<u>Summer 2022 MSU ECE REU Projects</u>

Quantifying subcellular mechanical actuation through light (Mentor: Prof. Anja Kunze, Mackenna Landis, 2 students)

Modulating brain cell activity through mechanical forces has the potential to interfere with neuro-degenerative processes such as the loss of synaptic connections, the mis-location of proteins, and the dysregulation of secondary messengers. In the Kunze Lab we use fine-tuned static magnetic field gradient patterns to superimpose mechanical forces at the sub-cell scale to modulate brain cell function. The interplay between designing accurate force patterns and delivering physiological force ranges to the cells, however, requires precise force measurements for which we use light microscopy to quantify force amplitude and direction. The REU student will be exposed to the current challenges of light-based methods to quantify forces at the nanometer scale, perform force-characterization experiments in the lab, and potentially design new force fields to optimize mechanical stimulation in neurons. Depending on the student interests and background they can delve into developing computational models, or design novel micro magnetic structures, which will be fabricated using on-campus cleanroom fabrication and subsequent in-lab characterization techniques. Furthermore, the REU student can expect to get integrated into a highly interdisciplinary, friendly, vibrant, and interactive bioengineering lab.

Nanofabrication of Optical Devices (Mentor: Prof. Wataru Nakagawa, Prof. David Dickensheets, 1–2 students)

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, optical imaging, and LIDAR. 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 cleanroom facility.

Optical Metamaterial Characterization (Mentor: Prof. Wataru Nakagawa, 1–2 students)

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. Prior experience with Matlab, LabView, polarimetry, and/or benchtop optical measurements desirable but not required.

Drone-based River Imaging (Mentor: Prof. Joe Shaw, 1–2 students)

In this project, a student will help fly drones carrying hyperspectral and RGB imagers in field experiments to detect and map harmful algal blooms in rivers. The student will assist with regular field experiments by setting out calibration tarps and helping with drone flights, then will help calibrate, process, and georeference imagery from those flights. Analysis will be done using primarily Matlab and Python programming languages. The student also will conduct experiments to characterize the different kinds of algae collected from the river or grown in the lab by river ecology colleagues. For this project, interest and experience in environmental science, photography, imaging, and optical systems will be helpful.

Lidar Processing and Target Identification with Machine Learning (Mentor: Prof. Bradley Whitaker, 1–2 students)

The Whitaker Lab is collaborating with the Optical Remote Sensor Laboratory (ORSL) and Spectrum Lab to develop machine learning approaches for identifying targets in cluttered LiDAR environments. The techniques have applications from environmental monitoring (detecting fish in lakes or insects in a field) to military surveillance (detecting flying drones or camouflaged materials). In this REU project, we will use signal processing and machine learning techniques to identify targets of interest in labeled and unlabeled data collected using LiDAR devices.

Machine Learning for Touchless Respiratory Monitoring (Mentor: Prof. Bradley Whitaker, 1–2 students)

The Whitaker Lab is developing a touchless respiratory monitoring system to measure respiratory signals in subjects in a noninvasive manner. The end goal of the research is to be able to use this system to autonomously identify symptoms of respiratory disease (apnea, COVID, etc.) while improving the comfort of subjects in a clinical setting. Our current results indicate a high correlation between our novel touchless sensors (LiDAR and thermal measurements) and traditional contact sensors (spirometry, capnometry, respiratory inductance plethysmography) when measuring breathing rates and volumes. In this REU project, we will use machine learning tools to improve respiratory monitor measurements by automatically identifying irregular body positions that should be ignored. Considering various body positions will remove spurious measurements when calculating respiratory information such as breathing rate and breath volumes.

Die Attach and Wirebonding Process Characterization for Sensors and Integrated Circuits (Mentor: Dr. Andrew Oliver, 1 student)

Our world has been changed by integrated circuits. From smart phones, to the internet, to automobiles, integrated circuits are everywhere. In the last couple of years, the technology has been extended to build micro sized sensors. Researchers at MSU are working in this exciting area including applying integrated circuit and sensor technology to more novel and advanced applications such as lidar and screening for disease. This is an exciting opportunity for a hands-on undergraduate student to help develop this technology and help create next generation devices. Specifically, we are looking for an undergraduate student to help develop processes and process characterization equipment for die attach and wire bonding. This technology is necessary to move devices from the laboratory to an application. Specifically, the student will build the characterization machine, calibrate it and use it to develop standard processes in our laboratory. The student will also go into the microfabrication facility to help build the test samples. This project will involve an introduction to machine design, process control, experimental measurements, statistics, process development, and microfabrication. The student will also learn about Matlab and how to communicate and present experimental results.

Characterizing MEMS Mirror Perform in Lidar Systems (Mentors: Dr. Andrew Oliver, Prof. David Dickensheets, 1 student)

Microelectromechanical systems, or MEMS, is the technology of building sophisticated mechanical structures at micro-scale - so called "micromachines." MEMS micromirrors for laser beam scanning have emerged as enabling components for medical endoscopes, virtual reality headsets and LIDAR (LIght Detection And Ranging) cameras for smart and autonomous cars. Researchers at MSU are designing and building new types of micromirrors and optical sensors for many applications, including long-range LIDAR. This is an exciting opportunity for a hands-on undergraduate student to help develop this next generation of optical sensors and devices. Specifically, we are looking for an undergraduate student to develop a control system for the MEMS mirrors and to measure their performance inside a lidar system. This project will involve an introduction to and learning about optics and optical measurement techniques, microcontroller programming, lidar, control systems and statistics. They will also learn about Matlab and how to present experimental results.

Semiconductor Process Development (Mentor: Dr. Andrew Lingley, 1 student)

The Montana Microfabrication Facility is a resource for Montana State University, external academics, and commercial entities that provides affordable access to a range of micro and nanofabrication equipment. We support applications ranging from fundamental physics to biology, microfluidics, MEMS and MOEMS, and sensors. Our mission is to accelerate and simplify the process of designing and fabricating micro and nanoscale devices for scientific research, device development, and prototyping. To better achieve this mission, we need to understand and characterize semiconductor equipment and processes so our users can achieve their goals quicker. We will work with 1 REU student to better characterize one of the following processes, depending on the student's interest: 1) anodic bonding for microfluidics, 2) glancing angle electron beam evaporation for control over nanoscale crystal growth, 3) reactive sputtering for thin-film dielectrics. The participating student will be trained to work in the microfabrication (cleanroom) facility, as well as on the specific fabrication steps for the chosen process. This project will provide introductory experience for a motivated student to learn about micro- and/or nano-fabrication, with a broad range of potential applications. Prior cleanroom experience, while welcome, is not required; prior hands-on laboratory experience strongly preferred.

Image Recognition of Microbial Cells During Mechanical Loading (Mentor: Prof. Stephan Warnat**,** 1–2 students)

In natural environments, most microorganisms exist as organized communities known as biofilms. Biofilms are complex communities composed of multiple microorganisms and organic matter attached to surfaces that often cause microbial-induced corrosion. Studying biofilm growth is challenging owing to its heterogeneous structure and diverse microbial composition. The Warnat lab wants to develop an image recognition system that differentiates the diverse composition. The created database will be used in future work to determine mechanical biofilm properties. Image recognition algorithms need to be developed in Matlab for an autonomous detection machine on a single board computer such as the NVIDIA Jetson. Matlab offers existing functions that can be tested and optimized for biofilm characterization. The realized algorithm is expected to measure size and location in the field of view of beads and one defined biofilm-forming microorganism. Students will work and learn in an interdisciplinary team of biologists, physicists, mechanical and electrical engineering at the Center for Biofilm Engineering.

Optimization of Solar Cell Microfabrication Process for Education (Mentor: Prof. Todd Kaiser, 1 student)

The ECE Dept. at MSU has developed courses incorporating the hands-on fabrication of Silicon photovoltaic devices (solar cells) for both undergraduate students and K-12 teachers (in summer). Course participants are trained to work in the cleanroom, then fabricate and test a working solar cell over the duration of the course. The current process is focused on educational impact (as opposed to commercial value), however it is hoped that targeted improvements to a few steps in the process improve the efficiency of the resulting devices. Silicon solar cells typically will use a thermally grown silicon oxide layer that simultaneously acts to passivate the silicon surface while proving an antireflection (AR) coating for the front solar facing surface. Students participating in this project will go into the Montana Microfabrication Facility (MMF) and experimentally obtain the oxidation parameters for a thermally grown oxidation process, and then use these results to optimize the AR coating for the fabrication of single crystalline solar cells. While prior cleanroom experience is desirable, it is not expected; however strong motivation to learn these skills and gain microfabrication experience is required.