<u>Preliminary List of REU Projects for the Summer of 2017</u>

Advanced active imaging devices and systems (2 student, Mentor: Prof. David Dickensheets)

Prof. Dickensheets' group is developing active optical devices for advanced imaging applications. One example is tunable reflective lenses (variable curvature mirrors) with fast and precise control over focal power and spherical aberration. These mirrors are useful for laser scanning systems such as confocal or two-photon microscopes, and also for fast-response zoom lenses for small format cameras. In addition to device engineering, Dickensheets' group is building complete optical instruments such as a miniaturized microscope for skin cancer detetion, and a full-sized two-photon fluorescence microscope with advanced active and adaptive optics to facilitate research in developmental biology. These instrument development efforts are inherently interdisciplinary, and REU students engaged on these projects will work side by side with graduate and undergraduate students pursuing degrees in engineering, cell biology, neuroscience and physics. Depending on student interest, the REU student will be afforded the opportunity to learn microfabrication processing techniques in the Montana Nanotechnology Facility, optical characterization and metrology techniques applicable to micro-mirrors and active optical systems, or optical system control, modeling and software development. Importantly the student will learn tangible research skills while simultaneously learning about the cross-disciplinary applications and challenges these projects address.

Light and Sound in Nanotechnology (2 students, Mentors, Prof. David Dickensheets, Dr. Phillip Himmer, Dr. Recep Avci, Mr. Chris Arrasmith)

Several projects are available for students interested in learning about and contributing to research in nano/microfabrication. We are developing light-based metrology tools to measure film stress, and new coating methods to make high-reflectivity optical mirrors, especially on flexible substrates. Other projects will advance our capabilities for assembly and packaging of optical MEMS devices so that they can be deployed in instruments outside the cleanroom laboratory. Finally, MSU is home to some of the most advanced thin films characterization and imaging instruments available today, and opportunities exist to learn advanced SEM and Auger spectroscopy techniques. Students interested in these applications will receive training to work in the Montana Nanotechnology Facility (MNF), which is part of a national network of such facilities called the National Nanotechnology Coordinated Infrastructure (NNCI). With additional support from NSF through NNCI, our Nanotechnology students will have the opportunity to visit one of the other NNCI sites and interact with REU students from around the nation doing research related to nanotechnology.

Three-dimensional interconnect thermography (Mentor: Prof. Todd Kaiser)

As personal electronic devices have matured, the drive for more processing power and more memory in a smaller volume has forced the semiconductor industry to develop packaging schemes that stack thinned silicon die on top of each other with three dimensional interconnects between them. Currently, there is no non-destructive method to monitor the electrical continuity between stacked silicon die during the assembly process creating these interconnects. The REU student will assess the possibility of using pulsed, step or lock-in thermography to verify continuity of electrical connections between stacked die. Good thermal continuity will imply good electrical continuity. The experiments can be performed in three separate excitation modes: reflection, where both the heating and recording are performed on the same side of the device under test; transmission, where the surface is heated on one side and data is obtained from the opposite side; and waveguide, where multiple IR lasers are focused into the silicon substrate of the die heating the internal through silicon vias (TSV's) and then monitored from the surface.

Understanding subcellular mechanical actuation through light (Mentor: Prof. Anja Kunze)
Stimulating neuronal cell activity to overcome neuro-degenerative processes such as the loss of synaptic connections are achieved through electrical, chemical or biophysical signals. Recent advancements in the field are based on nanoparticle mediated stimulation of neuronal activity either based on mechanical forces, heat or light interactions. The efficiency of these methods are monitored through electrophysiology, or fluorescent microscopy e.g. by labeling and analyzing intracellular calcium concentrations ($Ca2+$ signals) with fluorescent markers. The REU student will be exposed to the current challenges of light-based methods to analyses neuronal cell behavior in neuroengineering. Depending on the student interests and background they can delve into developing computational models, which link spatial calcium activity to nanoparticle-mediated stimulation, or design and develop novel micro magnetic devices for magnetic molds, cell assembly, or subcellular mechanical actuation.

Acoustical monitoring of parks, wilderness, and other natural areas in Montana (Mentor: Prof. Rob Maher)
According to current U.S. National Park Service (NPS) management policies, the natural soundscape of parks and historic sites is a protected resource just like the physical ecosystems, landscapes, and historic artifacts for which the parks were formed. While several NPS sites have been studied extensively for noise intrusions by tour aircraft and mechanized recreation, most parks and historic sites do not yet have an acoustic baseline for management purposes. Moreover, very little is known in a scientific sense about the diurnal and seasonal variations in natural sound, nor about the long-term trends in the natural soundscape. This lack of data prevents scientists and NPS managers the ability to inventory and monitor the natural soundscape in order to provide accurate baselines and sustainable park management practices and guidelines. Ongoing research at Montana State University involves long-term acoustical monitoring research at remote locations. Students participating in this research will gain a theoretical and practical understanding of environmental acoustics (the propagation, reflection, absorption, and attenuation of sound in the atmosphere), experience designing and conducting field research, scientific interpretation and documentation of acoustical recordings, and the development of new means for automated acoustical processing and analysis.

Computational modeling of adaptive vision (Mentor: Prof. Neda Nategh)
An important problem in image and video processing is to automatically adjust the imaging device's settings in response to the changing statistics of the visual scene. This problem can be applied to a variety of tasks, including medical imaging, natural scene photography, and tracking moving objects. Similarly, dynamic adjustment of the visual sensitivity is an indispensable part of biological visual systems to process the environment in real-time, which is an essential part of survival, from humans to insects. Retinal ganglion cells, which convey the visual image from the eye to the brain, have been shown to change their response function or their spatio-temporal receptive fields quickly in a new environment. This strategy maintains the neural coding efficiency under the new image statistics. In the MSU Vision Lab, we are interested to transform our knowledge of visual neuroscience to imaging-system engineering applications. The participating student will be given an introduction to the adaptive visual processing in natural vision and hands-on training in processing and analyzing neural data. The student will be

assigned a sequence of steps in simulating such an adaptive system, from developing models to coding, training and testing them and visualizing the data produced.

High-capacity local area networks using plastic optical fibers (Mentor: Prof. Ioannis Roudas)
During the last two decades, there has been increasing interest in large-diameter step-index and graded-index plastic optical fibers for short-haul high-capacity applications. In the near future, plastic optical fiber based local area networks will be required to support 1-10 Gbps serial transmission in order to comply with short-reach Ethernet standards. The major goal of this project is to use the high-spectral-efficiency advanced modulation formats in order to exceed the Gb/s barrier and achieve 10 Gigabit Ethernet transmission over 1-mm core plastic optical fibers for the first time.

Measuring sky polarization during a solar eclipse (2 students, Mentor: Prof. Joseph Shaw)
REU students will join a team of graduate and undergraduate students from Electrical Engineering, Physics, and Optics and Photonics to develop optical instruments for studying the polarization pattern of skylight before, during, and after a total solar eclipse. The eclipse will occur in August 2017, and in previous years the students will design, build, calibrate, and test instruments to measure skylight polarization at visible and near-infrared spectral wavelengths. During summer 2017, the REU students will deploy the instruments to study skylight polarization as it makes a drastic transition from the usual pattern created by scattering of direct sunlight to a very different pattern created by multiply-scattered sunlight during the eclipse. This project will provide students the opportunity to “see” the world through optical polarization – an extra dimension that provides information about atmospheric scattering that extends beyond the traditional methods of color and intensity. This project connects with ongoing MSU research funded by the Air Force and NASA.

Machine learning of sensor data (Mentor: Prof. Ross Snider)
REU students will learn to answer the questions, ‘once you have detected, observed, and measured natural phenomena, what do you do with the data you have collected?’ and ‘how do you make sense of the data by classifying it?’ Students will learn how to apply state-of-the-art machine learning algorithms, such as Support Vector Machines (SVM) on multidimensional data. One possible application of this method is to analyze the output data from optical sensing systems, such as deformable optical waveguide sensors, which may provide a high number of information channels, but in a convolved and noisy form. Advanced signal processing is required to analyze these output signals, and extract the measurement parameters of interest. Students also will learn how to implement these algorithms and visualize data in MATLAB, the primary language and interactive environment used by engineers and scientists worldwide.

Biomedical optical sensor characterization (Mentor: Prof. Wataru Nakagawa)
The Nano Optics group is developing and testing pressure sensors with interferometric optical readout for biomedical applications. These sensors consist of nanostructured optical waveguides fabricated in a soft optical polymer material. Applied pressure deforms the sensor, changing its optical characteristics, which can be measured using laser readout. The REU student will be trained on the operation of this testing system for deformable optical sensors. The student will then assist in the calibration and testing of sensor elements.

Nanofabrication of optical devices (Mentor: Prof. Wataru Nakagawa)

Micro- and nano-fabrication technologies based on silicon have enabled a vast range of technological advances, including microprocessors, integrated systems, and optoelectronics. The Nano Optics group uses these manufacturing technologies to produce functional optical devices based on nanostructures in silicon and related materials, optimized for applications in polarimetry and optical imaging. The participating student will be given an introduction to these fabrication technologies and hands-on training in working in a clean room facility. Working with group members, the REU student will be assigned a sequence of steps in the fabrication process chain to understand and optimize, and to assist in fabricating functional optical devices in our facility. Next summer we anticipate being in the process of designing and building combined polarization and color filters in the near infrared for atmospheric sensing applications.