UCLA Samueli
School of Engineering

Summer Undergraduate Research Program at the Engineering Student Resource Center
Office of Academic and Student Affairs
UCLA Samueli School of Engineering
420 Westwood Plaza, 6288 Boelter Hall, Los Angeles, CA, 90095-1600
310.825.9478 | www.samueli.ucla.edu

UCLA Samueli
School of Engineering

SUMMER
UNDERGRADUATE
RESEARCH PROGRAM

2019

RESEARCH JOURNAL

DEAN'S MESSAGE

The Summer Undergraduate Research Program (SURP) provides participants with an intensive 8-week summer research experience in a wide range of engineering fields. Undergraduate students participate in research with UCLA Samueli School of Engineering faculty and research teams to gain real-world lab experience. As part of this program, SURP students:

- Meet and network with peers who have similar goals and interests
- Learn to communicate research outcomes by participating in weekly Technical Presentation Labs
- Create a professional scientific poster of their research
- Write and publish a research abstract
- Present a detailed Summary of Project
- Become more competitive when applying to engineering graduate schools

This year, 39 undergraduate students were selected to join the 2019 SURP cohort. I would like to congratulate this SURP class on completion of their amazing research projects. Creating new knowledge is a very important, and a very difficult, task. These high-performing students have done an outstanding job working through the rigors and challenges of full time research. They should be very proud of the abstracts and posters they have published today. I encourage you to meet the students, ask questions about their projects, and learn about the cutting-edge knowledge that is being created here at the UCLA Samueli School of Engineering.

Sincerely,

Jayathi Murthy
Ronald and Valerie Sugar Dean

LAB NAME
UCLA Visual Machines Group Laboratory

FACULTY ADVISOR
Professor Achuta Kadambi

GRADUATE STUDENT DAILY LAB SUPERVISOR
Guangyuan Zhao

DEPARTMENT
Electrical and Computer Engineering

Brian Chap
Electrical Engineering
First Year
UCLA
Functional Nanomaterials

Implementing Kinematic Prediction via Physics-Guided Neural Networks

Physics-guided neural networks (PGNNs) are crucial for modeling resistive behaviors in real- life scenarios ranging from vehicle tracking to aerial trajecto- ries. In prior papers, bounding box construction for videos would entail construc- tion for every individual frame, hindering progress in terms of speed-up without significant computational power. This paper aims to bridge the divide between image and video object detection, utilizing kinematic priors to predict the motion of subjects via the incorporation of affine transformations and per- spective consid- eration (horizon, side-to-side, overhead, etc.). Approaches based on optical flow algorithms and tubelet architectures are considered, and blended with physical mod- ules to harness spatiotemporal coherence among individual frames. Py- Torch 1.0 acts as the framework for code development, and all code is expected to be open-source for future development.

LAB NAME
Visual Machine Learning Group

FACULTY ADVISOR
Professor Achuta Kadambi

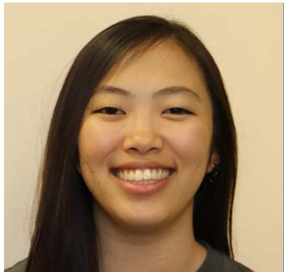
GRADUATE STUDENT DAILY LAB SUPERVISOR
Guanyang Zhou

DEPARTMENT
Electrical and Computer Engineering

Lucas He
Electrical Engineering
First Year
UCLA
Functional Nanomaterials

Physics-Based Object Temporal Localization Via Video Segmentation

The field of object detection has seen much advancements over the past years, especially in videos with the implementation and improvements of architectures such as Optical Flow, Tubelets, and Temporal Action Localization. However, such methods are still limited in their speed, efficiency, and accuracy, with the current fastest method running at an average of two frames per second. Thus, we propose the usage of the Physics Guided Neural Network (PGNN) to aid this task. By specifically tailoring this to detection of cars we hope to produce a naive form of detection that can track and solve transformations (i.e. scale, sheer, and direction) of cars as they travel down a road. Using segmentation, we would then be able to establish instances of the cars as apply a physics model and determine each object's trajectory based on the previous frames of the object's path. The application of the physics model will serve to reduce the computational requirements of previous methods and allow for a more accurate prediction of an object's temporal location.



LAB NAME

Fang Lu Mesoscopic Optics and Quantum Electronics Laboratory

FACULTY ADVISOR

Professor Chee Wei Wong

GRADUATE STUDENT DAILY LAB SUPERVISOR

Dr. Wenting Wang

DEPARTMENT

Electrical and Computer Engineering

Tz-Wei Hung

Electrical Engineering

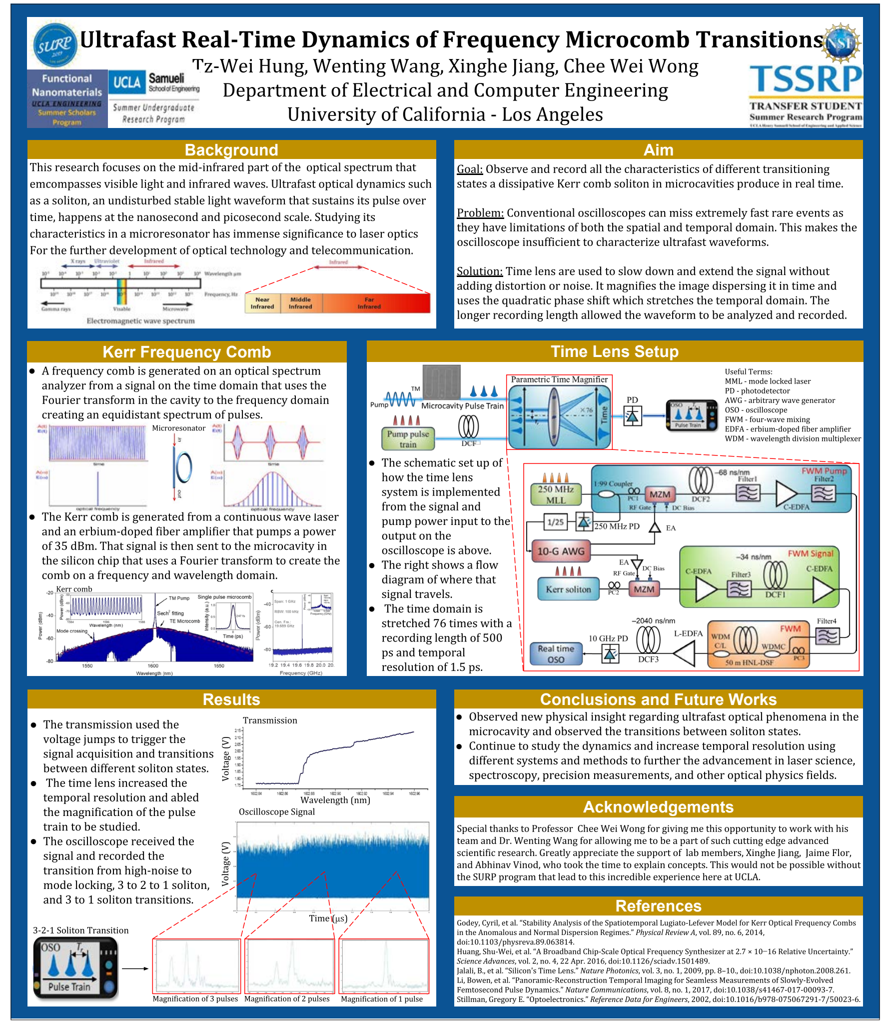
First Year

Pasadena City College

Functional Nanomaterials

Ultrafast Real-Time Dynamics of Frequency Microcomb Transitions

Temporally stabilized optical solitons, also known as self-sustaining nonlinear pulses at a mid-infrared frequency, confined in a microcavity driven by a continuous-wave laser has attracted tremendous attention due to its fascinating spectral and temporal features and corresponding intriguing cavity dynamics. A real-time ultrafast oscilloscope characterization system demonstrates the dynamics in the microcavity with picosecond resolution and a 500 picosecond recording length over each frame. However, the recording length is limited by the sampling rate due to the restricted memory depth of the oscilloscope during data acquisition. To bypass this complication, time lens was used to stretch the timescale of the waveform without adding distortion or noise. After finding the optimum recording length and temporal resolution, a Kerr frequency comb is generated in the micro-resonator with a laser which is then sent through optical fibers to the oscilloscope to be studied. We were then able to record the mode-locking formation and the transitions between different soliton states during the formation process. The real-time observations of the ultrafast optical dynamics provides new physical insight for ultrafast phenomena that happens in the microcavity.



LAB NAME
Neural Computation and Engineering Laboratory

FACULTY ADVISOR
Professor Jonathan Kao

GRADUATE STUDENT DAILY LAB SUPERVISOR
Professor Jonathan Kao

DEPARTMENT
Electrical and Computer Engineering

Alicia Mercado

Biochemistry and Mathematics

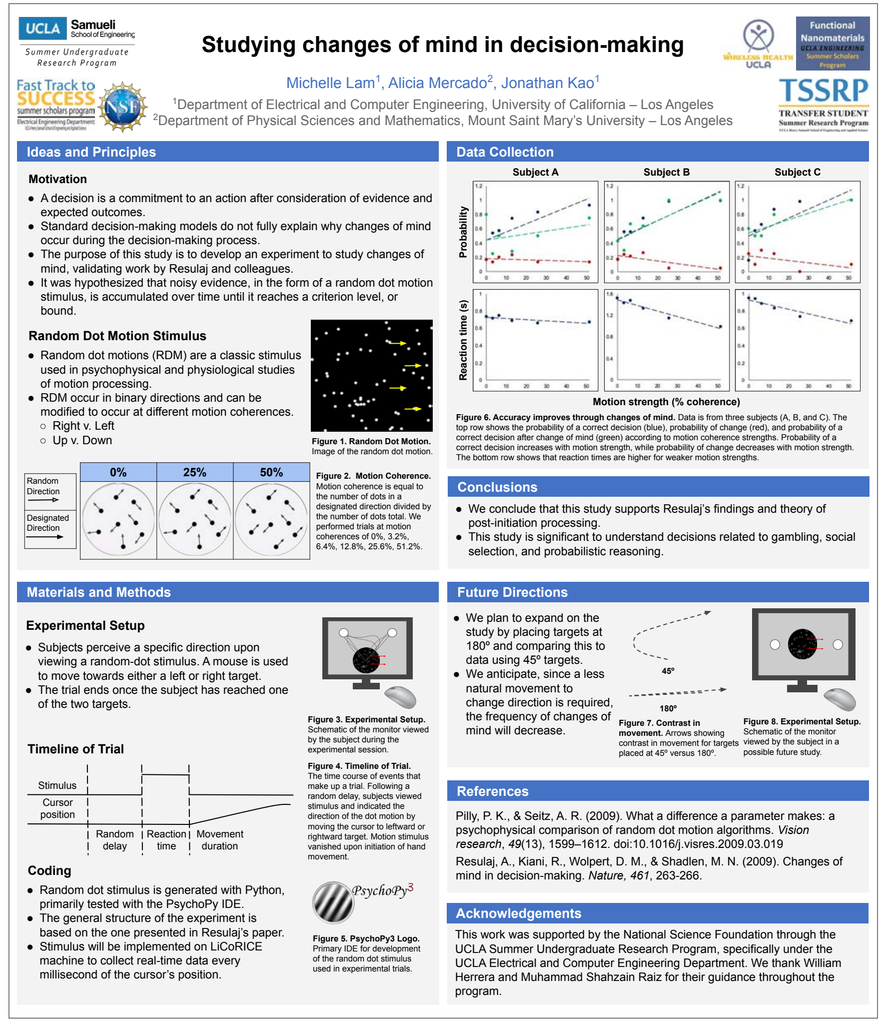
Second Year

Mount Saint Mary's University

Functional Nanomaterials

Studying changes of mind in decision-making

A decision is a commitment to an action after consideration of evidence and expected outcomes. The brain deliberates on available evidence to yield an action or decision. However, during cognition, we often change our minds; standard decision-making models do not fully explain why these changes of mind occur. The purpose of this study is to develop an experiment to study changes of mind, validating work by Resulaj and colleagues. It was hypothesized that noisy evidence, in the form of a random dot motion stimulus, is accumulated over time until it reaches a criterion level, or bound. An initial decision is made once this criterion is achieved. While the trials were conducted, subjects made decisions about a noisy visual stimulus, and then they indicated their choice of direction by moving a joystick according to the direction inferred. The brain then exploited further information that either reversed or reaffirmed the initial decision made. We conclude that this study supports Resulaj's findings and theory of post-initiation processing. This study is significant to understand decisions related to gambling, social selection, and probabilistic reasoning.



LAB NAME
Center for Heterogenous Integration and Performance Scaling (CHIPS)

FACULTY ADVISOR
Professor Subramanian Iyer

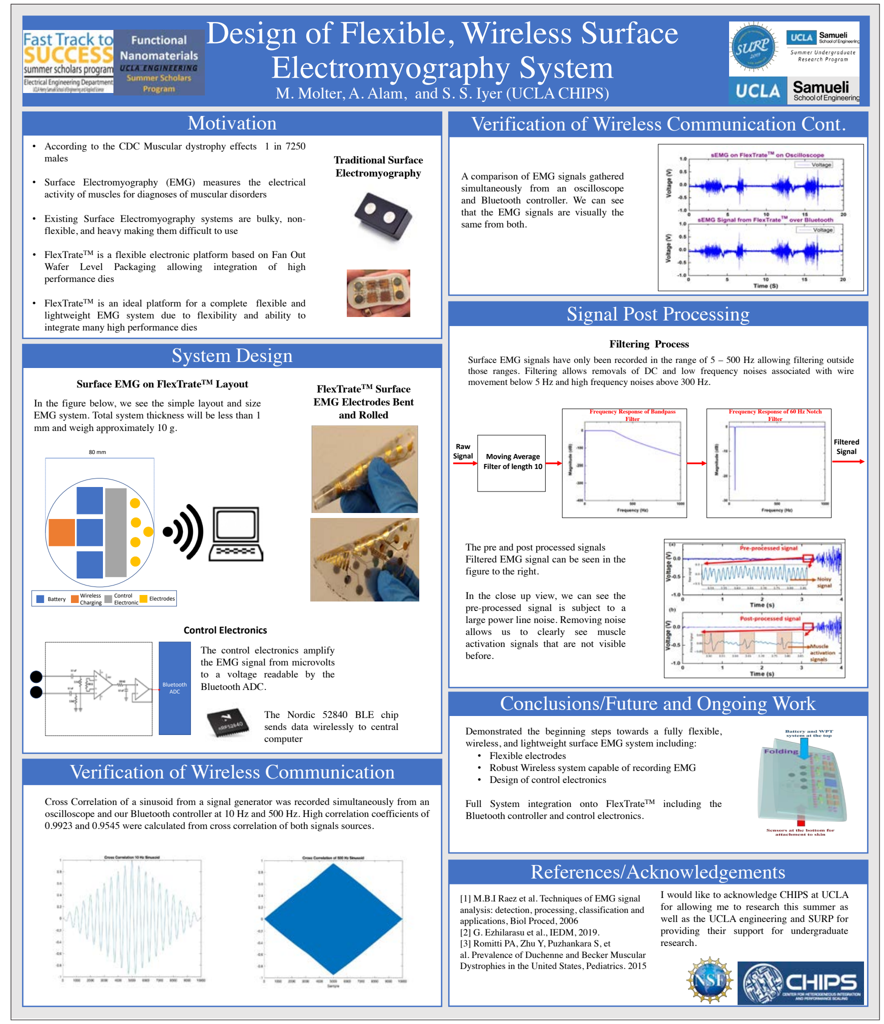
GRADUATE STUDENT DAILY LAB SUPERVISOR
Arsalan Alam

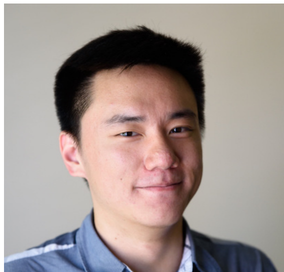
DEPARTMENT
Electrical and Computer Engineering

Michael Molter
Electrical Engineering
Third Year
UCLA
Functional Nanomaterials

Design of Flexible, Wireless Surface Electromyography System

According to the CDC 1 in every 7,250 males are afflicted by Duchenne and Becker muscular dystrophy, a disease that affects muscle strength and leads to muscle degeneration. Surface Electromyography (EMG) is a non-invasive method used to measure muscle activity that can help in the diagnosis and treatment of musculoskeletal diseases such as muscular dystrophy. Typical Surface Electromyography machines are often bulky, rigid, and heavy which makes them difficult to use in a clinical setting, and it means they cannot be used as wearable devices. In addition, these systems are often single-channel systems which limit the spatial and temporal information that the system can gather, making readings incomplete. To help solve these issues, a full multi-channel electromyography system that is lightweight, flexible, and wireless will be integrated on FlexTrate™ , a flexible electronic platform based on Fan-Out Wafer Level Packaging (FOWLP). The surface EMG will take advantage of FlexTrate™ to integrate a variety of different integrated circuit (IC) dies such as amplifiers, passive components, and a Bluetooth Low Energy (BLE) chip as well as electrodes to detect the EMG signal. For wireless communication, the Nordic nRF52840 BLE module is used for low system power. Using FlexTrate™, the overall system will be lightweight, thickness less than 1 mm, and flexible enough to conform to skin allowing for a wearable device that can be used easily in a clinical setting.





LAB NAME
Sensors and Technology Laboratory

FACULTY ADVISOR
Professor Rob Candler

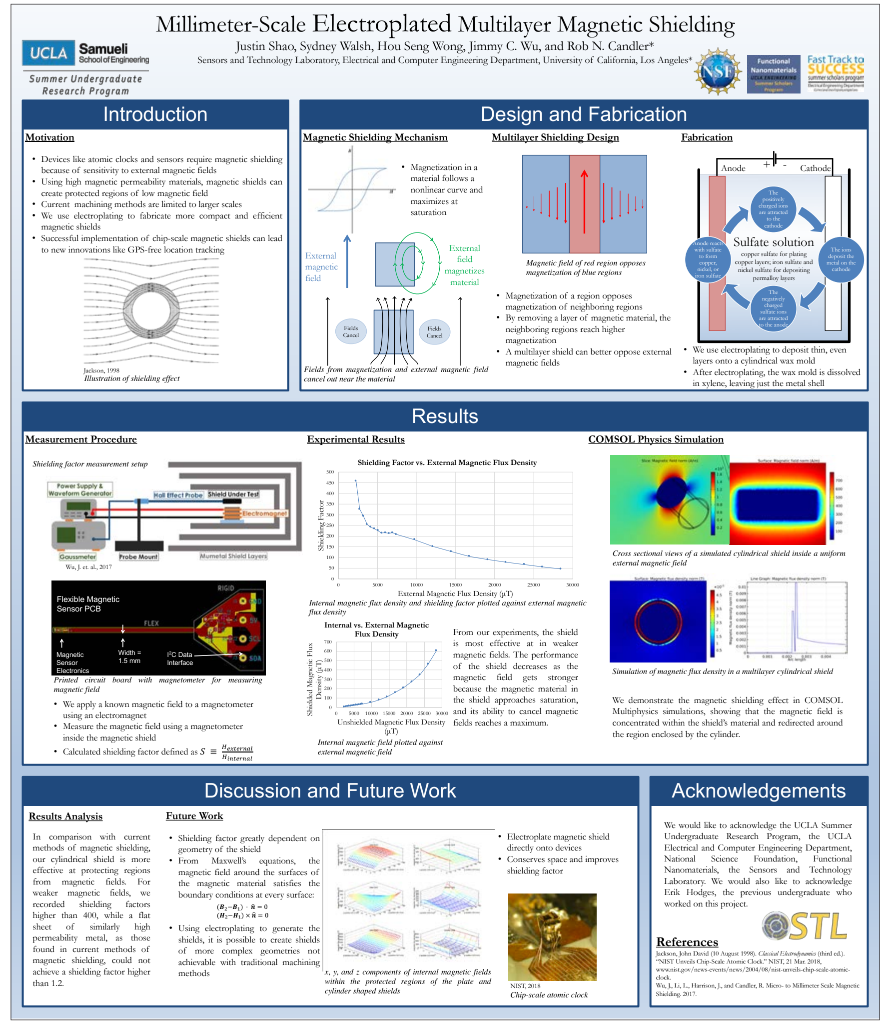
GRADUATE STUDENT DAILY LAB SUPERVISOR
Jimmy Wu

DEPARTMENT
Electrical and Computer Engineering

Justin Shao
Electrical Engineering
Second Year
UCLA
Functional Nanomaterials

Millimeter-Scale Electroplated Multilayer Magnetic Shielding

Many devices that rely on atomic spectroscopy, like gyroscopic sensors and atomic clocks, require magnetic shielding to function as intended because of interference by external magnetic fields. Although no known material is able to stop a magnetic field, high permeability materials are able to effectively redirect magnetic field lines, creating protected regions of low magnetic field strength. Current methods of magnetic shielding involve inserting a sheet of high permeability material on a circuit board underneath a device or wrapping a region in a sheet of the high permeability material. In this project, we fabricate high performance chip-scale magnetic shields by electroplating alternating layers of nickel-iron alloy, which has a high relative permeability, and copper, which has a low relative permeability, onto a cylindrical shell. By alternating layers of high and low permeabilities, we minimize the influence of the demagnetization field, achieving a higher ability to redirect magnetic field lines. To test the shields, we use an electromagnet to generate a magnetic field and a magnetometer to measure the magnetic field inside the shield. We record the shielding factor of the shield, which is defined as the ratio of the external magnetic field strength to the internal magnetic field strength. Successful millimeter-scale shielding would allow for effective chip-scale implementation of devices that would function in external magnetic fields while conserving space.



LAB NAME
Visual Machines Laboratory

FACULTY ADVISOR
Professor Achuta Kadambi

GRADUATE STUDENT DAILY LAB SUPERVISOR
Guangyuan Zhao

DEPARTMENT
Electrical and Computer Engineering

Irfan Syed
Electrical Engineering
First Year
El Camino College
Functional Nanomaterials

Tracking Objects Using Physics-Guided Neural Networks

Incorporating physics into neural networks, known as physics guided neural networks (PGNN), has been explored for object detection and tracking. The proposed method aims to enhance accuracy by merging regional convolutional neural networks (R-CNN) and physics-guided models. Using video segmentation methods, it uses a physics guided neural network to classify, detect, and track objects. A self-made dataset created with ideal scenarios involving linear motion such as object drops and tosses is the testing framework for the physics-guided model. The dataset contains scenarios involving the complexity of object occlusion for future development of the prediction model to increase accuracy in realistic, occluded situations. Classification and motion tracking of objects through predicted patterns rely on physics-based learning. By predicting trajectories in later frames based on kinematic calculation in earlier frames within the video, the model is able to detect and track the target object and increase accuracy. Pytorch 1.0 is the framework used for developing this platform and the code will be open source for future development.

Implementing Kinematic Prediction via Physics-Guided Neural Networks

Brian Chap, Lucas He, Irfan Syed
Guangyuan Zhao, Achuta Kadambi
Department of Electrical and Computer Engineering, UCLA

Using Physics-Based Machine Learning to Track Objects

Physics-guided neural networks (PGNNs) are crucial for modeling resistive behaviors in real life scenarios ranging from vehicle tracking to aerial trajectories. In prior papers, bounding box construction for videos would entail construction for every individual frame, hindering progress in terms of speed without significant computational power. This paper aims to bridge the divide between image and video object detection, utilizing kinematic priors to predict the motion of subjects via the incorporation of affine transformations and perspective consideration (horizon, side-to-side, overhead, etc.). Approaches based on optical flow algorithms and tubelet architectures are considered and blended with physical modules to harness spatiotemporal coherence among individual frames. PyTorch 1.0 acts as the framework for code development and all code is expected to be open-source for future development.

Regional Convolutional Neural Networks

Figure 1 : Improvements such as clearer annotations and bounding box representations were made on a Faster R-CNN framework with 20 different classifications of objects. The physics model resulted from this framework of Faster R-CNN.

Dataset

Applications of physics-based calculations on the Faster R-CNN framework were tested on a self-made dataset of videos that captured optimal scenarios, including drops, tosses, and object sliding on surfaces to model the effects of gravity, resistance, and object motion. The added complexity of object occlusion was captured for the purpose of modeling realistic difficulties in object detection and motion prediction.

Physics-Based Model

Frame
Bounding box coordinates
Class labels
Confidence probabilities

For Frames 1 and 2, Frames 2 and 3

Calculate Euclidean distances between bounding boxes of the same class

Remove "camera motion" if all subjects move consistently between frames

Identify the shortest distance between bounding boxes of the same class (velocity).

Find the change in velocity between two pairs of frames (acceleration).

For next 17 frames

Use kinematic equations to predict locations of future bounding boxes.

The midpoint of a bounding box (above) was used to calculate distance

If ground truth is close to the predicted bounding box, increase confidence probabilities.

If ground truth is far from the predicted bounding box, decrease confidence probabilities.

Future Plans

The proposed physics model performs with high confidence values in the ideal scenarios created within the dataset. Expectations for future improvements include higher efficiency rates, faster processing rates, greater accuracy between multiple objects, and more accurate predictions for accounted complexities such as occlusions, lighting, and camera motion.

Limitations of current model:

Inability to account for changing acceleration
Inability to predict object motion with occlusions
Prediction model accounts for only 2D object transformations.
Unidentified objects lack physics-based machine learning

Applications:

Self-Driving
Defense Industry
Autonomous Drones
Movement Prediction

Preliminary Results

Figure 4: Bottle detection without physics-based learning (left) and with physics-based learning (right)

Figure 5: Multiple object detection without physics-based learning (left) and with physics-based learning (right)

The physics-based model results indicate significant increases in the accuracy of the model when compared with simply the Faster R-CNN framework. Faster R-CNN with physics-based machine learning increases the confidence of object detection and removes classification errors for objects.

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LAB NAME
Sensors and Technology Laboratory

FACULTY ADVISOR
Professor Robert Candler

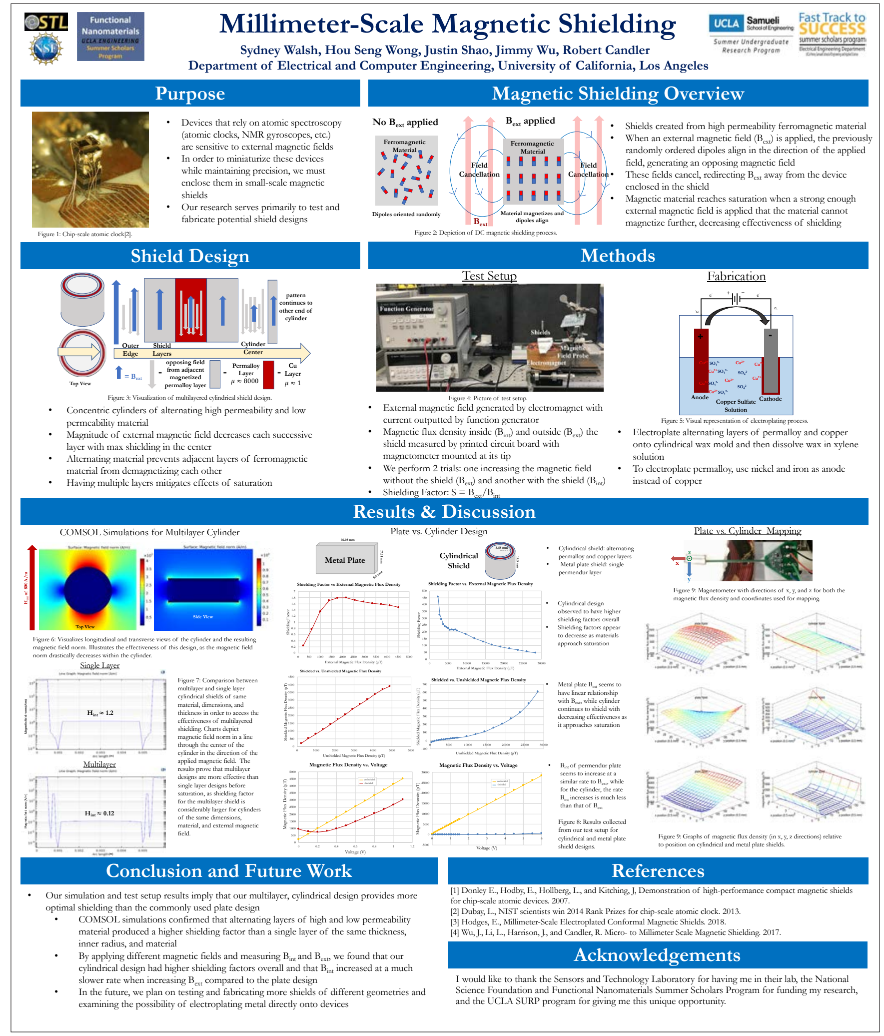
GRADUATE STUDENT DAILY LAB SUPERVISOR
Jimmy Wu

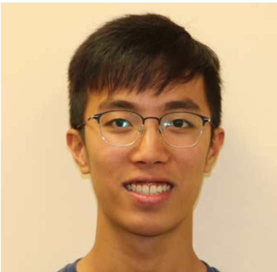
DEPARTMENT
Electrical and Computer Engineering

Sydney Walsh
Electrical Engineering
Second Year
UCLA
Functional Nanomaterials

Millimeter-Scale Magnetic Shielding

Devices that rely on atomic spectroscopy, such as nuclear magnetic resonance gyroscopes and atomic clocks, are strongly affected by external magnetic fields. Thus, in order to miniaturize these devices while maintaining precision, small-scale magnetic shields must be developed to properly redirect magnetic field lines away from the enclosed devices. The purpose of our research is to fabricate and test potential shield designs. Based on previous research, we determined that the optimal design would consist of concentric cylinders of alternating high permeability and low permeability material. By alternating layers, we partially prevented adjacent ferromagnetic material from reducing the magnetization of that layer. Moreover, multilayer shielding allowed us to mitigate the effects of magnetic saturation, as a single layer of magnetic material would reach saturation more quickly, limiting the shield's ability to generate an opposing field. We conducted our research by simulating potential shield designs in COMSOL Multiphysics, developing an appropriate test setup to assess the effectiveness of our shields, and fabricating shields to test. For our test setup, we generated a magnetic field using an electromagnet and measured the magnetic flux density using a printed circuit board with a magnetometer mounted at its tip; shielding factor was determined by taking the ratio of external to internal magnetic field. Shields were fabricated by electroplating alternating layers of permalloy and copper.





LAB NAME
Sensors and Technology Laboratory

FACULTY ADVISOR
Professor Robert Candler

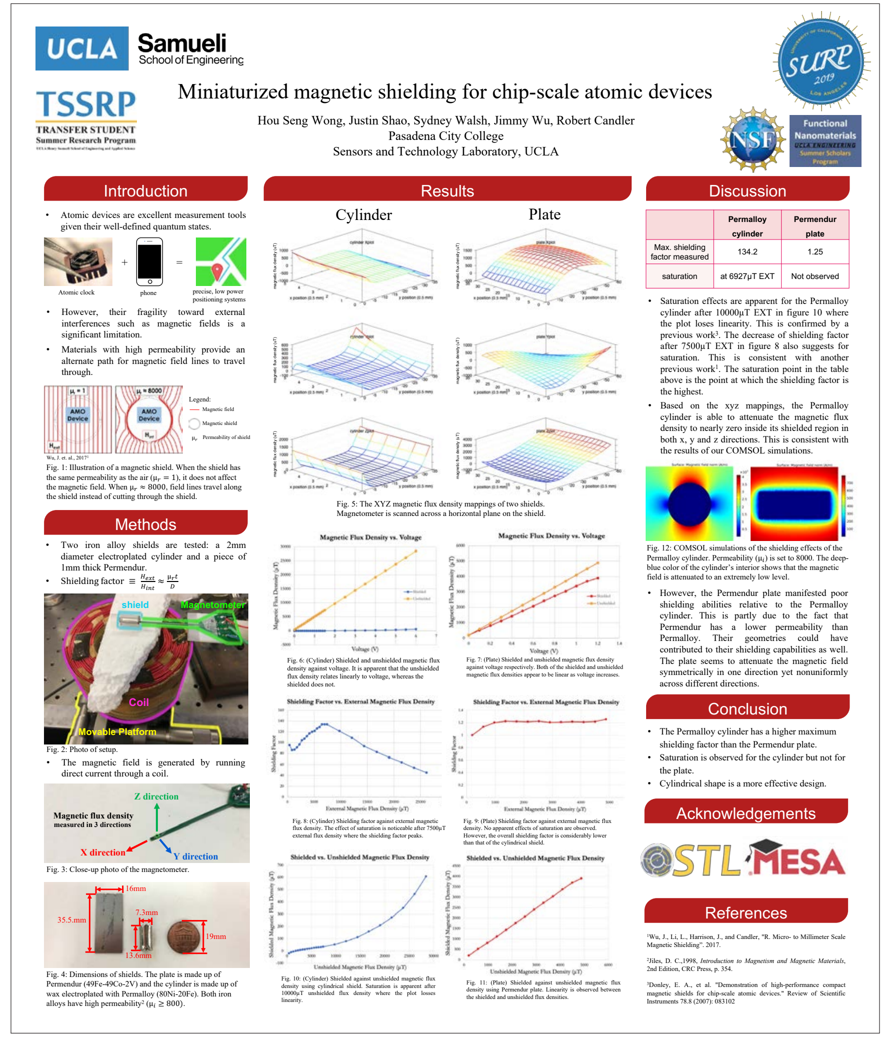
GRADUATE STUDENT DAILY LAB SUPERVISOR
Jimmy Wu

DEPARTMENT
Electrical and Computer Engineering

Hou Seng Wong
Computer Science
First Year
Pasadena City College
Functional Nanomaterials

Miniaturized magnetic shielding for chip-scale atomic devices

Atomic devices such as atomic clocks and nuclear magnetic resonance (NMR) gyroscopes are excellent for taking measurements because of their well-defined quantum properties. The miniaturization of atomic devices would allow for them to be combined with phones and wearables, which allow for extremely precise, low power positioning systems. However, such devices must be extremely well-isolated against external interference, such as a magnetic field, to preserve their accuracy. For example, atomic clocks need to be shielded to prevent magnetic fields from interfering with the energy spectrum of atoms and to maintain the clock's frequency. Recent efforts have been made to miniaturize chip-scale atomic devices. But to further scale down the size of atomic devices, smaller magnetic shields must be fabricated to accommodate the compact environment inside electronic devices. In this research, the magnetic behavior of a flat piece of Permendur and a cylinder of Permalloy was measured to study the shape-dependency of magnetic shields as well as their effectiveness to attenuate an external magnetic field. The results of this research would provide insights for the optimal design of a miniaturized magnetic shield.



If you would like to find out more about the Summer Undergraduate Research Program, please contact Director William Herrera:

William Herrera
Director
Undergraduate Research Program
310.825.9478
williamh@seas.ucla.edu
Engineering Student Resource Center, 6288 Boelter Hall

Or visit our website at https://tinyurl.com/uclasurp.

UCLA Samueli School of Engineering