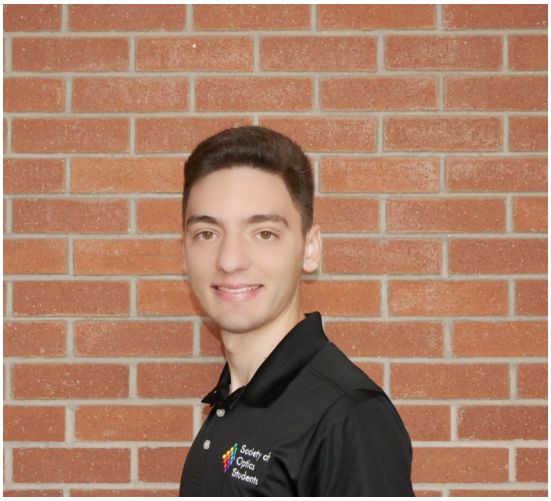
Research in Optics (RiO)

Cameron Perl

“MEMS Based Beam Steering for Holographic LIDAR Systems”

ABSTRACT: Light Detection and Ranging (LIDAR) is a time-of-flight based, 3D range-finding method used for spatial awareness in autonomous and manned vehicles and machines. Takashima Lab’s development of new beam steering technologies using commercially available components enables a new, highly competitive LIDAR system with a wide Field of View (FOV), high frame rate, small package size, and low production cost. A high-resolution beam steering mechanism is achieved by synchronizing, through a Field Programmable Gate Array (FPGA), two different Micro-Electro-Mechanical Systems (MEMS) for interleaved, sub-raster scanning: a Digital Micromirror Device (DMD) for coarse, diffraction-order-based scanning, and a Mirrorcle Mirror for fine, analog-rotation-based raster scanning. The summer developments focused on software, hardware interfacing, and MEMS synchronization. FPGA code was developed using previous Arduino-based implementations, and MATLAB code was developed to interface the Mirrorcle Mirror. The return-signal amplifier chain was optimized for higher speeds and integrated with a programmable potentiometer for gain-configurability by the FPGA.

Nicholas Kosan



“Identifying Sources of Particle Placement Error in Optical Tweezers”

ABSTRACT: Optical tweezers (OTs) offer a method of noncontact manipulation of micro-particles and nano-particles, providing a useful tool for small-scale assembly as well as enable the study of micro-scale and nano-scale objects. In these applications, OTs are used to place particles in desired locations with a high degree of precision. Many OTs are custom-built with unique control systems. Two primary potential causes of positional error in the OT system were investigated: the chemical functionalization of the surface to which particle are mount by the OT, and potential aberrations in the imaging system through which particles were viewed during assembly. The chemical functionalization was studied experimentally by varying the concentration of adhesive chemical. These results remain inconclusive as different experimental methods produce different results. The aberrations were quantified by imaging a United States Air Force (USAF) standard target in the OT system and comparing it to the known target dimension. This analysis did not indicate strong aberrations in the imaging system. By correcting any sources of inaccuracies found, OTs perform better in assembly and scientific study applications.

Paul Johnson

THE UNIVERSITY OF ARIZONA

"Reconstructing Diffusely Reflected Images"

ABSTRACT: Where specular reflections clearly display light interacting with a surface, diffuse reflection spreads the light out in random ways that cannot be easily detected. Using a single photon camera and an iterative reconstruction algorithm, it could be possible to reconstruct a diffusely reflected image. A current algorithm that acts to reconstruct an 8x8 pixel painting around a corner lacks both the accuracy and efficiency necessary to model lab data. Given how new this process is, modifications to the reconstruction have yet to be implemented. In this project, I use knowledge of the binary image to improve on the reconstruction algorithm. By comparing simulations of painting reconstructions from a forward mode, I am able to notice patterns and develop new improvements. By successfully reconstructing binary images, methods for reconstruction more complicated images can be figured out, leading to imaging and security applications.

Caleb Nunn

“Design and Evaluation of a Cassegrain Telescope Mount for Break-Down of Dissolved Organic Nitrogen”

ABSTRACT: High concentrations of dissolved organic nitrogen particles (DONs) can be harmful to aquatic ecosystems if left unchecked. DONs are under a wide umbrella of nitrogen based particles that make up much of the man-made nutrient pollution in lakes and rivers, but the difference is that DONs are much harder to remove than other particles. However, results of a recent study indicate that concentrated ultraviolet radiation, or UV light, is able to break DONs into smaller, more easily removable substances, primarily ammonia. In the study, the source of UV light was a UV lamp, and although that produces the desired result, it lacked in efficiency. This project focuses on the design of a scaled-down optomechanical mount for three mirrors that will be arranged in a manner similar to a classical Cassegrain telescope. This telescope will function as a solar condenser, producing a higher level of intensity than a UV lamp and requiring independence from a power supply. One of the main difficulties of the project is utilizing ultra-thin, flexible Willow glass for our mirrors. Willow glass is relatively inexpensive, easily adjustable, and is incredibly light in weight. However, Willow glass is quite vulnerable, as micro-cracks along the edges of the glass can easily propagate throughout a sample. Designing an optomechanical mount around the properties of this glass, 3D printing the mount, and testing the mount for its viability were the main focuses of this research project.

Heather Cihak

"Improving Quantum Control Waveforms"

ABSTRACT: The purpose of this research project is to improve the ability to control a multidimensional quantum system that is based on the 16 magnetic sublevels of the ground state of 133Cesium atoms. To control the system, external magnetic fields are applied using a combination of radio-frequency and microwave control signals. Theoretically, these applied waveforms allow for complete control of the system; however, the electrical system used to apply these signals has a response that causes them to deviate from the ideal waveform. In previous attempts to address this issue, the transfer function of the system was measured. An attempt was made to compensate for these deviations by applying the transfer function of the inverse system to the control waveform. Numerical results confirmed that this compensation would yield improved performance; however, the opposite occurred, and the fidelity of our control decreased. After a thorough investigation of possible sources of error in this previous method, it was determined that the synchronization of the control fields was being disrupted by the compensation procedure. This problem was solved by aligning the fields properly and consistently in time. Experimental results showed that the updated procedure performed better over the previous attempts at compensation, but not over the uncompensated waveforms. Although the results of this project do not show a gain in overall fidelity, there is potential for this method of compensation to be further improved to achieve better control over the quantum system.

Daniel Xu

“Tracking and Control Methods for Portable Optics Polishing Machines”

ABSTRACT: The fabrication process of large optics relies on exceptionally precise grinding and polishing methods to produce an almost perfectly smooth surface. Existing techniques utilize a polishing robotic arm with extension and angle control, as well as a rotating optics platform, to reach any point on an optical surface. However, this positioning method is only practical for polishing detached optics and requires a large amount of equipment to execute. Under circumstances in which environment conditions make traditional polishing techniques impossible, it will be more sensible to rely on smaller robotic instruments. In this project, we prototype a mobile polishing robot and position-tracking algorithm that allows adaptation of robot behavior on different portions of a test surface according to varying surface data. An image processing algorithm was created to continuously track the pixel location of a moving LED’s centroid, which is processed and transmitted to a robot prototype to govern its behavior. This positioning method compresses the necessary equipment for optical surface polishing to a significantly reduced size, and once compatible hardware is designed, will enable accurate optics polishing under an expanded range of environments.

Kellen Arnold

“Investigation in Visible and Ultraviolet Imaging”

ABSTRACT: While the human eye is sensitive to wavelength from 380 to 700 nanometers, other animals such as birds, insects, and fish can see different and extended ranges of the visible electromagnetic spectrum, particularly in the ultraviolet (UV). Images of different objects are taken in various locations in the Tucson area using a modified digital camera with a UV passing lens and filters and a conventional digital camera. The UV photographs are compared with color RGB images to study the interaction of visible and ultraviolet light on different surfaces. Approximate week-long studies were conducted in four categories: art, moths and butterflies, flowers, and portraiture. In butterflies, the differences in some specimens between the visible and the ultraviolet are very distinct and may be consequence of evolutionary processes and adaptations. In particular, the scales of the Southern Dogface (Zerene cesonia) butterfly were studied using scanning electron microscopy (SEM). The nanostructures of the butterfly scales exhibit properties of structural coloration.