REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: **1**

Project Title: **Developing a Optical Phantom to Evaluate Mechanisms to Detect and Stage Bladder Cancer**

Faculty Advisor: Audrey Ellerbee
Faculty Advisor Email: audrey@ee.stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Gennifer Smith
Graduate Student Mentor Email: gsmith9@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Traditional white light cystoscopy (WLC), endoscopy for bladder, often fails to find subsurface bladder tumors. Optical coherence tomography (OCT), a high-resolution imaging technique, has shown great promise an adjunct to WLC for detection of tumors. Not only can OCT aid in the detection of tumors but its ability to see below the surface allows for staging of the tumors as well. Unfortunately, its development as a tool for comprehensive bladder imaging and automated disease detection is hampered by the lack of suitable large-animal models -- or adequate phantoms -- to test new hardware and software designs. In this project we aim to fabricate an artificial bladder that mimics the optical, mechanical and structural features of a bladder. In doing so, we will also be modifying the fabrication process to create areas in the bladder that mimic different stage tumors as seen by OCT. We will collect and analyze images from a commercial OCT system in order to improve the fabrication process.

Recommended Courses/Readings: Some previous experience in a wet lab is desired but not required.

Desired Qualifications of REU Intern:

- Ideal candidates are:
    - consciousness, independent and hard-working
    - interested in applying engineering tools and material fabrication techniques to medical problems

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

Project #: 2

Project Title: Microscopy Equipment for Imaging Large Populations of Neurons in the Primate Motor Cortex

Faculty Advisor: Krishna Shenoy
Faculty Advisor Email: shenoy@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Eric Trautmann
Graduate Student Mentor Email: etraut@stanford.edu
Graduate Student Mentor #2 (if applicable): Dan O'Shea
Graduate Student Mentor Email: djoshea@stanford.edu

Project Description:

The purpose of this project is to design, build, and test equipment to enable proof of concept experiments to establish calcium imaging methods in primates. Neuroscientists currently use intra-cortical electrodes to record from populations of neurons in order to understand how the brain controls behavior in both humans and animals. For example, in our lab, we record from neurons in the primary and pre-motor cortices to understand how neural signals in these areas control muscles to produce movements in our limbs. Existing electrode array technologies limit us to record a subset of roughly 100 neurons of the many millions of neurons involved in these neural circuits. Imaging methods, recently demonstrated in flies and mice, present the potential for recording from much larger populations of neurons, while also providing unprecedented access to information about the types of cells and fine spatial patterns of activity in motor cortex. Our lab is working to establish the first proof of concept imaging methods in primates. If successful, this will enable a wide range of new scientific questions that we are unable to address using current techniques.

REU students will work closely with graduate students to develop hardware (laser optics and microscopy) and software (image processing, simulation and modeling, and experiment automation) to enable these experiments. Programming (MATLAB, C, or Python) programming experience required and CAD (Solidworks/Autodesk) experience preferred.

Recommended Courses/Readings: N/A

Desired Qualifications of REU Intern: Programming (Matlab, C, or Python - required)

CAD (Solidworks/Autodesk - desired)

Analog and digital electronics (desired)

Interest in neuroscience

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 3

Project Title: Validation of Complex Multi-Core System-on-Chips (SoCs)

Faculty Advisor: Subhasish Mitra
Faculty Advisor Email: subh@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: David Lin
Graduate Student Mentor Email: linhai88@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Computing systems are an indispensible part of all our lives. We depend on powerful portable devices (smartphones, tablets, and notebooks) as well as cloud-based computing servers for communication, e-commerce, finance, entertainment, education, scientific research, public administration, enterprise management, and even socializing. These computing systems are becoming increasingly complex in order to meet performance and energy-efficiency demands. However, such increasing complexities make it very challenging to design computing systems are robust and free of design flaws (bugs). For example, we are already seeing serious design flaws that escape to the field, which can jeopardize correct system operations and cause serious security vulnerabilities. Therefore effective verification and validation techniques are essential to guarantee that future computing systems can continue to provide us with the level of reliability, performance and energy efficiency that we all expect.

Towards this goal, our research group is creating new techniques for effective verification and validation of complex computing systems. Our group has extensive collaboration with several industrial leaders in the area of integrated circuit (IC) design, such as AMD, Freescale, IBM, Intel, and Renesas. Recently, our group has demonstrated 9 orders of magnitude improvement in error detection capabilities on a commercial multi-core System-on-Chip (SoC) using our Quick Error Detection (QED) technique.

We are looking for students to work on creating new techniques to effectively validate and debug large computing systems. In this project, students will be exposed to the cutting edge of computer architecture, system level programming, circuit design, design emulation, verification and validation techniques, and a variety other topics in electrical engineering and computer science.

Recommended Courses/Readings: EE108, EE282, CS143, CS 140 are desirable, but not required.

Desired Qualifications of REU Intern:

- Familiarity in a programming language or scripting language.
- Familiarity in a hardware description language (Verilog or VHDL).
- Some knowledge of computer architecture is desirable.

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 4

Project Title: High Power Interconnects for Dielectric Laser Accelerators

Faculty Advisor: James Harris
Faculty Advisor Email: jharris@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Ken Leedle
Graduate Student Mentor Email: kleedle@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Dielectric laser accelerators are poised to revolutionize the accelerator and x-ray laser fields and have recently been demonstrated with very high accelerating gradients (over 300MeV/m). One of the challenges is driving the dielectric structures with high stability at the required laser powers as we move from single stage to multi-stage accelerators. This project seeks to explore high-power on-chip interconnects for laser coupling to the accelerator structures. It will involve simulation and fabrication of devices in the SNF and performing precision measurements with high power lasers and electron beam systems.

Recommended Courses/Readings: EE134, EE136, and EE116 would be useful but don't worry if you haven't taken them.

Desired Qualifications of REU Intern:

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: **5**

Project Title: **Fabrication and Characterization of STM Tips Using Different Metal Materials as Nanosensor for Quantum Biomolecular Transducer (QBT)**

Faculty Advisor: Roger Howe
Faculty Advisor Email: rthowe@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Shuai Chang
Graduate Student Mentor Email: schang23@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

The Quantum Biomolecular Transducer (QBT) is a micro-/nano-fabricated biosensor platform, which attempts to transduce quantum-mechanical information about a biological molecule (frequencies of vibration associated with the different bonds in the molecule) into a discriminating electronic signal. It measure these fundamental frequencies by "illuminating" the molecule of interest by a tunneling electron stream with a well-defined energy level and the scattering of these electrons from the vibrating bonds in the molecule is extracted from the measured current, as a function of the electronic energy. With the success of this platform, QBT enables the development of an all-electronic "spectroscopic" tool that has applications in point-of-care medical sensing systems.

Scaling down the size of those biosensors is the key in the fabrication of the QBT sensors. STM tips are great candidates for QBT sensors because of low overhead in fabrication and atomic scale sharpness of the tips, which makes them ideal leads for contacting the functional sensor interface. In this project, a repeatable and reliable technique will be built to fabricate STM tips from different metals, including gold, palladium, platinium/Iridium, nickel, and silver using electro-chemical etching methods, wherein custom circuits will be fabricated for automated, rapid and reliable etching of tips. Atomic layer deposition (ALD) will be utilized as a tool for insulating the fabricated tip structures with different insulation materials, and focused ion beam (FIB) will be employed to open the sensing area at the nano-scale.

Recommended Courses/Readings: Circuit design

Desired Qualifications of REU Intern:

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 6

Project Title: Studying Biomolecular Sensor in Nanoscale Metal-Insulator-Metal (MIM) System Based on Atomic Force Microscopy

Faculty Advisor: Roger Howe
Faculty Advisor Email: rthowe@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Shuai Chang
Graduate Student Mentor Email: schang23@stanford.edu
Graduate Student Mentor #2 (if applicable): Chaitanya Chaitanya
Graduate Student Mentor Email: cgupta2@stanford.edu

Project Description:

This project is to design and fabricate a metal/semiconductor-insulator-metal/semiconductor heterojunction capable of transducing vibrational and electronic mode information about the properties of the enclosed interfaces. This micro-/nano-fabricated junction measures the fundamental frequencies of these discrete modes by "illuminating" the heterojunction with a tunneling electron stream with a well-defined energies and the scattering of these electrons from the vibrating bonds in the molecule is extracted from the measured current, as a function of the electronic energy. It enables the development of an all-electronic "spectroscopic" tool for the characterization of these mesoscopic junction interfaces. A suitable target analyte will be â€œsandwichedâ€ within the heterojunction such that its electronic and vibrational frequencies will also be elucidated from the tunneling current information, thereby enabling the development of an all-electronic nose for sensing odorant molecules of interest.

The test prototype for the â€œe-noseâ€ concept will be built using the conductive AFM (cAFM) platform, where the nanoscale tip of the force microscope will be used as the top metal contact for the nanoscale heterojunction structure. Besides extracting tunneling current information, we will utilize additional capabilities of the AFM like the sample topography, surface potential and interactive force between tip and surface, to characterize the junction interfaces. Additional surface analysis tools like SIMS and XPS may also be employed to characterize the fabricated junctions. The cAFM may also be employed for the fabrication of the interface using local electric fields and thermal gradients for nanoscale patterning.

Recommended Courses/Readings: Quantum Physics

Desired Qualifications of REU Intern:

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 7

Project Title: Developing a Cystoscopy Database for Bladder Cancer Prediction

Faculty Advisor: Audrey Ellerbee
Faculty Advisor Email: audrey@ee.stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Kristen Lurie
Graduate Student Mentor Email: klurie@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Routine surveillance of the bladder using cystoscopy (endoscopy for the bladder) is critical to detect recurrence for patients diagnosed with bladder cancer. The current qualitative reporting of cystoscopy images, however, is poor at detecting early-stage cancers. We seek to improve on current diagnostics because early detection of bladder cancer plays a critical role in preventing the recurrence and progression of the disease. The long-term vision of this project is to develop a database of cystoscopy images that we can use to determine image-based features that can help predict cancer at its earliest stages. There are several short-term projects that will help facilitate our long term vision. These may include implementing algorithms to convert existing video data into image mosaics or developing tools to aid image annotation. The specific project will be designed to be commensurate with the studentâ™s programming experience.

Recommended Courses/Readings: Necessary: Programming experience at the level of CS106A and familiarity with MATLAB

Desired: Additional programming experience past CS106A, computer vision, imaging processing or machine learning experience (e.g., CS231A, EE368, CS229A or related)

Desired Qualifications of REU Intern:

*consciousness, independent and hard-working
*interested in image processing and applying engineering tools to medical problems
*excited about programming

Maximum number of REU intern positions available: 2

Attachments: N/A

Additional Comments: N/A

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: **8**

Project Title: **Integrated Cell Phone Microscopy for Point of Care Urinalysis**

Faculty Advisor: Audrey Ellerbee
Faculty Advisor Email: audrey@ee.stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Audrey Ellerbee
Graduate Student Mentor Email: audrey@ee.stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Urinalysis is one of the most prevalent tests conducted in the primary care setting because it can diagnose for a number of important diseases and conditions. Existing dipstick assays â“ the most common form factor for urinalysis â “are, however, at best semi-quantitative and provide unreliable results when performed outside of the clinical setting. The goal of this project is to help develop a prototype holder and cell phone application to automatically analyze the results of of a dipstick assay collected with our novel microfluidic chip. Depending on the stage of the project by the summer, the project may involve some fabrication (likely 3D printing, soft lithography), optical design, or computer programming (design of an app for cell phone analysis). Hence a student with multiple skillsets is highly desired.

Recommended Courses/Readings: (Phy 45, EE41 or EE134 or equivalent), CS106, EE108A

Desired Qualifications of REU Intern: Interested students must demonstrate: creativity, initiative, self-motivation, good programming skills and like to build things and have experience with lab courses.

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 9

Project Title: Design and Fabrication of Germanium Surface-plasmon-enhanced Light-emitting Diodes

Faculty Advisor: Jelena Vuckovic
Faculty Advisor Email: jela@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Alexander Piggott
Graduate Student Mentor Email: piggott@stanford.edu
Graduate Student Mentor #2 (if applicable): Jan Petykiewicz
Graduate Student Mentor Email: janp@stanford.edu

Project Description:

Germanium-based light sources are attractive for on-chip optical interconnects due to Germanium's compatibility with standard CMOS processing, unlike the III-V semiconductors which are commonly used in LEDs and lasers. Recently, we have developed a Germanium strain-enhanced optically pumped light emitting diode. Our goal is to further enhance light emission from this device by adding metal structures that support surface-plasmon polaritons, which has been demonstrated to enhance light emission from quantum dots and quantum wells.

The student will design suitable metal gratings for plasmonic enhancement using finite-difference time domain (FDTD) simulations. They will then fabricate the surface-plasmon enhanced germanium LEDs at the Stanford Nanofabrication Facility (SNF) and Stanford Nano Center (SNC), and perform optical measurements to determine if the device performs as designed.

Recommended Courses/Readings: CLASSES (recommended)

EE340 (Optical micro- and nano-cavities)

EE336 (Nanophotonics)

EE216 (Principles and Models of Semiconductor Devices)

EE410 (Integrated Circuit Fabrication Laboratory)

READINGS

A. Taflove and S. C. Hagness, Computational Elec

Desired Qualifications of REU Intern: Previous experience with any of the following would greatly aid the student: electromagnetic simulations, micro/nanofabrication, and hands-on optics experience.

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: **10**

Project Title: **Optical Measurement of the Mechanical Properties of Developing Embryos**

Faculty Advisor: Audrey Ellerbee
Faculty Advisor Email: audrey@ee.stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: N/A
Graduate Student Mentor Email:
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

The morphological heterogeneity of the cell is a hallmark of life that critically underpins the mystery of how a single cell develops into a complex organism comprising millions of differentiated and physically distinct cells that carry out unique functions. The goal of this project is to assist with development new multi-functional imaging platform to extract novel morphological and biomechanical markers that are predictive of viability in the early-stage embryo. REU students would be asked to carry out components of the design and construction of an imaging chamber or processing of images.

Recommended Courses/Readings: optics (Phy45, EE134 or equivalent). Any human biology or embryology courses would be an additional bonus.

Desired Qualifications of REU Intern: Interested students must demonstrate: creativity, initiative, self-motivation and like to build things and have experience with lab courses.

Maximum number of REU intern positions available: 2

Attachments: N/A

Additional Comments: N/A

Project #: **11**

Project Title: **Modeling and Experimental Study of Quasi-Electrostatic (QE) Fields and High Altitude Discharges Above Thunderstorms**

Faculty Advisor: Umran Inan
Faculty Advisor Email: inan@stanford.edu
Faculty Advisor #2 (if applicable): Nikolai Lehtinen
Faculty Advisor #2 Email: nleht@stanford.edu
Graduate Student Mentor: Rasoul Kabirzadeh
Graduate Student Mentor Email: rasoulk@stanford.edu
Graduate Student Mentor #2 (if applicable): Patrick Blaes
Graduate Student Mentor Email: prblaes@stanford.edu

Project Description:

Quasi-electrostatic (QE) fields, created by fast (~1 ms) removal of electric charges from a thundercloud, can lead to ionization, heating, and optical emissions at high altitudes (~70 km). Many important questions such as the effects of the horizontal transport of the charges and also multiple discharges at different locations both on the thundercloud and high altitude environment have not been studied due to the modeling constraints. A detailed and realistic study of these phenomena requires a three-dimensional model which is computationally challenging. In this study, we have developed a fully scalable parallel 3D numerical model to solve for the QE fields. The new model has been verified against the previous 2D models.

The students will have the opportunity to work on either improving the existing model or working with experimental optical data from two state-of-the-art optical instruments developed at Stanford University and Air Force Academy to test the predictions of the model against observations. The student would be also responsible to read scientific papers and may have the opportunity to prepare the results for publication in a journal.

Recommended Courses/Readings: C++ coding (CS106B), parallel computing (CS149/CME213 or equivalent), Matlab programming, signal processing

Desired Qualifications of REU Intern: Higher level undergraduate students (3rd or 4th year) with high proficiency in programming and data analysis skills.

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

Project #: 12

Project Title: GridSpice: A Virtual platform for modeling, analysis, and optimization of the smart grid.

Faculty Advisor: Abbas El Gamal
Faculty Advisor Email: abbas@ee.stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Kyle Anderson
Graduate Student Mentor Email: kyle.anderson@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

GridSpice is a scalable, open-source simulation framework for modeling, designing, and planning of the smart grid. GridSpice seamlessly integrates existing electric power simulation tools to allow developers to apply statistical learning and optimization techniques to analyze smart grid control systems. The framework is built on cloud architecture that allows for parallelizing large simulation jobs across many virtual machines using a pay-as-you-go model. GridSpice simulations can be managed through a REST API or through a python library, allowing users to run simulations programmatically and interface with disparate data inputs, energy management systems (EMS), supervisory control and data acquisition (SCADA) feeds, external simulation tools, and post-processing tools. These capabilities make GridSpice a particularly ideal tool for the development and testing of new smart grid systems which blur the traditional boundaries between wholesale markets, generation, transmission, distribution, and enduse loads. GridSpice also provides an easy-to-use browser-based interface to allow novice users to begin without any setup or configuration on their local PC.

Recommended Courses/Readings: Electric power industry is undergoing a transformation unlike anything it has seen in over a century. Utilities are absorbing new technologies and innovative pricing models while being subjected to an increasingly competitive marketplace. To meet the chan

Desired Qualifications of REU Intern: Programming experience at level of CS107 or greater

Familiarity with Machine Learning and Data Analytics techniques

Maximum number of REU intern positions available: 4

Attachments: N/A

Additional Comments: N/A

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 13

Project Title: Siple Station Experiment: Processing Large Analog Datasets for Digital Archival and Analysis

Faculty Advisor: Donald Carpenter
Faculty Advisor Email: dlc@eemail.stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Justin Li
Graduate Student Mentor Email: jdli@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

A long-running ELF/VLF (extremely and very low frequency) experiment at Siple Station, Antarctica from 1973 to 1988 generated prodigious amounts of data. Limitations in digital computing and storage at the time mean that significant amounts of data have yet to be analyzed. Work is being conducted into digitizing analog data tapes and in automating the extraction of salient features for analysis. Students would work on implementing more automated approaches to preprocessing large sets of data and on identifying and analyzing interesting events.

Recommended Courses/Readings:

Desired Qualifications of REU Intern: Some familiarity in Matlab

Maximum number of REU intern positions available: 2

Attachments: N/A

Additional Comments: N/A

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: **14**

Project Title: **Bio-Sensing for Rare-Cell Detection**

Faculty Advisor: Amin Arbabian
Faculty Advisor Email: arbabian@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Jayant Charthad
Graduate Student Mentor Email: jayantc@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Accurate sensing of rare biological cells such as circulating tumor cells (1 CTC per billion red blood cells) is important for the early detection of cancer. The most critical challenge for such a biosensor is to simultaneously achieve very high specificity and sensitivity. In this project, we employ a new multi-modality sensing approach using the electromagnetic, thermal and vibrational properties of the target entities for achieving high specificity. For enhancing the signal-to-noise ratio (SNR) of the biosensor, various signal processing techniques are being investigated.

This position focuses on designing a signal acquisition and processing platform in MATLAB aimed at enhancing the accuracy of event detection of the biosensor. Students will learn about the sources and characteristics of noise in a practical biosensor and apply signal processing and modulation techniques to improve the SNR. By contributing to this project, students will also have an opportunity to build their proficiency in using MATLAB for signal analysis. If time permits, the signal detection techniques will be implemented on a circuit board using discrete electronic components.

Recommended Courses/Readings:

Recommended Readings: Signal processing, Fourier transform, basics of electronic circuits

Recommended Courses: Introductory courses in signals & systems (EE102A, EE102B or equivalent) and electronic circuits (EE101A, EE101B or equivalent). Prior experi

Desired Qualifications of REU Intern:

Maximum number of REU intern positions available: 1

Attachments: 2014 REU_description_form_Jayant_Charthad.doc *See next page.

Additional Comments: N/A

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Position Description for 2014 REU Students (Project #14)

Faculty Advisor	Amin Arbabian
Email	arbabian@stanford.edu
Graduate Student Mentor	Jayant Charthad
Email	jayantc@stanford.edu
Project Description	Bio-Sensing for Rare-Cell Detection: Accurate sensing of rare biological cells such as circulating tumor cells (1 CTC per billion red blood cells) is important for the early detection of cancer. The most critical challenge for such a biosensor is to simultaneously achieve very high specificity and sensitivity. In this project, we employ a new multi-modality sensing approach using the electromagnetic, thermal and vibrational properties of the target entities for achieving high specificity. For enhancing the signal-to-noise ratio (SNR) of the biosensor, various signal processing techniques are being investigated. This position focuses on designing a signal acquisition and processing platform in MATLAB aimed at enhancing the accuracy of event detection of the biosensor. Students will learn about the sources and characteristics of noise in a practical biosensor and apply signal processing and modulation techniques to improve the SNR. By contributing to this project, students will also have an opportunity to build their proficiency in using MATLAB for signal analysis. If time permits, the signal detection techniques will be implemented on a circuit board using discrete electronic components.
Recommended Courses/Readings	Recommended Readings: Signal processing, Fourier transform, basics of electronic circuits Recommended Courses: Introductory courses in signals & systems (EE102A, EE102B or equivalent) and electronic circuits (EE101A, EE101B or equivalent). Prior experience with signal processing using MATLAB is highly recommended.
Maximum number of REU students you are willing to supervise	1

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 15

Project Title: Deep Trench Isolation for High Pixel Density Retinal Prosthesis

Faculty Advisor: James Harris
Faculty Advisor Email: jharris@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Xin Lei
Graduate Student Mentor Email: leixin@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Retinal prosthesis devices restore vision to blind people by electrically stimulating the surviving neurons in the retina. The pixel density of the retinal prosthesis is a limiting factor of the resolution that can be achieved. To further increase the pixel density, the current method of pixel isolation becomes a bottleneck because the isolation area does not scale down. This project will focus on a new isolation scheme, which combines high aspect ratio deep trench etching technique and thermal oxidation to minimize the isolation area and therefore increase the pixel density.

Recommended Courses/Readings: EE212 or the textbook of this course: "Silicon VLSI Technology: Fundamentals, Practice and Modeling" by James Plummer, Michael Deal and Peter Griffin

Desired Qualifications of REU Intern:

1) Strong motivation to have hands-on experiences;

2) Interest in neural science and healthcare, such as prosthetic devices;

3) Some knowledge about semiconductor physics and silicon-based processing.

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: **16**

Project Title: **Medical Imaging at Microwave Frequencies**

Faculty Advisor: Amin Arbabian
Faculty Advisor Email: arbabian@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Hao Nan
Graduate Student Mentor Email: haonan@stanford.edu
Graduate Student Mentor #2 (if applicable): Miaad Aliroteh
Graduate Student Mentor Email: miaad@stanford.edu

Project Description:

Microwave signals can be used to detect and distinguish tissue based on dielectric properties. Hybrid microwave imaging leverages multiple modalities to achieve both high resolution and contrast. This is significant in efforts to develop techniques that facilitate more frequent and economical cancer screening.

The position focuses on the designing parts of the receiver for the hand-held imaging device. The goal is to design a board for the control circuitry as well as the reconstruction algorithms. The hardware implementation also involves 2D beam steering for the imaging array.

Recommended Courses/Readings: Students should have taken 102A or equivalent. Familiarity with signal processing and 102B is preferable.

Desired Qualifications of REU Intern: MATLAB

Maximum number of REU intern positions available: 2

Attachments: N/A

Additional Comments: N/A

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 17

Project Title: MRI Image Reconstruction

Faculty Advisor: John Pauly
Faculty Advisor Email: pauly@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Tao Zhang
Graduate Student Mentor Email: tzhang08@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

With the development of Parallel Imaging (PI), MRI data acquisitions have been significantly accelerated. This has made many lengthy MR exams clinically feasible. PI uses receiver arrays with multiple coils to simultaneously acquire data. The different coil sensitivities of the receiver coils are used to partially replace traditional k-space encoding and reduce scan time. In addition to PI, there is a growing trend towards utilizing constrained reconstruction in MRI, such as compressed sensing. While these techniques can achieve better image quality, enhanced resolution, and improved signal-to-noise ratio (SNR), the required image reconstructions are often iterative and much more computationally intensive. Furthermore, the reconstruction time is highly dependent on the number of coils used.

To reduce the reconstruction computation with large receiver arrays, coil compression can be used. Coil compression linearly combines the raw data from multiple coils into fewer so-called virtual coils. Coil compression can be achieved by selecting a subset of coils that has the best SNR or a singular value decomposition (SVD) of the received data. For example, with careful design, MRI data acquired with a 32-channel torso coil can be compressed to only 6 virtual coils, without image quality degradation. This can speed up the reconstruction by up to 28 times.

In this project, coil compression technique will be studied for various coils with different coil geometries, including but not limited to, brain coils, cardiac coils and breast coils. Algorithms that can automatically determine the optimal number of virtual coils will be compared on in vivo volunteer or patient datasets.

Recommended Courses/Readings: EE 102A and EE 102B are very useful. EE 168, EE 169, and any other image processing or medical imaging courses would be helpful, but not required.

Desired Qualifications of REU Intern: Matlab programming. Interest in imaging.

Maximum number of REU intern positions available: 2

Attachments: N/A

Additional Comments: N/A

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 18

Project Title: Table-top MRI System

Faculty Advisor: John Pauly
Faculty Advisor Email: pauly@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Greig Scott
Graduate Student Mentor Email: greig@mrsrl.stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

The project is to build a small, table-top sized, MRI system. Our lab has many of the key components. The goal will be to develop some additional components, and integrate all of these into a system that could be used for imaging animals the size of mice.

Recommended Courses/Readings: ee102a, ee101a, ee108a are all very useful. ee122 and ee133 would also be very helpful.

Desired Qualifications of REU Intern: There will be project components that involve analog electronics (RF and audio frequencies), digital control and software, as well is signal processing. Students don't need expertise in all areas.

Maximum number of REU intern positions available: 4

Attachments: N/A

Additional Comments: N/A

Project #: **19**

Project Title: **FPGA Emulation for Robust System Design**

Faculty Advisor: Subhasish Mitra
Faculty Advisor Email: subh@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Hyungmin Cho
Graduate Student Mentor Email: endroit@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Realistic error emulation plays a key role in robust system design for energy and cost efficiency. In this project, we build an efficient and realistic error injection platform on large-scale FPGA emulation platforms. The error injection platform is capable of various error models. Possible error model includes (i) the error statistics resulted from over-scaling of voltage level and clock frequency, and (ii) flexible and accurate timing emulation for variability effects. Unlike conventional FPGA emulation that emulates only logic values, variability modeling emulates both logic and timing effects on conventional FPGA platforms.

Participants in this project will get familiar with hardware design using RTL languages and FPGA emulation platforms.

Recommended Courses/Readings:

EE108A/B
EE271
EE282

Desired Qualifications of REU Intern:

- Understanding of computer architecture and system software
- Programming skills for system programming (C, C++, assembly) or hardware description languages (Verilog or VHDL)
- Strong Mathematical background

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

Project #: **20**

Project Title: **High Efficiency Nano-structured Solar Cells Fabrication and Characterization**

Faculty Advisor: James Harris
Faculty Advisor Email: jharris@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Yangsen Kang
Graduate Student Mentor Email: kys86@stanford.edu
Graduate Student Mentor #2 (if applicable): Yijie Huo
Graduate Student Mentor Email: yjhuo@stanford.edu

Project Description:

Solar cell market is 46B USD and growing at 39% annually. However, right now, it is the key moment for technique consolidation. We are study the most possible ways for both break fundamental physics limitation as well as economic possible. One of our approach is applying nanoscale light trapping structures on thin film III-V solar cell to retain high efficiency but significant reduce the cost. Our current design has achieved one of the most efficient nanostructured solar cells. Meanwhile, our theoretical studies have found several potential methods to boost the efficiency even higher. We need your help to utilize these ideas and build the high efficiency and low cost solar cells for the future.

The students will work with our solar cell researchers and technicians, and learn solar cell device fabrication and characterization skills. Make their own solar cells with standard fabrication processes in clean room, and characterize it with photocurrent, efficiency measurement, optical measurement, IV curve analysis, etc.

Recommended Courses/Readings: EE 116, EE 216, EE 243

Desired Qualifications of REU Intern: The essential knowledge of solid state physics, semiconductor device, electromagnetic wave and optoelectronics is highly preferred.

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 21

Project Title: High Efficiency Nano-structured Solar Cells Design and Fabrication

Faculty Advisor: James Harris
Faculty Advisor Email: jharris@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Yangsen Kang
Graduate Student Mentor Email: kys86@stanford.edu
Graduate Student Mentor #2 (if applicable): Yijie Huo
Graduate Student Mentor Email: yjhuo@stanford.edu

Project Description:

Solar cell market is 46B USD and growing at 39% annually. However, right now, it is the key moment for technique consolidation. We are study the most possible ways for both break fundamental physics limitation as well as economic possible. One of our approach is applying nanoscale light trapping structures on thin film III-V solar cell to retain high efficiency but significant reduce the cost. Our current design has achieved one of the most efficient nanostructured solar cells. Meanwhile, our theoretical studies have found several potential methods to boost the efficiency even higher. We need your help to utilize these ideas and build the high efficiency and low cost solar cells for the future.

The students will work with our solar cell researchers and technicians, and learn the essential device physics from hand-on solar cell design experience. Optimize the cell structure, doping profile, band gap, material composition based fundamental physics models. Grow III-V material for nano-structured solar cell with industry standard epi-taxis equipment.

Recommended Courses/Readings: EE 116, EE 216, EE 243

Desired Qualifications of REU Intern: The essential knowledge of solid state physics, semiconductor device, electromagnetic wave and optoelectronics is highly preferred.

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 22

Project Title: A Novel Label Free and Real Time Electrical Bio-sensor for Biomarkers Detection

Faculty Advisor: Ronald Davis
Faculty Advisor Email: dbowe@stanford.edu
Faculty Advisor #2 (if applicable): James Harris
Faculty Advisor #2 Email: harris@snow.stanford.edu
Graduate Student Mentor: Rahim Esfandyarpour
Graduate Student Mentor Email: rahimes@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

In this project we develop a novel and new electrical biosesnor which is call Nanoneedle biosensor. Nanoneedle biosensor is a real-time, label-free, direct electrical detection platform, which is capable of high sensitivity detection, measuring the impedance modulation, due to the presence or reaction of biomolecules such as proteins, nucleic acids, cells or Bacteria. Due to its suspended rigid nano-structure, the injection through the cell membrane can be envisioned. One of the other major benefits of this sensor is the option to process a parallel array of this sensor in microfluidic channels for the detection of multiple biomarkers simultaneously contained on a single chip. This sensor has the potential to significantly lower the cost of diagnostics in clinical settings. Students might be working on the simulation (COMCOL), data analyzing, circuit design or possibly some biology experiments.

Recommended Courses/Readings: N/A

Desired Qualifications of REU Intern:

1) Third- and fourth-year students have the highest priority.

2) Candidates familiar with analog circuit design, signal processing or data analysis have a higher priority.

3) Preferred experience with software such as Labview, Matlab, AutoCad, or COMS

Maximum number of REU intern positions available: 2

Attachments: N/A

Additional Comments: N/A

<u>Project #:</u> 23

<u>Project Title:</u> Crossbar Carbon Nanotube Memories

Faculty Advisor: Philip Wong
Faculty Advisor Email: hspwong@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Ji Cao
Graduate Student Mentor Email: jicao@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

<u>Project Description:</u>

With the ubiquitous presence of portable electronics, non-volatile memories (NVMs) have witnessed unprecedented progress in the past decades. The sustained growth in NVM technologies is fueled by the continued scaling-down of device sizes by exploring alternative memory concepts and new materials. Among them, phase change memory (PCM) offers high scalability, low fabrication cost, fast programming speed, good endurance and multi-level cell capability, and is widely considered as one of the most promising candidates for the next-generation NVMs. The ultimate scale limit of a functional PCM cell and its properties at the nanometer scale are of great interest and importance.

Carbon nanotube (CNT), a nanoscale one-dimensional material, stands out as a promising candidate for PCM memory electrodes. In this research plan, novel crossbar PCM memory arrays, utilizing CNTs as the bottom and top memory electrodes are proposed to explore the ultimate scaling limit. The use of CNT bottom and top electrode brings the critical dimension down to ~1 nm and the Ge2Sb2Te5 alloy (GST) path to sub-4 nm2. The previously developed resist-assisted CNT precise assembly technology makes the crossbar CNT structure of the PCM array possible.

In the project, one student will focus on the demonstration and improvement of high-yield dense CNT crossbar structure (Fig.1a), which serves as the basis for the crossbar PCM array. The crossbar CNT structure can also work as nano-electro-mechanical (NEM) switches.

The other student will work on how to combine the CNT crossbar electrode arrays with the PCM technology to fabricate crossbar CNT PCM array (Fig.1b).

They will collaborate on the investigation of switching characteristics, programming current, programming energy, read immunity and resistance distribution of the crossbar CNT PCM array.

<u>Recommended Courses/Readings:</u> [1] Jiale Liang, PhD Thesis, Towards sub-10 nm phase change memory�“device structure and array analysisâ ��

[2] Ji Cao, et al., Resist-assisted assembly of single-walled carbon nanotube devices with nanoscale precision, Carbon 50, pp. 1720, 201

<u>Desired Qualifications of REU Intern:</u>

*You may select up to 8 projects. You also have the option to specify a first choice project.

Maximum number of REU intern positions available: 3

Attachments: EE REU-Proposal-Ji.pdf **Please see attachment at the end of this document.

Additional Comments: N/A

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: **24**

Project Title: **Investigation of the Unique Etch Stop Properties of GeSn Alloys for Ge-based Electronics and Photonics**

Faculty Advisor: James Harris
Faculty Advisor Email: harris@snow.stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Colleen Shang
Graduate Student Mentor Email: ckshang@stanford.edu
Graduate Student Mentor #2 (if applicable): Robert Chen
Graduate Student Mentor Email: robert.chen@stanford.edu

Project Description:

The proposed REU project involves the investigation of a unique etch resilience of GeSn alloys, a Si-compatible material system that has promise for electronics and photonics applications. Recently, it was discovered that GeSn does not etch under certain Fluorine-based chemistries; the same chemistries, however, quickly etch Ge and Si materials. This powerful property of GeSn allows it to act as a perfect etch stop layer, enabling the creation of 3D micro- and nano-structures for photonics and MEMS applications that would not be possible otherwise. This technology has been used to create suspended GeSn nanowires and GeSn-based microdisk optical resonators for photonics applications.

While the basic surface chemistry of this etch resilience is understood, further studies are needed to fully understand the capabilities and limitations of GeSnâ€™s resilience. It is presumed that a small amount of GeSn must be consumed to form SnFx prior to acting as an etch stop, but the thickness consumed and its dependence on the Sn content in the GeSn alloy is unknown. Furthermore, the chemical mechanism for why SnFx prevents subsequent etching is not well understood.

The goal of this summer project is to investigate the consumption of GeSn required to form an etch stop layer as a function of Sn content. This particular project has a well-defined path with many milestones; the number of milestones met is dependent on the enthusiasm of the student researcher. Additionally, there are many opportunities for creative exploration at several of these milestones. The project will be supervised by a materials science PhD student in a research group with materials characterization and fabrication expertise.

The selected student researcher will have the opportunity to work hands-on with state-of-the-art Ge and GeSn technology in an experimental environment. The student researcher will gain cleanroom experience and learn to use tools for both wet and dry etching of semiconductor materials. Additionally, the student researcher will learn basic material characterization techniques such as atomic force microscopy (AFM) for surface profilometry, scanning electron microscopy (SEM) for structural imaging, and x-ray photoemission spectroscopy (XPS) for chemical investigation. If of interest to the student researcher, there are also opportunities to gain experience with photoluminescence and microfabrication.

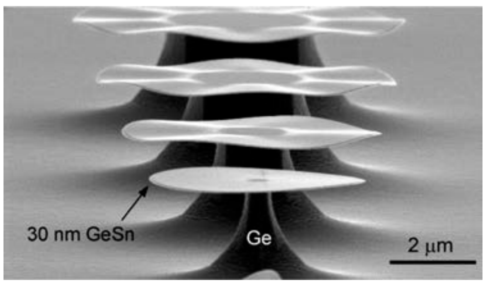
Recommended Courses/Readings: S. Gupta, R. Chen, Y.-C. Huang, Y. Kim, E. Sanchez, J.S. Harris, K.C. Saraswat, Nano Lett. 13, 3783 (2013).

R. Chen, S. Gupta, Y.-C. Huang, Y. Huo, C.W. Rudy, E. Sanchez, Y. Kim, T.I. Kamins, K.C. Saraswat, J.S. Harris, Nano Lett. DOI: 10.1021/nl40281

Desired Qualifications of REU Intern: We are looking for a motivated undergraduate with a background or interest in the areas of chemistry, physics, materials science, or electrical engineering. Because much of the work is experimental, candidates should be comfortable learning new tools, bei

Maximum number of REU intern positions available: 1

Attachments: nl-2013-017286_0008.jpeg



Additional Comments: N/A

Project #: **25**

Project Title: **Robust Digital VLSI Using Carbon Nanotubes**

Faculty Advisor: Subhasish Mitra
Faculty Advisor Email: subh@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Gage Hills
Graduate Student Mentor Email: ghills@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Carbon nanotube field-effect transistors (CNFETs) are promising candidates for building energy-efficient digital systems at sub-10nm technology nodes. However, carbon nanotubes (CNTs) are inherently subject to variations that reduce circuit yield, increase susceptibility to noise, and severely degrade their anticipated energy and speed benefits. Joint exploration and optimization of CNT processing options and CNFET circuit design are required to overcome this outstanding challenge.

This project defines two possible options for overcoming CNT variations:

1. We develop novel design methodologies to systematically and efficiently explore the large space of CNT processing options to derive optimized CNT processing and CNFET circuit design guidelines. The circuit-level impact of CNT variations on energy, delay, and noise susceptibility are minimal once these design guidelines are satisfied.

2. We develop error-resilient circuit architectures, including machine learning applications, that are robust to CNT variations. CNT processing requirements & guidelines are relaxed under these architectures.

As part of our design framework, we develop unique delay, noise margin, and energy models that model the effect of unique CNT variations. Such models are built using CNFET SPICE device simulations and are calibrated to electrical measurements from CNFET devices fabricated at Stanford.

Recommended Courses/Readings: Courses:

EE108A
EE108B
EE271
EE116
EE263

Desired Qualifications of REU Intern: Background in semiconductors & digital design

Proficiency in linear algebra

Proficiency in C++, Matlab, SPICE

Experience with oscilloscope & electrical measurements

Maximum number of REU intern positions available: 2

Attachments: N/A

Additional Comments: N/A

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 26

Project Title: Microfluidic Chip Design for Automated Single Cell Analysis

Faculty Advisor: Mark Horowitz
Faculty Advisor Email: horowitz@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Brian Yu
Graduate Student Mentor Email: brianyu@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

This project lies in the bioEE space, where student will design and test a Polydimethylsiloxane (PDMS) microfluidic device for single bacterium genetic analysis. This device will include modules for cell capture, lyse, DNA amplification, and sample prep steps for genetic sequencing. The resulting device will be an automated platform for genetic analysis of environmental or cultured samples of bacteria. In order to control the microfluidic platform, the student will be using a custom hardware setup developed previously that can be controlled via an iPhone App.

As an introduction to the advantages of microfluidics, we take a look at how biological experiments are conducted traditionally. Biological experiments are usually performed in tubes in microliter volumes of reagents. The protocols of these experiments often involve low throughput and labor intensive steps that are costly in terms of reagents and human effort. The emergence of a technological platform called microfluidics in the last 10 years provided new ways of performing these biological experiments and assays in academic and clinical environments. Due to small length scales of features in microfluidic platforms, this technology offer orders of magnitude smaller reaction volumes, high throughput parallel processing of multiple samples, and amenability for automation and integration.

Recommended Courses/Readings: N/A

Desired Qualifications of REU Intern: The student should have a basic understanding of microfabrication technologies used in the electronic manufacturing industry. It is also desirable if the student is familiar with MATLAB, AutoCAD, and python.

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: **27**

Project Title: **SiGe Quantum Well Modulator and Laser for Optical Interconnects**

Faculty Advisor: James Harris
Faculty Advisor Email: harris@snow.stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Xiaochi Chen
Graduate Student Mentor Email: chenxchi@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Thanks to Moore's law, modern ICs are ever increasing their performance with increased processor speeds and parallel processing. The communication delay between parts of the chip becomes comparable to processing time. Thus, further improvements in processing power will ultimately be limited by on-chip and chip-to-chip communication speeds--a phenomenon known as the "Interconnect Bottleneck". Replacing current metallic interconnects with optical interconnects vastly will improve chip-scale communication similarly to how optical fibers revolutionized telecommunication. Our Ge/SiGe multiple quantum well (MQW) modulators and lasers are two important components in the realization of optical interconnects. We have demonstrated proof-of-concept Ge/SiGe modulators and LEDs operating at ~1.45Î¼m. This project will focus on the research of MQW and development of modulators and LEDs operating at 1.3Î¼m.

Recommended Courses/Readings: EE116, EE216, EE222

Desired Qualifications of REU Intern:

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: Project includes:

QW simulation, SiGe materials growth, material characterization, device design, device fabrication, device testing

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 28

Project Title: Machine Learning Image Processing in Medical Imaging Applications

Faculty Advisor: Daniel Rubin
Faculty Advisor Email: dlrubin@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Francisco Gimenez
Graduate Student Mentor Email: fgimenez@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Cancer is the second leading cause of death in the United States (after heart disease). Breast cancer is the most common form of cancer in women, and an estimated one in eight women will contract breast cancer in their lifetimes. Not all patients respond well to chemotherapy treatment, which means that there is a critical need to predict in advance which patients will respond to therapy; accurate prediction would allow patients who are not likely to be cured to pursue alternative or experimental treatments.

We are developing machine learning methods use quantitative information derived from breast imaging to predict which patients will respond to therapy. A major challenge in this approach lies in comparing the tumor in pre-chemotherapy and post-chemotherapy images; to accurately compare the images, they must be spatially aligned (registered) using non-linear algorithms.

A number of summer projects are possible, such as comparing non-rigid registration algorithms (of which there are many) to perform 3D registration of pre-chemotherapy and post-chemotherapy MRI images of breast cancer in order to compare changes in the tumor on a pixel-by-pixel basis. Another possible project is deep learning with quantitative imagign cancer images to predict treatment response.

Experimentation with pre-existing tools will be encouraged, but students may also modify or extend them if warranted. If the project is successful, the results of the project may be included in a publication with the student as a co-author.

Recommended Courses/Readings: Gonzalez and Woods, Digital Image Processing Using MATLAB

Desired Qualifications of REU Intern: The ideal candidate will have programming experience at least at the level of CS 106a. EE 168 would also be good and EE 368 would be very useful as would CS229. It may also be helpful to have experience with Matlab, though this is not strictly required.

Maximum number of REU intern positions available: 2

Attachments: N/A

Additional Comments: N/A

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: **29**

Project Title: **Energy Harvesting Using Off-the-Shelf Components**

Faculty Advisor: Eric Pop
Faculty Advisor Email: epop@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Feifei Lian
Graduate Student Mentor Email: flian@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Did you know you could power watches, fitness sensors (e.g. the FitBit), or even mobile phones using only the energy of your body? Theoretically, one could harvest up to 1 W of power from the thermal output of a person, and up to 4 W from mechanical motion (e.g. walking, running, dancing). In this project we will build thermal energy harvesters using off-the-shelf components such as small thermoelectric modules. The goal is to show we can harvest up to a few mW from "band-aid"-like patches or "sleeves" that a human could easily wear.

Recommended Courses/Readings: basic thermodynamics and circuits

Desired Qualifications of REU Intern: ability to solder, meticulousness in working with small (mm-size) components, curiosity in trying out new (exciting!) things

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: Also see our web site, http://poplab.stanford.edu

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: **30**

Project Title: **Thermoelectric Properties of Nano- to Macro-Scale Materials**

Faculty Advisor: Eric Pop
Faculty Advisor Email: epop@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Feifei Lian
Graduate Student Mentor Email: flian@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

We will work with nanomaterials which have energy harvesting properties, particularly for converting thermal energy into an electrical voltage. These include carbon nanotube and polymer composites. We will work on calibrating, programming and measuring samples in a thermal conductivity measurement tool. This tool will be modified for simultaneous thermal and thermoelectric measurements of samples ranging from microns to mm's thick. We will use LabView to program controllers for measuring and controlling temperature. We will also calibrate the tool using standard materials with well-known thermal and thermoelectric properties, before moving on to characterizing the novel nanomaterials of interest.

Recommended Courses/Readings: basic modern physics or thermodynamics

EE 116 or equivalent

Desired Qualifications of REU Intern: LabView programming (or equivalent) desirable but not required

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: Also see our web site, http://poplab.stanford.edu

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 31

Project Title: Growth and Characterization of Atomically Thin Films of Graphene and Other 2-Dimensional Materials

Faculty Advisor: Eric Pop
Faculty Advisor Email: epop@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Kirby Smithe
Graduate Student Mentor Email: ksmithe@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Graphene and other 2D atomically thin materials (known as transition metal dichalcogenides, or TMDs) have recently attracted attention due to their unique electrical and thermal properties. In order to integrate these materials into nanoelectronic device and circuit applications, we aim to develop and improve high-quality deposition techniques that yield consistent and reproducible films. Characterization methods will involve Raman spectroscopy, scanning electron microscopy, and atomic force microscopy.

Recommended Courses/Readings: basic chemistry and/or thermodynamics

EE 116 or equivalent

Desired Qualifications of REU Intern:

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: Also see our web site, http://poplab.stanford.edu

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 32

Project Title: An Engineer's View of Learning in Human Neurons and Synapses

Faculty Advisor: Bernard Widrow
Faculty Advisor Email: widrow@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Dookun Park
Graduate Student Mentor Email: dkpark@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

learning algorithm simulation and development that could help explain learning in human synapses.

Recommended Courses/Readings: TBD

Desired Qualifications of REU Intern:

Maximum number of REU intern positions available: 3

Attachments: N/A

Additional Comments: N/A

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 33

Project Title: Multifunctional optical fiber sensors

Faculty Advisor: Olav Solgaard
Faculty Advisor Email: solgaard@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Cathy Jan
Graduate Student Mentor Email: cathyjan@stanford.edu
Graduate Student Mentor #2 (if applicable): Sandra Kjono
Graduate Student Mentor Email: kjono@stanford.edu

Project Description:

Develop fiber optic sensor systems for temperature, pressure, chemical composition, and bio-molecular associations.

Recommended Courses/Readings: Basic electromagnetism, EE134

Desired Qualifications of REU Intern: Basic electronics and programming

Maximum number of REU intern positions available: 3

Attachments: N/A

Additional Comments: N/A

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 34

Project Title: Acceleration for Cloud Computing

Faculty Advisor: Christos Kozyrakis
Faculty Advisor Email: christos@ee.stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: David Lo
Graduate Student Mentor Email: davidlo@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Chips for cellphones and tablets include general-purpose cores and custom accelerators for important tasks (image processing, video decoding, etc). These accelerators provide higher performance and better energy efficiency. The same approach is not becoming popular for server chips: integrate on the same chip with the server cores a few key accelerators for cloud computing workloads.

The goal of this project is to provide a platform to experiment with such as design. Specifically, you will port a high-end network interface (NetFPGA) to an Zynq FPGA platform that includes two ARM cores and an FPGA fabric for prototyping custom accelerators. The task includes porting the Verilog design from NetFPGA to the Zynq design and modifying the Linux device driver for the network interface to work properly. The project will help you build experience in all aspects of cloud computing (hardware, networking, system software, and cloud applications).

Appointed REU intern has the option to start the project earlier (during the spring quarter). Details to be worked out with faculty mentor and the REU coordinator.

Recommended Courses/Readings:

EE108A (required)
Optional but definitely helpful: EE108b and EE109
Optional: CS140

Desired Qualifications of REU Intern: Verilog and FPGA design experience

Maximum number of REU intern positions available: 2

Attachments: N/A

Additional Comments: N/A

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: **35**

Project Title: **Distortion in Sub-Nyquist Sampling and Quantization**

Faculty Advisor: Andrea Goldsmith
Faculty Advisor Email: andrea@ee.stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: **Alon Kipnis**
Graduate Student Mentor Email: alonkipnis@gmail.com
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

We are interested in analyzing practical quantization schemes in terms the average distortion they introduce when the quantization occurs after sub-Nyquist sampling.

We will look at the following specific schemes:

- Sigma-Delta Encoder with varying sampling frequency and varying order. Parameters: decoder order and sampling frequency.
- Sampling followed by block-scalar quantization. Parameters: number of quantization bits and block length.

This analysis can be included in a paper that compares popular sampling + quantization techniques with respect to their informational theoretic limits.

Recommended Courses/Readings:

EE102A is required. More advanced courses on signal processing, probability, and random processes will be helpful.

Desired Qualifications of REU Intern: See above recommended courses.

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

Project #: **36**

Project Title: **Massive MIMO Communication System Design**

Faculty Advisor: Andrea Goldsmith
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Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Alexandros Manolakos
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Graduate Student Mentor #2 (if applicable): Mainak Showdhury
Graduate Student Mentor Email: mainakch@stanford.edu

Project Description:

Massive MIMO (Multiple-Input Multiple-Output) systems have recently emerged as a novel communication paradigm, especially inside the framework of millimeter wave communications. The high number of transmit or receive antennas (e.g. of the order of 100 antennas) makes significant performance gains feasible.

However, an important challenge in the implementation of such systems is the acquisition of channel state information (CSI). In our line of work, we are interested in different ways of transmitting information without the use of CSI. Specifically, we have proposed a simple communication system design for a Massive SIMO (Singe-Input Multiple-Output) system. More work is needed to further optimize the performance of our system. Several ideas remain to be explored in our system design, e.g. constellation design optimization, introduction of space-time codes in our design. These extensions will require basic familiarity with communication systems, and optimization tools and packages.

Recommended Courses/Readings:

Required Courses: EE 102A, EE 178, EE 179
Suggested Courses: EE 102B, EE279, EE 278B, EE261

Desired Qualifications of REU Intern:

Very good understanding of fundamental principles of Digital Communication Systems. Excellent knowledge of a high level programming language, e.g. Matlab, Python.

Maximum number of REU intern positions available: 2

Attachments: N/A

Additional Comments: N/A

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 37

Project Title: Mapping Tool for Large Scale Neural Networks

Faculty Advisor: Kwabena Boahen
Faculty Advisor Email: boahen@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Sam Fok
Graduate Student Mentor Email: samfok@stanford.edu
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Previously, the Brains in Silicon Lab developed Neurogrid, a mixed analog-digital hardware platform that emulates up to a million spiking neurons while consuming power only a few watts of power. A supercomputer would consume hundreds of kilowatts to simulate a neural network of the same scale and detail. This presents an unprecedented opportunity to explore real world applications of highly parallel, ultra-low power, biologically plausible neural networks. Using Neurogrid and the Neural Engineering Framework, a principled method for mapping functions onto spiking neurons, the lab has implemented networks for robot control in Neurogrid and is exploring applications in signal estimation as well. However, as the functions and algorithms computed by Neurogrid grow more complicated, the task of mapping the functions onto Neurogrid grows more complicated. There are many ways to decompose a function prior to mapping it onto spiking neurons, and the neuron parameter space is large.

This project would be to build upon previous work seeking to automate the decomposition and mapping of mathematical functions onto pools of spiking neurons to facilitate construction of large scale neural networks.

Recommended Courses/Readings:

EE 263 or equivalent experience with linear algebra
CS 106B

Desired Qualifications of REU Intern:

Experience with programming in c++ an python.
Experience with linear algebra

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 38

Project Title: Real-Time Neuromorphic Computing

Faculty Advisor: Kwabena Boahen
Faculty Advisor Email: boahen@stanford.edu
Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Alex Neckar
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Graduate Student Mentor #2 (if applicable): Samir Menon
Graduate Student Mentor Email: smenon@stanford.edu

Project Description:

One of the Boahen lab's (brainsinsilicon.stanford.edu) primary projects is using our neuromorphic computing platform, Neurogrid, to control a robotic arm. One of the challenges for this project is creating a very low-latency interface between the robot and Neurogrid.

Currently, a PC sits in the loop between the robot and Neurogrid: the PC receives information about the robot state, repackages it, and sends it to Neurogrid; the neural networks on Neurogrid then perform the desired control computations; finally, the PC receives the output from Neurogrid and passes the commanded inputs to the robot's motors.

We would like to eliminate the PC from this loop by using an FPGA in its place. We would probably purchase 1 (or possibly 2) FPGA dev boards for the purpose. The REU student will select an appropriate dev board and then design the interfaces to the robot (etherCAT) and to Neurogrid (USB most likely), as well as the spike filtering operation that has to occur between. The REU student will also integrate the new hardware into our existing C++/Python software stack.

An alternative project would be to design an update to the current spike routing FPGA daughterboard (different from the FGPA previously described: this FPGA facilitates the weighted connections in the neural network). The chief motivation for upgrading the FPGA would be to achieve greater memory access throughput. The REU student would design a new memory interface, constrained by the specifications of the FPGAs and discrete memory components available. PCB design experience would also be helpful for this alternative project.

Recommended Courses/Readings: EE108 or other substantial FPGA programming experience. CS106, CS107, CS110 or other python/C++ experience.

Desired Qualifications of REU Intern: N/A

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: 39

Project Title: 3D modeling and manufacturing of power electronics components

Faculty Advisor: Juan Rivas-Davila
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Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: Luke Raymond
Graduate Student Mentor Email: lraymond@stanford.edu
Graduate Student Mentor #2 (if applicable): Junwong Choi
Graduate Student Mentor Email: jwonchoi@stanford.edu

Project Description:

The new Power Electronics group is developing circuits and components for switching power converters at frequencies greater than 10MHz. This is more than order of magnitude higher than conventional power electronics designs. Among the advantages of this approach are the reductions in size, and the possibility to operate in harsh environments.

The student(s) working in this project will help us 3D models and tools to fabricate and characterize passive components for power converters.

Recommended Courses/Readings:

EE101A, EE101B

Desired Qualifications of REU Intern: Electric circuits, basic electro-magnetics, basic semiconductors , familiarity (or willingness to learn) Matlab and Pspice, Comsol.

Maximum number of REU intern positions available: 2

Attachments: N/A

Additional Comments: N/A

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: **40**

Project Title: **Radar Remote Sensing**

Faculty Advisor: Howard Zebker
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Faculty Advisor #2 (if applicable):
Faculty Advisor #2 Email:
Graduate Student Mentor: TBD
Graduate Student Mentor Email:
Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

Radar remote sensing offers a way to measure tiny deformations of the Earth's crust resulting from a variety of natural and anthropogenic processes. We offer an opportunity to develop and apply signal processing software to the study of the Earth from space-based radars. The projects all involve coding with high-level languages such as C++ or Fortran, along with some scripting using Python. Our goal is to code such algorithms and apply them to measurements of the Earth's surface response to groundwater flow, climate change, and volcanic eruption precursors.

Recommended Courses/Readings: N/A

Desired Qualifications of REU Intern: N/A

Maximum number of REU intern positions available: 1

Attachments: N/A

Additional Comments: N/A

REU 2014 Project Proposals

*You may select up to 8 projects. You also have the option to specify a first choice project.

Project #: **41**

Project Title: **Characterizing an Algorithm to Automatically Detection of 0+ Whistlers Emitted from Lightning**

Faculty Advisor: Umran Inan
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Graduate Student Mentor #2 (if applicable):
Graduate Student Mentor Email:

Project Description:

The French Space Agency CNES is building a satellite called TARANIS to be launched in 2016 to study a number of phenomena related to lightning. Among these are a special kind of electromagnetic wave known as 0+ whistlers, and the Stanford VLF Group has developed an algorithm to automatically detect these waves in space on the satellite. The algorithm works by creating spectrograms of the incoming signal and looking for the characteristic shape that a 0+ whistler makes in them. So in essence it is a shape detection scheme, with the particular shape sought depending on the (electromagnetic) physics of both the lightning and the space between the lightning and satellite. We will be delivering an instrument (FPGA) on which the algorithm is encoded later this year.

What remains to be done is to characterize how well the algorithm works. We have a large data set from a satellite operating between 2004 and 2010 which had an identical orbit that TARANIS will have and so can be used to model the data TARANIS will see. Questions include: What will the detection efficiency be (i.e., how many can we detect)? What will the false positive rate be? How do the various algorithm parameters (e.g., specific shape, threshold) affect the detection efficiency and false positive rate? Is there an optimum set of parameters that maximizes the detection efficiency while minimizing the false positive rate? Will that optimum set change in different space environments? As you might guess, answers to these questions will be crucial in analyzing the data from our instrument after it launches.

Recommended Courses/Readings:

MATLAB (ENGR 154/CME 100, ENGR 155A/CME 102)
Signal Processing (EE 102A, EE 102B)
Electromagnetics (PHYSICS 43, EE 41, EE 141)

Desired Qualifications of REU Intern: Our data and algorithm are all coded in MATLAB, so working knowledge of MATLAB is an essential requirement. Otherwise, we are looking for an inquisitive, hard-working individual who has broad interests in EE (programming/algorithms, physics, signal processing), isn't intimidated by complex problems, and wants to have a direct impact on a space project.

<u>Maximum number of REU intern positions available:</u> 1

<u>Attachments</u>: N/A

<u>Additional Comments:</u> N/A

Crossbar Carbon Nanotube (CNT) Memories

Supervisor: Dr. Ji Cao, Prof. H.-S. Philip Wong

Key words for literature preparation: Carbon Nanotube (CNT), Nano-Electro-Mechanical systems (NEMS), Phase Change Memory (PCM)

Skills involved: Nano-fabrication, Characterization.

Students required: 2

With the ubiquitous presence of portable electronics, non-volatile memories (NVMs) have witnessed unprecedented progress in the past decades. The sustained growth in NVM technologies is fueled by the continued scaling-down of device sizes by exploring alternative memory concepts and new materials. Among them, phase change memory (PCM) offers high scalability, low fabrication cost, fast programming speed, good endurance and multi-level cell capability, and is widely considered as one of the most promising candidates for the next-generation NVMs. The ultimate scale limit of a functional PCM cell and its properties at the nanometer scale are of great interest and importance.

Carbon nanotube (CNT), a nanoscale one-dimensional material, stands out as a promising candidate for PCM memory electrodes. In this research plan, novel crossbar PCM memory arrays, utilizing CNTs as the bottom and top memory electrodes are proposed to explore the ultimate scaling limit. The use of CNT bottom and top electrode brings the critical dimension down to ~1 nm and the $Ge_2Sb_2Te_5$ alloy (GST) path to sub-4 nm^2. The previously developed resist-assisted CNT precise assembly technology makes the crossbar CNT structure of the PCM array possible.

In the project, one student will focus on the demonstration and improvement of high-yield dense CNT crossbar structure (Fig.1a), which serves as the basis for the crossbar PCM array. The crossbar CNT structure can also work as nano-electro-mechanical (NEM) switches.

The other student will work on how to combine the CNT crossbar electrode arrays with the PCM technology to fabricate crossbar CNT PCM array (Fig.1b).

They will collaborate on the investigation of switching characteristics, programming current, programming energy, read immunity and resistance distribution of the crossbar CNT PCM array.

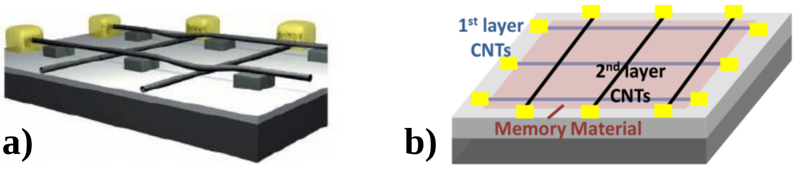

Fig.1 a) A crossbar CNT structure; b) A crossbar CNT PCM array

Recommended reading:

[1] Jiale Liang, PhD Thesis, "Towards sub-10 nm phase change memory–device structure and array analysis".

[2] Ji Cao, et al., "Resist-assisted assembly of single-walled carbon nanotube devices with nanoscale precision", Carbon 50, pp. 1720, 2012.