List of Potential REU Projects for Summer 2018

Electrical and Computer Engineering Dept., Montana State University

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. Understanding ecosystems and the role of human activity in the natural world benefits from observing natural acoustics of animal communication, environmental sound from wind, rain, and flowing water, and anthropogenic sound sources. 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.

Advanced active imaging devices and systems

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 detection, 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.

Drone-based imaging
Mentor: Prof. Joe Shaw

On this project, a student will work with graduate students and faculty to mount imagers on drones and test their capabilities for ecological and environmental remote sensing. Imagers will include conventional visible-wavelength cameras, multi-spectral and hyperspectral imagers, as well as thermal imagers. Collected data will be analyzed using a combination of software tools including Matlab and Python. The ideal student will have interests in optical imaging and remote sensing.

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.

Light and sound in nanotechnology
Mentors: Prof. David Dickensheets, Dr. Phillip Himmer, Prof. 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.

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.

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.

Optical metamaterial characterization
Mentor: Prof. Wataru Nakagawa

The Nano Optics group is developing and testing composite optical materials (metamaterials) with engineered polarization properties for sensing and other applications. The optical properties including polarization characteristics of these devices must be thoroughly measured and analyzed in order to understand their performance and give feedback to the design and manufacturing processes. This involves using an optical characterization system to measure the spectral and polarization properties of the metamaterials under test, including laboratory automation and signal processing/analysis tools. The REU student will be trained on the operation of this system, assist in its calibration and testing, perform measurements on fabricated metamaterial devices, and potentially assist in making improvements to the system.

Polarization imaging
Mentor: Prof. Joe Shaw

We are developing and using polarization imaging systems to study atmospheric polarization, which has applications ranging from climate science to military surveillance. The project will involve laboratory calibration measurements of polarization imagers, as well as outdoor measurements of skylight polarization during day and night. Students working on this project also will help with data analysis using Matlab and other computer languages, and will help collect data using optical sensing instruments that include lidars, radiometers, thermal imagers, and radiosondes for characterizing meteorological conditions.

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 cells either based on mechanical forces, heat or light interactions. The efficiency of these methods is monitored through electrophysiology and 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. Depending on the student interests and background they can delve into developing computational models, which link spatial calcium activity to nanoparticle-mediated stimulation, design and fabricate new micro magnetic devices for nanoparticle mediated stimulation, or build and analyze small scale neuronal circuitries.