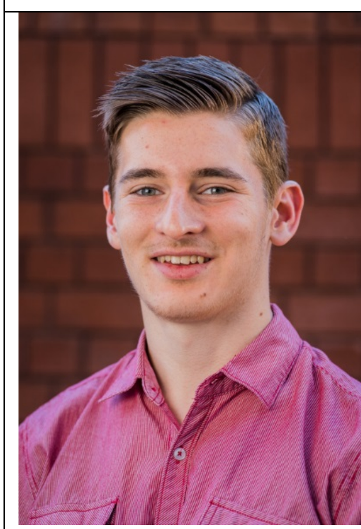
MADISON BURGER

Thermal Simulation of Laser Curing for 3D Optical Printing Application

Univ of Nebraska-Lincoln, Biological Systems Engineering
Mentor: Ronguang Liang Zhihan Hong

Abstract

3D printing of optical lenses is a fast, convenient, and customizable lens production method. This manufacturing technique still requires extensive research and improvement, including optimization and repeatability. The specific method of 3D printing explored in this project is laser curing of PDMS polymer. An IR pulse laser is utilized to heat and cure PDMS polymer, and a method for optimizing the curing process is explored. In order to determine the most effective laser curing conditions, a temperature simulation was created to better understand the curing process. MATLAB was used to create this temperature profile. The general heat conduction equation, boundary and initial conditions were translated into MATLAB's PDE Toolbox in order to generate the profile, and a Gaussian beam absorption power density model was used to view cross-sectional results. The temperature results were coincided with pulse layer curing experiments to observe resulting solid polymers. In the future, this simulation will be improved in accuracy and will be used to optimize the IR pulse laser parameters.



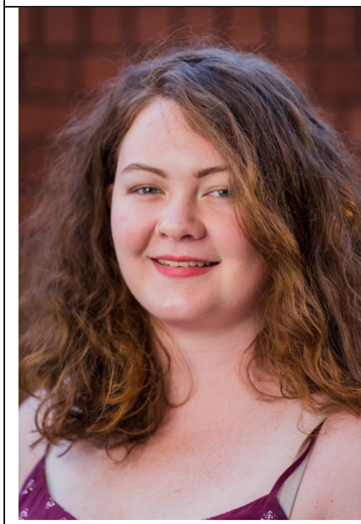
MICHAEL CHOQUER

Computational Modeling of Spintronic Terahertz Emitters

Univ of Washington, Electrical Engineering, Minor in Mathematical Physics
Mentor: Rolf Binder Samuel Ming Ho Luk, Dennis Nenno

Abstract

Terahertz waves have many useful applications in chemical spectroscopy, biological imaging, defense, and wireless communication. Smaller and less expensive terahertz emitters are now highly desirable. Our research analyzes a spintronic terahertz emitter (STE): a solid-state magnetic heterostructure designed for straightforward integration onto a silicon substrate. The STE makes use of the inverse spin-Hall effect, creating an oscillating electric field from a femtosecond laser pump pulse. This research focused on modelling and calculating the electric field spectrum. The STE's electric field was modelled using Maxwell's Equations and was calculated using the finite-difference method. Different boundary conditions and discretizations were investigated and compared for accuracy as well as computational expense. We discovered a finite difference that improves the discretization error of the first derivative to $O(\Delta x^2)$ while preserving the form of a tridiagonal matrix. The numerical error of this finite difference was within one order of magnitude of the error from using staggered grid for Neumann boundary conditions. A finite difference was found that matched the analytical solution with 10^{-3} relative error with only 201 grid points. The emitted terahertz field spectrum found shows a wide spectrum across the THz range without any gaps from 0.1 to 50 THz. The field has a full-width half-maximum of 14.5 THz and ranges from 0.1 to 50 Thz with greater than 1% of the original signal. These results indicate a promising future for spintronic terahertz emitters for low-cost and wide-bandwidth terahertz sensing.



ELIZABETH DEJONG

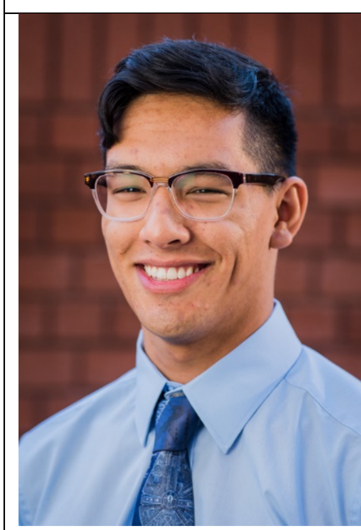
Creating, manipulating, and imaging complex quantum states in a single atom

Haverford College, Physics

Mentor: Poul Jessen Kevin Kuper

Abstract

The goal of this project is to find and then experimentally simulate F = 15/2 quantum spin states with arbitrarily chosen quasi-probability distributions (QPD), which would be a new approach to state preparation in quantum systems. A previously written Matlab program already allows the modelling the probability distributions for a system with a total atomic spin of F = 3 or F = 4; however, this number limits the “resolution” of the distribution. Modifying the algorithm that creates the theoretical system to combine the magnetic sublevels of the F = 3 and F = 4 spin manifolds allows us to expand the size of the QPD sphere, thereby increasing the resolution and allowing us to create more complicated distributions. Once the Matlab program is modified for the new, simulated atomic spin of F = 15/2, probability amplitudes can be found for the particular distribution. These can then be tested experimentally using a cloud of Cesium 133 atoms prepped with the theoretical quantum state found with the modified Matlab algorithm.



CHRISTIAN HAWKINS

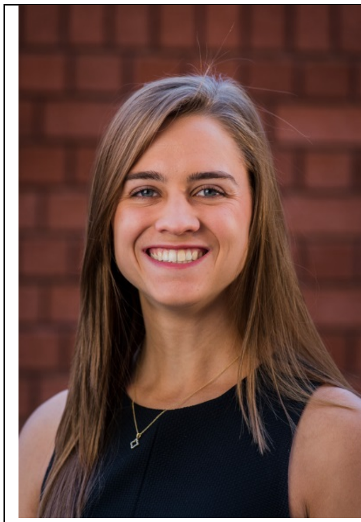
Studying the Form-Fit Time of Sheer-Thickening Fluids on a Concave Surface

College of Charleston, Physics

Mentor: Dae Wook Kim Logan Graves

Abstract

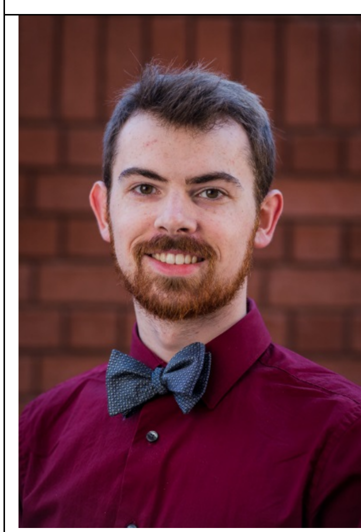
Previous studies in the University of Arizona College of Optical Sciences Large Optics Fabrication and Testing (LOFT) lab have shown the efficacy of using a visco-elastic polishing lap for removing mid to high frequency special-errors in large aspheric optics such as those used in large multi-mirror telescopes. Sheer-thickening fluids increase in viscosity as sheer strain is increased; this allows such fluids to be extremely effective at polishing free form optics since they conform to the overall shape of the optic during long slow motions but grind off deformities under high-frequency polishing motions. These previous studies were conducted using just Pink Silly Putty™. The purpose of this study was to serve as a proof of concept showing the possibility of formulating different types of non-Newtonian fluids for specific applications during the polishing and grinding of large free form optics. A series of six samples of sheer-thickening fluids with varying low -strain viscosities was then created. The time it took each fluid to conform to a large concave optic was then recorded using a pressure sensor and the data was then processed in MATLAB. The results have shown how differing types of fluids may be manufactured for different applications in large optics polishing, and have presented basis for which future studies on conformal polishing laps using non-Newtonian fluid may work off of.



MADISON JAEGER
Optical Incoherent Super Resolution
Rose-Hulman Institute of Technology, Optical Engineering
Mentor: Amit Ashok Ronan Kerviche

Abstract

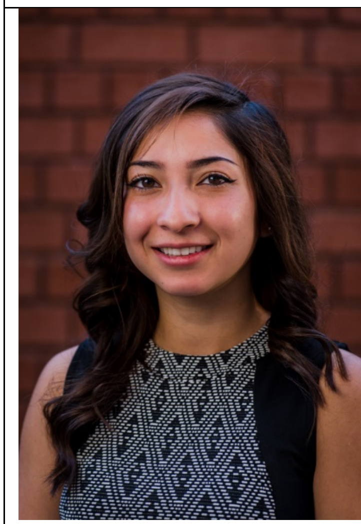
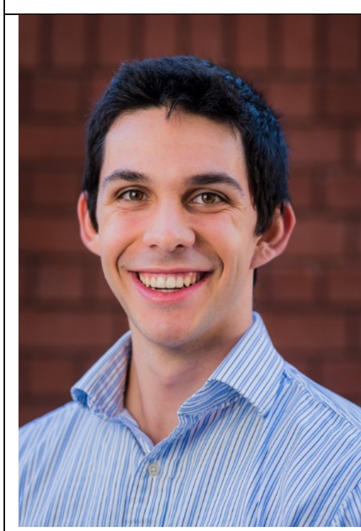
The resolution limit of a conventional incoherent and linear, shift-invariant imaging systems is imposed by the finite size of their pupil; as the aperture diffracts light, the blurred images of two closely spaced point sources overlaps significantly and their angular separation cannot be measured accurately below the diffraction limit i.e. Rayleigh limit. For instance, when observing binary stars their angular separation may be so small that their images in a telescope focal plane appears almost indistinguishable from a single star. Tsang and Nair (2016) have recently shown that the phase of quasi-monochromatic incident light waves contains additional information about this separation which remains hidden to direct measurement of the optical intensity in the focal plane of conventional imaging systems. Furthermore, they demonstrated via the analysis of the Quantum Fisher Information and the associated Quantum Cramer-Lower Bound that it is possible to design measurements which are globally optimal in mean square error (MSE) sense for this measurement problem, thereby improving the effective system resolution beyond the Rayleigh limit. In this study, our goal is to measure the angular width of a single extended (rectangular) incoherent source-object for two competing measurement designs, including the traditional imaging measurement. For this task, we implement an architecture based on a Mach-Zehnder interferometer, with optical spatial and amplitude inverters in one of the arms, which is capable of recovering the embedded wavefront phase information optimally towards improving the resolution performance beyond the Rayleigh limit. For this system, we perform a micron-level alignment to correctly self-modulate the incident optical wavefront and use photon counting shot-noise limited detectors to sense the scarce incident photon flux.

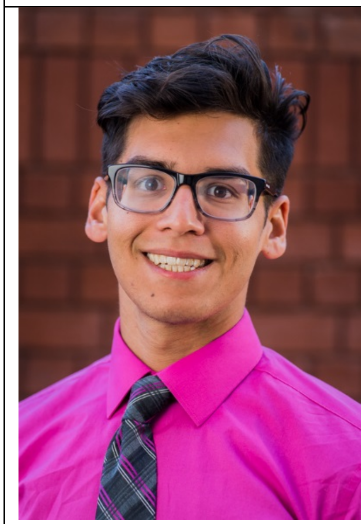


JOHN KOOPAL
Telescopic Solar Condenser for Destruction of Dissolved Organic Nitrogen Molecules in Waterways
Rose-Hulman Institute of Technology, Optical Engineering
Mentor: Tom Milster Emily Finan

Abstract

Nitrogen based molecules account for much of man-made nutrient pollution in lakes and rivers. Though a source of nitrogen is required in aquatic ecosystems, too much can cause harmful algae blooms. These sources of nitrogen come in many flavors, some more problematic and harder to remove than others. Dissolved Organic Nitrogen is one of these. A recent study has indicated that concentrated ultraviolet radiation (UV light) is able to break apart the bonds of these molecules and reduce them down to other, more easily/conventionally removed sources of nitrogen (primarily ammonia). A simple solution to utilize this phenomenon would be to just use a UV lamp to provide the desired radiation. However, a more novel solution would be to

	focus the light from the sun to provide the same desired radiation. The advantages to this approach include an independence from a power supply and perhaps even higher irradiance. This research examines the engineering viability of using this second approach by constructing a small model Parabolic Cassigrain telescope using flexible Willow glass as a proof of concept.
	**DANIELA MARIN** *Circular Polarization Signatures in Nature* William Jewell College, Physics Mentor: Stanley Pau Yitian Ding **Abstract** Abstract: Polarized light is ubiquitously found across the globe. Whether it be from the sky or through reflections off of glass, water, or other surfaces, the linear state of polarization is most commonly found in nature. Circularly polarized light (CPL) on the other hand, is seldom found. Traces of CPL have been detected in the reflection of the exoskeleton of certain species of beetles, bird feathers, and the lanterns of firefly larvae. The structure of the beetle cuticle can serve as a biological model for cholesteric liquid crystals, crystals that respond to stimuli with a change in color. Moreover, humans are not able to distinguish the differences between polarization states, but studies have shown that some animals exhibit polarization vision. This particular type of vision has the capability of producing light information used in contrast enhancement, camouflage breaking and object recognition. This project aimed to contribute to the understanding of CPL in the biological sciences and to further investigate the functionality of CPL in organisms. Empirical data was obtained by employing a division-of-time polarimeter to photograph three categories of nature: animals, plants and landscapes. Data reinforces that indeed, CPL is rare in nature and ascertains the existence of CPL in certain organisms and terrestrial objects.
	**NICHOLAS MENNONA** *Interactive Graphical User Interface for Ray Aberration Generator 3.0* Vasser College, Physics Mentor: Yuzuru Takashima Guanghao Chen **Abstract** With the goal of enhancing optics education, the Takashima Lab has developed the Ray Aberration Generator (RAG) to better showcase optical aberrations. The RAG is a physical device that uses fog to visualize the optical aberrations manifested when ray beams propagate through a lens located inside a cylindrical chamber. With the assistance of LabView controlled movements, the RAG 3.0, the latest edition, extends the capabilities of the system by interfacing the RAG with MATLAB. The Graphical User Interface (GUI) developed in MATLAB pairs the animations of a ray tracing software, CodeV, with the entire network of additional software controlling the RAG. The GUI simultaneously powers the CodeV display and the remote-controlled RAG movements for real-time comparison. PowerPoint and an Arduino-controlled flip mirror (enabling switching between either the lasers or the projector used to produce the ray beams for the chamber) have been introduced alongside LabView in this network of additional software so that users can operate the RAG 'hands-free.' The other features added to

	the RAG are two 3D printed lens mounts and a magnetically operated lid. The lens mounts and the magnetically operated lid generalize the educational value of the setup by allowing the swapping between lenses inside the chamber. The RAG 3.0 is the most interactive version of this educational tool.
	**AUSTIN SINGH** *Construction of an Apparatus to Monitor Trapped Particles in Optical Tweezers* Univ of Central Florida, Photonics Science & Engineering Mentor: Euan McLeod Jeffrey Melzer **Abstract** Optical tweezers are an incredible tool that allow for the manipulation of particles on a nanometer to micron scale. This technology has widespread applications in physics, engineering, chemistry, and biomolecular research and development. A common limitation to such a system lies in manual observation. To gather or interact with thousands of particles, the trap is generally imaged with a camera, requiring an observer to be involved with the process. The purpose of my project was to construct an apparatus that allows for automated detection and tracking of particles inside an optical tweezer. As such, a quadrant photodiode (QPD) was positioned in the system as to interact with the electric field of the trapping laser backscattered off a trapped particle. The voltages produced by the photodiode were gathered with LabVIEW and analyzed with MATLAB. The power spectrum of each signal was found and fitted with a Lorentzian curve allowing for the corner frequency to be computed and averaged over several trials. Utilizing a 1064nm fiber laser at 600 mW to trap an average 5 µm diameter polystyrene bead resulted in corner frequencies on the order of 30 Hz, markedly different from the high (>15 kHz) frequencies computed for an empty trap. Using this data, parameters for the detection of particles in the trap are easily established, as well as a simple, direct process for establishing parameters for particles of differing size.